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INDC INTERNATIONAL NUCLEAR DATA COMMITTEE

HANDBOOK

OF

NUCLEAR DATA FOR SAFEGUARDS

Preliminary Issue

M. Lammer, O. Schwerer

Nuclear Data Section
International Atomic Energy Agency
Vienna, Austria

June 1991

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

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ABSTRACT

This handbook contains nuclear data needed by safeguards users for their work. It was initiated by an IAEA working group, and the contents were defined by the replies to a questionnaire sent to safeguards specialists. This is a preliminary edition of the handbook for distribution to safeguards and nuclear data experts for review.

The present edition of the handbook contains the following basic nuclear data:

actinides: nuclear decay data
thermal neutron cross sections and resonance integrals
prompt neutron data
delayed neutron data

fission products: nuclear decay data
thermal neutron capture cross sections and resonance integrals

fission product yields

Also included are appendices that summarize the data requested by safeguards users, and that present a number of questions to them and to data experts on the data contained in this preliminary issue and about additional data for possible inclusion in future editions and updates of the handbook.

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INTRODUCTION

This handbook contains recommended values of nuclear data needed for the development and application of safeguards nuclear materials accounting techniques. We have included only those data that were requested by safeguards users (see **Appendix A**) and which were readily available to us. The data given are grouped in 3 sections: Section A contains decay data, thermal neutron cross section data, resonance integrals and data on neutron emission in fission for actinide isotopes. Section B contains decay data and thermal neutron cross section data of fission product nuclides. Section C contains fission product yield data.

Internationally recommended values exist only for some of the presented data. In such cases data recommended by international committees or working groups have been included in the present handbook. In other cases, when different values were found in different data files, we have chosen most recent suitable values. In the case of fission yield data, a group of specialists recommended not to give a single "best" data set; considering the different existing views on data evaluation methods in this case, two data sets have been included.

Introductory pages to the data tables give further explanations, arguments for the selection of the recommended values (special remarks are given in footnotes), references of the sources of data and information on the availability of larger or complete data sets that are not included in the handbook.

Users of this handbook who wish to receive **complete data files** in computer media, i.e. magnetic tapes or PC diskettes, are invited to contact one of the four regional **Nuclear Data Centres** given below.

For USA and Canada:

National Nuclear Data Center
Brookhaven National Laboratory
Upton, N.Y. 11973
USA
BITNET: NNDCVM@BNL

For other OECD countries

Banque de Donnees de l'AEN
NEA Data Bank
B.P. 9
F-91190 Gif-sur-Yvette
France
EARN: WEBSTER@FRNEAB51

For USSR:

Centr Po Jad. Dannym
Fiziko-Energeticheskij Institut
Ploschad Bondarenko
249 020 Obninsk, Kaluga Region
USSR
EARN: CJD@FEIMO.OBNINSK.SU

For all other countries:

IAEA Nuclear Data Section
P.O. Box 100
A-1400 Vienna
Austria
EARN: RNDS@IAEA1

COMMENTS ON THIS PRELIMINARY EDITION

This handbook was initiated by an IAEA working group, and the contents were defined by the replies to a questionnaire sent to safeguards experts, as outlined in Appendix A.

The present edition of the handbook is a preliminary version distributed to safeguards and nuclear data specialists for review. The **"Request to safeguards and data experts"** on the following page outlines in more detail what these experts are asked to do. In addition to the data tables themselves that are to be reviewed, a number of questions are presented in the appendices, which are only included in this preliminary version of the handbook.

After receipt of experts' replies and reviews, the first edition of the final version of the handbook will be edited and published. Revisions will again be sent to experts for review prior to distribution. Also, new suggestions for data to be included will be sent to safeguards experts for judgement.

Scientists who wish to be included in the **distribution list of this handbook**, should contact us at the address given below. Then they will also automatically receive all later revisions of the handbook.

Acknowledgement

We would like to thank Ms. M.M. Seits and M. O'Connell for their assistance in the extraction of the required data from files and the production of user friendly formatted tables and text pages of the handbook.

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REQUEST TO SAFEGUARDS AND DATA EXPERTS

We ask experts upon receipt of this preliminary handbook to review the information and data tables presented, and to help us with the questions and problems included in the appendices.

From **safeguards experts** we solicit more information on:
- which data exactly are needed,
- which representation of the data is preferred,
- whether the tables in the present version are incomplete with respect to nuclides or data included,
- whether the format of the presently completed tables is satisfactory.

From **data experts** we solicit information on:
- check of the data presented in the tables and information about sources for the best data presently available (mainly evaluated data will be included, preferably with uncertainties; only if these are not available, will reliable experimental results or calculated data be used),
- how some of the requested data can be represented,
- whether the proposed representations of the data are available.

The data collected so far are presented in **Sections A to C**. There the introductory pages as well as the tables should be checked for
- quality of the data (sources for the best available data)
- completeness of the data (data types, nuclides, etc.)
- representation (particularly of fission yields, section C).

Appendix A gives background information on the development of the handbook, how and which data were selected for inclusion, and some general questions to experts. Tables App-1 to App-4 list the requested data. These tables should be checked, especially when going through the questions in **Appendix C**.

Appendix B shows the proposed structure of the final handbook, providing for the inclusion of all the information requested in the replies to the questionnaire. Comments on this proposal are appreciated.

Appendix C contains specific questions to open problems regarding the data already presented as well as those not yet included. This part is very **important** as the inclusion of additional data depends on the replies we hope to receive. To make life easier for reviewers, we have enhanced the words "**question**", "**safeguards experts**" and "**data experts**" by using bold face letters in this appendix. In some cases we will have to contact data experts again after receipt of the feedback from safeguards experts.

We want to thank you in advance for your assistance.

A-1: Half-lives and decay branching fractions

Description of table entries:

decay mode:	α	alpha decay	IT	isomeric transition
	β-	beta decay	SF	spontaneous fission
	ec	electron capture	T	total half-life
units:	s	second	d	day
	m	minute	y	year (= 365.2422 days)
	h	hour		

rel err: relative error (in %)

branching: given for each decay mode (should sum up to 100%)

Source of data:

The tabulated data have been extracted from a data set recommended by participants of an IAEA Co-ordinated Research Programme (CRP).
The complete data set is published in:
IAEA Technical Report Series NO. 261(STI/DOC/10/261), 154-159 (1986), and available on magnetic tape from the IAEA Nuclear Data Section upon request.

nuclide	decay mode	half-life units	half-life value	half-life rel err	branching (percent/decay)
81-Tl-208	β-	m	(3.053 ± 0.004) E+00	(0.13)	
82-Pb-212	β-	h	(1.064 ± 0.001) E+01	(0.09)	
83-Bi-212	T	m	(6.055 ± 0.006) E+01	(0.1)	
	α	m	(1.685 ± 0.003) E+02	(0.18)	35.94 ± 0.06
	β-	m	(9.452 ± 0.013) E+01	(0.14)	64.06 ± 0.06
86-Rn-220	α	s	(5.56 ± 0.01) E+01	(0.18)	
87-Fr-221	α	m	(4.9 ± 0.2) E+00	(4.1)	
88-Ra-224	α	d	(3.66 ± 0.04) E+00	(1.1)	
88-Ra-225	β-	d	(1.48 ± 0.02) E+01	(1.4)	
88-Ra-226	α	y	(1.600 ± 0.007) E+03	(0.44)	
88-Ra-228	β-	y	(5.75 ± 0.03) E+00	(0.52)	
89-Ac-225	α	d	(1.00 ± 0.01) E+01	(1.0)	
89-Ac-227	T	y	(2.177 ± 0.003) E+01	(0.14)	
	α	y	(1.578 ± 0.011) E+03	(0.7)	1.38 ± 0.01
	β-	y	(2.207 ± 0.003) E+01	(0.14)	98.62 ± 0.01
89-Ac-228	β-	h	(6.15 ± 0.02) E+00	(0.33)	
90-Th-228	α	y	(1.913 ± 0.002) E+00	(0.1)	
90-Th-229	α	y	(7.34 ± 0.16) E+03	(2.2)	
90-Th-230	α	y	(7.54 ± 0.03) E+04	(0.4)	
	SF	y	1.5 E+17		5.0 E-11
90-Th-231	β-	h	(2.552 ± 0.001) E+01	(0.04)	
90-Th-232	α	y	(1.405 ± 0.006) E+10	(0.43)	
	SF	y	1. E+21		1.4 E-09
90-Th-233	β-	m	(2.23 ± 0.01) E+01	(0.45)	
90-Th-234	β-	d	(2.410 ± 0.003) E+01	(0.12)	
91-Pa-231	α	y	(3.276 ± 0.011) E+04	(0.34)	
	SF	y	1.1 E+16		3.0 E-10
91-Pa-233	β-	d	(2.70 ± 0.01) E+01	(0.37)	
91-Pa-234	β-	h	(6.70 ± 0.05) E+00	(0.75)	
91-Pa-234m	β-	m	(1.17 ± 0.03) E+00	(2.6)	99.87 ± 0.02
	IT	h	(1.5 ± 0.2) E+01	(10.)	0.13 ± 0.02
92-U -232	α	y	(6.98 ± 0.05) E+01	(0.72)	
	SF	y	(8. ± 6.) E+13	(80.)	(0.9 ± 0.7) E-10

nuclide	decay mode	half-life units	half-life value	half-life rel err	branching (percent/decay)
92-U -233	α	y	(1.592 ± 0.002) E+05	(0.13)	
	SF	y	>2.7 E+17		<0.59 E-10
92-U -234	α	y	(2.457 ± 0.003) E+05	(0.12)	
	SF	y	(1.42 ± 0.08) E+16	(5.6)	(1.73 ± 0.10) E-09
92-U -235	α	y	(7.037 ± 0.007) E+08	(0.1)	
	SF	y	(9.8 ± 2.8) E+18	(30.)	(7.2 ± 2.1) E-09
92-U -235m	IT	m	(2.6 ± 0.2) E+01	(7.7)	
92-U -236	α	y	(2.342 ± 0.003) E+07	(0.13)	
	SF	y	(2.43 ± 0.07) E+16	(2.9)	(9.64 ± 0.03) E-08
92-U -237	β-	d	(6.75 ± 0.01) E+00	(0.15)	
92-U -238	α	y	(4.468 ± 0.005) E+09	(0.11)	
	SF	y	(8.2 ± 0.1) E+15	(1.2)	(5.45 ± 0.07) E-05
92-U -239	β-	m	(2.347 ± 0.005) E+01	(0.21)	
93-Np-236	T	y	(1.15 ± 0.12) E+05	(10.)	
	β-	y	(1.3 ± 0.3) E+06	(20.)	8.9 ± 2.0
	ec	y	(1.26 ± 0.03) E+05	(2.4)	91.1 ± 2.0
93-Np-236m	T	h	(2.25 ± 0.04) E+01	(1.8)	
	β-	h	(4.69 ± 0.13) E+01	(2.8)	48. ± 1.
	ec	h	(4.33 ± 0.11) E+01	(2.5)	52. ± 1.
93-Np-237	α	y	(2.14 ± 0.01) E+06	(0.47)	
	SF	y	>1. E+18		<2. E-10
93-Np-239	β-	d	(2.355 ± 0.004) E+00	(0.17)	
94-Pu-236	α	y	(2.9 ± 0.1) E+00	(3.5)	
	SF	y	(3.4 ± 0.6) E+09	(20.)	(8.5 ± 1.5) E-08
94-Pu-238	α	y	(8.77 ± 0.03) E+01	(0.34)	
	SF	y	(4.7 ± 0.2) E+10	(4.3)	(1.87 ± 0.08) E-07
94-Pu-239	α	y	(2.411 ± 0.003) E+04	(0.12)	
	SF	y	5.5 E+15		4.4 E-10
94-Pu-240	α	y	(6.563 ± 0.007) E+03	(0.11)	
	SF	y	(1.16 ± 0.04) E+11	(3.5)	(5.7 ± 0.1) E-06
94-Pu-241	β-	y	(1.435 ± 0.01) E+01	(0.7)	
	α	y	(6.00 ± 0.05) E+05	(0.83)	(2.39 ± 0.04) E-03
94-Pu-242	α	y	(3.735 ± 0.011) E+05	(0.29)	
	SF	y	(6.8 ± 0.1) E+10	(1.5)	(5.49 ± 0.08) E-04
94-Pu-243	β-	h	(4.956 ± 0.003) E+00	(0.06)	
94-Pu-244	α	y	(8.00 ± 0.09) E+07	(1.1)	99.881 ± 0.006
	SF	y	(6.7 ± 0.3) E+10	(4.5)	0.119 ± 0.006

nuclide	decay mode	half-life units	half-life value	half-life rel err	branching (percent/decay)
94-Pu-245	β-	h	(1.05 ± 0.01) E+01	(0.95)	
94-Pu-246	β-	d	(1.085 ± 0.002) E+01	(0.18)	
95-Am-240	ec	h	(5.08 ± 0.03) E+01	(0.59)	
	α	y	(3.0 ± 1.1) E+03	(40.)	(1.9 ± 0.7) E-04
95-Am-241	α	y	(4.327 ± 0.005) E+02	(0.12)	
	SF	y	(1.147 ± 0.024) E+14	(2.1)	(3.77 ± 0.08) E-10
95-Am-242	T	h	(1.602 ± 0.002) E+01	(0.12)	
	β-	h	(1.937 ± 0.007) E+01	(0.36)	82.7 ± 0.3
	ec	h	(9.26 ± 0.16) E+01	(1.7)	1.73 ± 0.3
95-Am-242m	IT	y	(1.41 ± 0.02) E+02	(1.4)	99.55 ± 0.03
	SF	y	(8.8 ± 3.2) E+11	(40.)	(1.6 ± 0.6) E-08
	α	y	(3.11 ± 0.05) E+04	(1.6)	0.45 ± 0.03
95-Am-243	α	y	(7.370 ± 0.015) E+03	(0.2)	
	SF	y	(2.0 ± 0.3) E+13	(20.)	(3.7 ± 0.9) E-08
96-Cm-242	α	d	(1.629 ± 0.) E+02	(0.04)	
	SF	y	(7.05 ± 0.14) E+06	(2.0)	(6.33 ± 0.13) E-06
96-Cm-243	T	y	(2.85 ± 0.02) E+01	(0.7)	
	α	y	(2.86 ± 0.02) E+01	(0.7)	99.76 ± 0.03
	ec	y	(1.19 ± 0.15) E+04	(10.)	0.24 ± 0.03
96-Cm-244	α	y	(1.810 ± 0.002) E+01	(0.11)	
	SF	y	(1.344 ± 0.007) E+07	(0.52)	(1.347 ± 0.007) E-04
98-Cf-252	T	y	(2.645 ± 0.008) E+00	(0.3)	
	α	y	(2.73 ± 0.01) E+00	(0.37)	96.908 ± 0.008
	SF	y	(8.55 ± 0.03) E+01	(0.35)	3.092 ± 0.008

A-2: Alpha radiation energies and emission probabilities

Description of table entries:

The second column gives alpha energies and their errors in keV for the nuclides listed in the first column. The third column gives alpha emission probabilities and their errors in percent per decay and relative errors (in %) in brackets ("rel err").

Source of data:

The tabulated data have been extracted from a data set recommended by participants of the IAEA Co-ordinated Research Programme (CRP) on "Decay data of the transactinium nuclides" (1978-1984).

The complete data set is published in:
IAEA Technical Report Series No. 261 (STI/DOC/10/261), pp 168-170 (1986), also available on magnetic tape from the IAEA Nuclear Data Section upon request.

nuclide	energy (keV)	emission probability (percent per decay)	rel err
90-Th-228	5340.54 ± 0.15	26.7 ± 0.2	(0.75)
	5423.33 ± 0.22	72.7 ± 1.0	(1.4)
90-Th-229	4797.8 ± 1.2	1.27	
	4814.6 ± 1.2	9.30 ± 0.08	(0.86)
	4837.	4.8	
	4845.3 ± 1.2	56.2 ± 0.2	(0.36)
	4901.0 ± 1.2	10.20 ± 0.08	(0.78)
	4967.5 ± 1.2	5.97 ± 0.06	(1.0)
	4978.5 ± 1.2	3.17 ± 0.04	(1.3)
	5050.	5.2	
	5052.	1.6	
90-Th-230	4438.4 ± 1.6	0.030 ± 0.015	(50.)
	4479.8 ± 1.6	0.12	
	4621.2 ± 1.5	23.4 ± 0.1	(0.43)
	4687.7 ± 1.5	76.3 ± 0.3	(0.39)
90-Th-232	3830.	0.20 ± 0.08	(40.)
	3954. ± 8.	23. ± 2.	(8.7)
	4013. ± 3.	77. ± 2.	(2.6)
91-Pa-231	4506. ± 1.	0.0021 ± 0.0003	(10.)
	4567. ± 1.	0.0054 ± 0.0005	(10.)
	4598. ± 1.	0.020 ± 0.003	(20.)
	4631.4 ± 0.8	0.052 ± 0.003	(5.8)
	4640.7 ± 0.9	0.077 ± 0.003	(3.9)
	4678.6 ± 0.9	1.61 ± 0.07	(4.4)
	4710.7 ± 0.9	1.00 ± 0.07	(7.0)
	4734.7 ± 0.8	8.47 ± 0.40	(4.7)
	4792.4 ± 0.9	0.06 ± 0.01	(20.)
	4851.8 ± 0.9	1.4 ± 0.1	(7.1)
	4934.4 ± 0.9	3.0 ± 0.4	(10.)
	4951.0 ± 0.9	22.9 ± 0.5	(2.2)
	4976.0 ± 0.8	0.4 ± 0.1	(30.)
	4986.2 ± 0.8	1.4 ± 0.2	(10.)
	5013.5 ± 0.8	25.4 ± 0.5	(2.0)
	5029.6 ± 0.8	20. ± 2.	(10.)
	5032.2 ± 0.8	3.2 ± 0.3	(10.)
	5059.1 ± 0.8	11.0 ± 0.5	(4.6)
92-U -232	5139.0 ± 2.0	0.30 ± 0.02	(6.7)
	5263.41 ± 0.09	31.7 ± 0.4	(1.3)
	5320.17 ± 0.14	68.0 ± 0.4	(0.59)
92-U -233	4729.	1.85 ± 0.05	(2.7)
	4783.5 ± 1.2	14.9 ± 0.2	(1.3)
	4824.2 ± 1.2	82.7 ± 0.3	(0.36)
92-U -234	4603.8 ± 0.9	0.199 ± 0.002	(1.0)
	4722.6 ± 0.9	28.42 ± 0.02	(0.07)
	4774.9 ± 0.8	71.37 ± 0.02	(0.03)

nuclide	energy (keV)	emission probability (percent per decay)	rel err
92-U -235	4150. ± 5.	0.9 ± 0.2	(20.)
	4218. ± 2.0	5.7 ± 0.6	(10.)
	4325.0 ± 0.9	4.4 ± 0.5	(10.)
	4327.8 ± 0.9	0.21 ± 0.04	(20.)
	4361.6 ± 0.9	0.24 ± 0.07	(30.)
	4365.4 ± 0.9	17. ± 2.	(10.)
	4380.6 ± 0.9	0.31	
	4400. ± 2.	55. ± 3.	(5.5)
	4414. ± 4.	2.1 ± 0.2	(10.)
	4435. ± 5.	0.7	
	4502. ± 2.	1.7 ± 0.2	(10.)
	4556. ± 2.	4.2 ± 0.3	(7.1)
	4599. ± 2.	5.0 ± 0.5	(10.)
92-U -236	4332. ± 8.	0.26 ± 0.01	(3.9)
	4445. ± 5.	25.9 ± 4.0	(20.)
	4494. ± 3.	73.8 ± 4.0	(5.4)
92-U -238	4039. ± 5.	0.23 ± 0.07	(30.)
	4147. ± 5.	23. ± 4.	(20.)
	4196. ± 5.	77. ± 4.	(5.2)
93-Np-237	4581.1 ± 2.0	0.40 ± 0.04	(10.)
	4598.7 ± 2.0	0.34 ± 0.04	(10.)
	4639.5 ± 2.0	6.18 ± 0.12	(1.9)
	4664.1 ± 2.0	3.32 ± 0.10	(3.0)
	4766.1 ± 1.5	8. ± 3.	(40.)
	4771.1 ± 1.5	25. ± 6.	(20.)
	4788.1 ± 1.5	47. ± 9.	(20.)
	4803.4 ± 2.0	1.56	
	4817.4 ± 2.0	2.5 ± 0.4	(20.)
	4873.1 ± 2.0	2.6 ± 0.2	(7.7)
94-Pu-236	5614.1	0.18	
	5721.0 ± 1.0	31.7 ± 0.9	(2.8)
	5767.7 ± 1.0	68.1 ± 0.8	(1.2)
94-Pu-238	5205.6 ± 0.3	0.003 ± 0.001	(30.)
	5357.7 ± 0.1	0.102 ± 0.002	(2.0)
	5456.5 ± 0.4	28.84 ± 0.06	(0.21)
	5499.21 ± 0.20	71.04 ± 0.06	(0.08)
94-Pu-239	4829.45 ± 0.20	0.00371 ± 0.00008	(2.2)
	4866.97 ± 0.20	0.0010 ± 0.0001	(10.)
	4870.46 ± 0.20	0.0007 ± 0.0003	(40.)
	4911.77 ± 0.20	0.003 ± 0.001	(30.)
	4935.08 ± 0.20	0.0050 ± 0.0010	(20.)
	4962.92 ± 0.20	0.006 ± 0.003	(50.)
	4988.21 ± 0.20	0.004 ± 0.002	(50.)
	5008.76 ± 0.20	0.019 ± 0.002	(10.)
	5029.59 ± 0.20	0.005 ± 0.001	(20.)
	5055.42 ± 0.20	0.030 ± 0.004	(10.)
	5076.35 ± 0.20	0.036 ± 0.004	(10.)
	5105.5 ± 0.8	11.8 ± 0.2	(1.7)
	5143.8 ± 0.8	15.0 ± 0.2	(1.3)
	5156.70 ± 0.14	73.1 ± 0.7	(0.96)

nuclide	energy (keV)	emission probability (percent per decay)	rel err
94-Pu-240	4863.6 ± 0.5	0.00113 ± 0.00003	(2.7)
	5021.5 ± 0.5	0.089 ± 0.002	(2.3)
	5123.68 ± 0.23	27.0 ± 0.5	(1.9)
	5168.17 ± 0.15	72.9 ± 0.5	(0.69)
94-Pu-241	4784. ± 5.	0.000005 ± 0.000002	(40.)
	4798. ± 3.	0.000029 ± 0.000003	(10.)
	4853.4 ± 1.2	0.000292 ± 0.000005	(1.7)
	4896.4 ± 1.2	0.00201 ± 0.00002	(1.0)
	4972. ± 2.	0.000031 ± 0.000006	(20.)
	4998. ± 2.	0.000010 ± 0.000001	(10.)
	5042. ± 2.	0.000025	
	5054. ± 2.	0.0000025	
94-Pu-242	4598.5 ± 1.6	0.00086 ± 0.00007	(8.1)
	4754.6 ± 1.3	0.0307 ± 0.0014	(4.6)
	4856.2 ± 1.2	23.48 ± 0.17	(0.72)
	4900.5 ± 1.2	76.49 ± 0.17	(0.22)
95-Am-241	5322. ± 1.	0.015 ± 0.005	(30.)
	5388. ± 1.	1.4 ± 0.2	(10.)
	5442.90 ± 0.13	12.8 ± 0.2	(1.6)
	5485.60 ± 0.12	85.2 ± 0.8	(0.94)
	5512. ± 2.	0.20 ± 0.05	(30.)
	5544. ± 1.	0.34 ± 0.05	(10.)
95-Am-242m	5064.2	0.00099 ± 0.00007	(7.1)
	5082.	0.00014 ± 0.00001	(7.1)
	5088.4	0.00086 ± 0.00006	(7.0)
	5141.6 ± 0.5	0.0262 ± 0.0017	(6.5)
	5206.8 ± 0.5	0.404 ± 0.027	(6.7)
	5248.2	0.00050	
	5250.0	0.00018 ± 0.00001	(5.6)
	5273.	0.0039 ± 0.0003	(7.7)
	5313.5	0.0031 ± 0.0002	(6.5)
	5367.2	0.00527 ± 0.00035	(6.6)
	5409.3	0.00468 ± 0.00031	(6.6)
95-Am-243	4695. ± 3.	0.0017 ± 0.0005	(30.)
	4930. ± 3.	0.00018	
	4946. ± 3.	0.00034	
	5088. ± 3.	0.004	
	5113. ± 1.	0.0054	
	5181. ± 1.	1.1	
	5233.4 ± 1.0	10.6	
	5275.3 ± 1.0	87.9	
	5321. ± 1.	0.12	
	5350. ± 1.	0.16	
96-Cm-242	5814. ± 2.	0.0031 ± 0.0005	(20.)
	5971. ± 3.	0.035 ± 0.002	(5.7)
	6069.42 ± 0.12	25.0 ± 0.5	(2.0)
	6112.72 ± 0.08	74.0 ± 0.5	(0.68)

nuclide	energy (keV)	emission probability (percent per decay)	rel err
96-Cm-243	5267. ± 3.	0.0015	
	5316. ± 3.	0.001	
	5323. ± 3.	0.003	
	5332. ± 3.	0.003	
	5523. ± 3.	0.002	
	5532. ± 3.	0.006	
	5537. ± 3.	0.002	
	5568. ± 3.	0.007	
	5575. ± 3.	0.007	
	5582. ± 3.	0.009	
	5587. ± 3.	0.02	
	5593. ± 3.	0.01	
	5612. ± 3.	0.03	
	5622.	0.06	
	5639. ± 3.	0.14	
	5646. ± 3.	0.03	
	5682. ± 3.	0.2	
	5686. ± 3.	1.6	
	5742.2 ± 1.0	10.6 ± 0.2	(1.9)
	5785.1 ± 1.0	73.5 ± 1.0	(1.4)
	5876. ± 3.	0.6	
	5907. ± 3.	0.1	
	5992.2 ± 1.0	6.5 ± 0.2	(3.1)
	6010. ± 3.	1.0	
	6058. ± 3.	4.7	
	6067. ± 3.	1.5	
96-Cm-244	5515.5	0.0035	
	5665.7	0.0163 ± 0.0007	(4.3)
	5762.84 ± 0.03	23.00 ± 0.05	(0.22)
	5804.96 ± 0.05	76.98 ± 0.05	(0.06)
98-Cf-252	5976.6	0.23 ± 0.04	(20.)
	6075.7 ± 0.5	15.2 ± 0.3	(2.0)
	6118.3 ± 0.5	81.6 ± 0.3	(0.37)

A-3: Gamma ray energies and emission probabilities

Description of table entries:

The second column gives γ-ray energies and their errors in keV for the nuclides listed in the first column. The third column gives γ-ray emission probabilities and their errors in percent per decay and relative errors (in %) in brackets ("rel err").

Source of data:

The tabulated data have been extracted from a data set recommended by participants of the IAEA Co-ordinated Research Programme (CRP) on "Decay data of the transactinium nuclides" (1978-1984).

The complete data set is published in:
IAEA Technical Report Series No. 261 (STI/DOC/10/261), pp 162-166 (1986), also available on magnetic tape from the IAEA Nuclear Data Section upon request.

nuclide	energy (keV)	emission probability (percent per decay)	rel err
81-Tl-208	252.6 ± 0.3	0.807 ± 0.011	(1.4)
	277.35 ± 0.06	6.4 ± 0.06	(0.94)
	510.80 ± 0.08	22.8 ± 0.3	(1.3)
	583.191 ± 0.002	85.1 ± 0.6	(0.71)
	763.13 ± 0.08	1.89 ± 0.06	(3.2)
	860.37 ± 0.08	12.52 ± 0.12	(0.96)
	1093.1 ± 0.1	0.45 ± 0.06	(10.)
	2614.6 ± 0.1	99.83 ± 0.17	(0.17)
82-Pb-212	115.176 ± 0.007	0.6 ± 0.02	(3.3)
	238.632 ± 0.002	43.5 ± 0.4	(0.92)
	300.087 ± 0.010	3.25 ± 0.04	(1.2)
83-Bi-212	39.858 ± 0.004	1.03 ± 0.05	(4.9)
	288.07 ± 0.07	0.31 ± 0.04	(10.)
	327.96 ± 0.10	0.12 ± 0.008	(6.7)
	452.83 ± 0.10	0.36 ± 0.04	(10.)
	727.330 ± 0.009	6.64 ± 0.09	(1.4)
	785.42 ± 0.06	1.1 ± 0.02	(1.8)
	893.408 ± 0.005	0.381 ± 0.014	(3.7)
	1078.62 ± 0.10	0.574 ± 0.015	(2.6)
	1620.735 ± 0.010	1.49 ± 0.06	(4.0)
86-Rn-220	549.7 ± 0.5	0.114 ± 0.017	(10.)
88-Ra-224	241.0 ± 0.1	4.05 ± 0.04	(0.99)
90-Th-228	84.40 ± 0.05	1.22 ± 0.03	(2.5)
	131.62 ± 0.20	0.127 ± 0.007	(5.5)
	166.37 ± 0.20	0.107 ± 0.004	(3.7)
	215.94 ± 0.08	0.26 ± 0.01	(3.9)
90-Th-229	31.4 ± 0.2	2.45 ± 0.06	(2.5)
	42.7 ± 0.2	0.199 ± 0.006	(3.0)
	43.99 ± 0.01	0.762 ± 0.017	(2.2)
	56.52 ± 0.01	0.312 ± 0.007	(2.2)
	94.73 ± 0.02	0.465 ± 0.008	(1.7)
	107.11 ± 0.01	0.809 ± 0.013	(1.6)
	110.33 ± 0.01	0.128 ± 0.003	(2.3)
	123.19 ± 0.01	0.197 ± 0.003	(1.5)
	124.60 ± 0.05	1.449 ± 0.02	(1.4)
	131.93 ± 0.01	0.327 ± 0.005	(1.5)
	136.990 ± 0.004	1.171 ± 0.016	(1.4)
	142.96 ± 0.01	0.401 ± 0.006	(1.5)
	148.0 ± 0.2	1.091 ± 0.015	(1.4)
	156.41 ± 0.01	1.237 ± 0.018	(1.5)
	179.76 ± 0.01	0.215 ± 0.004	(1.9)
	193.509 ± 0.004	4.41 ± 0.06	(1.4)
	204.69 ± 0.01	0.595 ± 0.009	(1.5)
	210.8 ± 0.1	3.18 ± 0.04	(1.3)
90-Th-230	67.672 ± 0.002	0.376 ± 0.043	(10.)
	143.872 ± 0.004	0.0486 ± 0.0051	(10.)
	186.053 ± 0.004	0.0088 ± 0.0009	(10.)
	253.729 ± 0.010	0.0111 ± 0.0012	(10.)

nuclide	energy (keV)	emission probability (percent per decay)	rel err
90-Th-231	25.64 ± 0.02	14.6 ± 0.3	(2.1)
	58.570 ± 0.003	0.5 ± 0.05	(10.)
	72.751 ± 0.003	0.26 ± 0.02	(7.7)
	81.228 ± 0.003	0.85 ± 0.03	(3.5)
	82.087 ± 0.003	0.37 ± 0.02	(5.4)
	84.214 ± 0.003	6.71 ± 0.1	(1.5)
	102.270 ± 0.003	0.4 ± 0.02	(5.0)
	124.914 ± 0.017	0.06 ± 0.003	(5.0)
	134.03 ± 0.02	0.025 ± 0.005	(20.)
	135.664 ± 0.011	0.084 ± 0.007	(8.3)
	217.94 ± 0.03	0.037 ± 0.001	(2.7)
90-Th-232	59. ± 1.	0.19	
	126. ± 5.	0.043	
90-Th-233	29.36 ± 0.04	2.5	
	86.50 ± 0.05	2.7	
	88.0 ± 0.2	0.3	
	94.68 ± 0.05	0.8	
	162.5 ± 0.1	0.32	
	169.1 ± 0.2	0.34	
	170.7 ± 0.3	0.13	
	190.54 ± 0.08	0.13	
	194.90 ± 0.05	0.16	
	359.9 ± 0.2	0.12	
	441.0 ± 0.3	0.23	
	447.7 ± 0.3	0.15	
	459.2 ± 0.2	1.4	
	490.8 ± 0.3	0.17	
	499.0 ± 0.3	0.21	
	595.2 ± 0.2	0.16	
	669.8 ± 0.2	0.68	
	764.4 ± 0.4	0.12	
	890.1 ± 0.5	0.14	
90-Th-234	63.29 ± 0.02	4.47 ± 0.88	(20.)
	92.38 ± 0.01	2.6 ± 0.53	(20.)
	92.80 ± 0.02	2.56 ± 0.52	(20.)
	112.81 ± 0.05	0.256 ± 0.054	(20.)
91-Pa-231	16.39 ± 0.02	0.22 ± 0.01	(4.6)
	18.95 ± 0.02	0.354 ± 0.007	(2.0)
	27.360 ± 0.020	11.1 ± 0.4	(3.6)
	38.20 ± 0.03	0.143 ± 0.009	(6.3)
	46.370 ± 0.020	0.223 ± 0.006	(2.7)
	255.90 ± 0.04	0.107 ± 0.003	(2.8)
	260.3 ± 0.1	0.182 ± 0.005	(2.8)
	273.237 ± 0.117	0.059 ± 0.002	(3.4)
	277.322 ± 0.013	0.069 ± 0.002	(2.9)
	283.690 ± 0.013	1.65 ± 0.04	(2.4)
	300.069 ± 0.008	2.41 ± 0.06	(2.5)
	302.669 ± 0.006	2.47 ± 0.06	(2.4)
	330.057 ± 0.015	1.36 ± 0.03	(2.2)
	340.77 ± 0.07	0.178 ± 0.004	(2.3)
	354.474 ± 0.075	0.097 ± 0.003	(3.1)
	357.16 ± 0.07	0.169 ± 0.005	(3.0)

nuclide	energy (keV)	emission probability (percent per decay)	rel err
91-Pa-233	75.28 ± 0.01	1.32 ± 0.04	(3.0)
	86.59 ± 0.01	1.97 ± 0.12	(6.1)
	103.86 ± 0.02	0.87 ± 0.03	(3.5)
	271.48 ± 0.08	0.32 ± 0.01	(3.1)
	300.12 ± 0.03	6.63 ± 0.06	(0.9)
	311.98 ± 0.03	38.63 ± 0.39	(1.0)
	340.50 ± 0.04	4.5 ± 0.05	(1.1)
	375.45 ± 0.04	0.68 ± 0.01	(1.5)
	398.62 ± 0.08	1.41 ± 0.02	(1.4)
	415.76 ± 0.04	1.74 ± 0.02	(1.2)
92-U -232	57.78 ± 0.05	0.2 ± 0.002	(1.0)
	129.08 ± 0.05	0.0682 ± 0.0004	(0.59)
	270.2 ± 0.2	0.00316 ± 0.00005	(1.6)
	327.9 ± 0.2	0.00283 ± 0.00006	(2.1)
92-U -233	54.699 ± 0.001	0.0182 ± 0.0003	(1.7)
	118.968 ± 0.002	0.00406 ± 0.00004	(0.99)
	120.816 ± 0.001	0.00332 ± 0.00003	(0.9)
	135.3	0.00232 ± 0.00002	(0.86)
	146.345 ± 0.002	0.00657 ± 0.00006	(0.91)
	164.522 ± 0.002	0.00623 ± 0.00005	(0.8)
	208.171 ± 0.002	0.00229 ± 0.00003	(1.3)
	245.345 ± 0.002	0.00362 ± 0.00003	(0.83)
	291.354 ± 0.004	0.00537 ± 0.00005	(0.93)
	317.2	0.00776 ± 0.00007	(0.9)
	320.541 ± 0.005	0.0029 ± 0.00003	(1.0)
92-U -234	53.20 ± 0.02	0.123 ± 0.002	(1.6)
	120.90 ± 0.02	0.0342 ± 0.0005	(1.5)
92-U -235	109.16 ± 0.02	1.54 ± 0.05	(3.3)
	140.76 ± 0.04	0.22 ± 0.02	(10.)
	143.76 ± 0.02	10.96 ± 0.08	(0.73)
	163.33 ± 0.02	5.08 ± 0.04	(0.79)
	182.61 ± 0.05	0.34 ± 0.02	(5.9)
	185.715 ± 0.005	57.2 ± 0.5	(0.87)
	194.94 ± 0.01	0.63 ± 0.01	(1.6)
	202.11 ± 0.02	1.08 ± 0.02	(1.9)
	205.311 ± 0.010	5.01 ± 0.05	(1.0)
	221.38 ± 0.02	0.12 ± 0.01	(8.3)
92-U -236	49.369 ± 0.009	0.078 ± 0.008	(10.)
	112.750 ± 0.015	0.019 ± 0.005	(30.)
92-U -237	26.348 ± 0.010	2.24 ± 0.33	(10.)
	33.195 ± 0.011	0.112 ± 0.048	(40.)
	51.01 ± 0.03	0.2 ± 0.09	(50.)
	59.543 ± 0.015	34.5 ± 0.8	(2.3)
	64.83 ± 0.02	1.31 ± 0.03	(2.3)
	164.61 ± 0.02	1.87 ± 0.05	(2.7)
	208.005 ± 0.023	21.6 ± 0.5	(2.3)
	221.80 ± 0.04	0.0205 ± 0.0008	(3.9)
	234.40 ± 0.04	0.0205 ± 0.0008	(3.9)
	267.54 ± 0.04	0.73 ± 0.018	(2.5)
	332.36 ± 0.04	1.21 ± 0.03	(2.5)
	335.38 ± 0.04	0.097 ± 0.003	(3.1)
	368.59 ± 0.04	0.042 ± 0.002	(4.8)
	370.94 ± 0.04	0.11 ± 0.004	(3.6)

nuclide	energy (keV)	emission probability (percent per decay)	rel err
92-U -238	49.55 ± 0.06	0.064 ± 0.008	(10.)
92-U -239	43.533 ± 0.001	4.16 ± 0.11	(2.6)
	74.664 ± 0.001	48.1 ± 1.	(2.1)
93-Np-236	100.	0.5 ± 0.1	(20.)
	104.	7.5 ± 0.2	(2.7)
	160.2 ± 0.6	27.6 ± 0.6	(2.2)
93-Np-236m	44.6 ± 0.1	0.011 ± 0.0002	(1.8)
	538.09 ± 0.15	0.011 ± 0.001	(10.)
	642.33 ± 0.09	0.92 ± 0.06	(6.5)
	687.61 ± 0.10	0.25 ± 0.02	(8.0)
93-Np-237	29.373 ± 0.010	15.3 ± 0.3	(2.0)
	46.53 ± 0.04	0.106 ± 0.006	(5.7)
	57.15 ± 0.04	0.382 ± 0.011	(2.9)
	86.503 ± 0.020	12.3 ± 0.2	(1.6)
	88.04 ± 0.16	0.138 ± 0.003	(2.2)
	117.681 ± 0.030	0.173 ± 0.003	(1.7)
	131.04	0.086 ± 0.002	(2.3)
	134.23	0.071 ± 0.002	(2.8)
	143.208 ± 0.025	0.432 ± 0.008	(1.9)
	151.37 ± 0.04	0.234 ± 0.004	(1.7)
	155.22	0.092 ± 0.002	(2.2)
	169.17	0.071 ± 0.001	(1.4)
	195.096 ± 0.020	0.185 ± 0.002	(1.1)
	212.415 ± 0.025	0.151 ± 0.002	(1.3)
	238.0	0.059 ± 0.001	(1.7)
93-Np-238	101.9 ± 0.03	0.27 ± 0.01	(3.7)
	119.9 ± 0.1	0.108 ± 0.006	(5.6)
	882.63 ± 0.03	0.87 ± 0.03	(3.5)
	918.69 ± 0.04	0.59 ± 0.02	(3.4)
	923.98 ± 0.02	2.86 ± 0.09	(3.2)
	936.61 ± 0.06	0.4 ± 0.01	(2.5)
	941.38 ± 0.05	0.54 ± 0.02	(3.7)
	962.77 ± 0.03	0.7 ± 0.02	(2.9)
	984.45 ± 0.02	27.8 ± 0.8	(2.9)
	1025.87 ± 0.02	9.6 ± 0.5	(5.2)
	1028.54 ± 0.02	20.3 ± 0.8	(3.9)
93-Np-239	61.460 ± 0.002	1.29 ± 0.02	(1.6)
	106.123 ± 0.002	27.2 ± 0.4	(1.5)
	209.753 ± 0.002	3.42 ± 0.05	(1.5)
	226.42 ± 0.08	0.28 ± 0.02	(7.1)
	228.183 ± 0.001	11.27 ± 0.18	(1.6)
	277.599 ± 0.001	14.38 ± 0.21	(1.5)
	285.460 ± 0.002	0.79 ± 0.02	(2.5)
	315.880 ± 0.003	1.6 ± 0.03	(1.9)
	334.310 ± 0.002	2.07 ± 0.03	(1.5)
94-Pu-236	47.6	0.069 ± 0.021	(30.)
	109.0	0.012 ± 0.004	(30.)
	165.	0.00066 ± 0.0002	(30.)
	515.6	0.00017 ± 0.00005	(30.)
	563.2	0.0001 ± 0.00003	(30.)
	645.	0.00024 ± 0.00008	(30.)

nuclide	energy (keV)	emission probability (percent per decay)	rel err
94-Pu-238	43.498 ± 0.001	0.0395 ± 0.0008	(2.0)
	99.853 ± 0.003	0.00735 ± 0.00008	(1.1)
	152.720 ± 0.002	0.000937± 0.00001	(1.1)
94-Pu-239	38.660 ± 0.002	0.0105 ± 0.0002	(1.9)
	40.41 ± 0.05	0.000162± 0.000017	(10.)
	42.06 ± 0.03	0.000165± 0.000006	(3.6)
	46.218 ± 0.010	0.000737± 0.000075	(10.)
	46.69	(5.8 ± 0.4) E-05	(6.9)
	51.624 ± 0.001	0.0271 ± 0.0005	(1.9)
	56.825 ± 0.003	0.00113 ± 0.000025	(2.2)
	123.62 ± 0.05	(1.97 ± 0.21) E-05	(10.)
	124.51 ± 0.03	(6.13 ± 0.22) E-05	(3.6)
	125.21 ± 0.10	(7.11 ± 0.2) E-05	(2.8)
	129.296 ± 0.001	0.00631 ± 0.00006	(0.95)
	141.657 ± 0.020	(3.2 ± 0.09) E-05	(2.8)
	144.201 ± 0.003	0.000304± 0.000004	(1.2)
	146.094 ± 0.006	0.000119± 0.000003	(2.1)
	161.482 ± 0.021	0.000123± 0.000002	(1.6)
	171.393 ± 0.006	0.00011 ± 0.000002	(1.8)
	179.220 ± 0.012	(6.6 ± 0.1) E-05	(1.5)
	188.23 ± 0.10	(1.09 ± 0.11) E-05	(10.)
	189.360 ± 0.010	(8.3 ± 0.1) E-05	(1.2)
	195.679 ± 0.008	0.000107± 0.000001	(0.93)
	203.550 ± 0.005	0.000569± 0.000003	(0.53)
	255.384 ± 0.015	(8. ± 0.1) E-05	(1.3)
	297.46 ± 0.03	(4.98 ± 0.08) E-05	(1.6)
	311.78 ± 0.04	(2.58 ± 0.07) E-05	(2.7)
	332.845 ± 0.005	0.000494± 0.000003	(0.61)
	341.502 ± 0.019	(6.62 ± 0.14) E-05	(2.1)
	345.013 ± 0.004	0.000556± 0.000005	(0.9)
	375.054 ± 0.003	0.001554± 0.000009	(0.58)
	380.191 ± 0.006	0.000305± 0.000006	(2.0)
	382.698 ± 0.016	0.000259± 0.000005	(1.9)
	392.914 ± 0.014	0.000553± 0.000012	(2.2)
	413.713 ± 0.005	0.001466± 0.000011	(0.75)
	422.598 ± 0.019	0.000122± 0.000002	(1.6)
	445.81 ± 0.10	(8.8 ± 0.6) E-06	(6.8)
	451.481 ± 0.010	0.000189± 0.000002	(0.84)
	481.78 ± 0.12	(4.6 ± 0.2) E-06	(4.4)
	639.99 ± 0.10	(8.7 ± 0.2) E-06	(2.3)
	645.98 ± 0.03	(1.52 ± 0.03) E-05	(2.0)
	651.79 ± 0.10	(6.6 ± 0.2) E-06	(3.0)
	658.63 ± 0.15	(9.7 ± 0.2) E-06	(2.1)
	718.0 ± 0.5	(2.8 ± 0.2) E-06	(7.1)
	769.19 ± 0.04	(1.19 ± 0.02) E-05	(1.7)
94-Pu-240	45.242 ± 0.003	0.0447 ± 0.0007	(1.6)
	104.235 ± 0.005	0.00714 ± 0.00006	(0.84)
	160.307 ± 0.003	0.000402± 0.000004	(1.0)
94-Pu-241	77.10 ± 0.10	(2.07 ± 0.04) E-05	(1.9)
	103.680 ± 0.005	0.000102± 0.000002	(2.0)
	148.567 ± 0.010	0.000186± 0.000002	(0.86)
	159.955 ± 0.020	(6.58 ± 0.09) E-06	(1.4)
94-Pu-242	44.915 ± 0.013	0.0373 ± 0.0007	(1.9)
	103.50 ± 0.04	0.00255 ± 0.0001	(3.9)
	158.80 ± 0.08	0.0003 ± 0.00002	(6.7)

nuclide	energy (keV)	emission probability (percent per decay)	rel err
95-Am-241	26.345 ± 0.001	2.4 ± 0.1	(4.2)
	33.205 ± 0.010	0.12 ± 0.01	(8.3)
	43.423 ± 0.010	0.071 ± 0.01	(10.)
	59.537 ± 0.001	35.9 ± 0.4	(1.1)
	98.97 ± 0.02	0.02 ± 0.001	(5.0)
	102.98 ± 0.02	0.0196 ± 0.001	(5.1)
	123.01 ± 0.02	0.001 ± 0.0001	(10.)
	125.30 ± 0.02	0.0041 ± 0.0001	(2.4)
	146.55 ± 0.03	0.00046 ± 0.00002	(4.4)
	164.69 ± 0.04	(7.2 ± 1.5) E-05	(20.)
	169.56 ± 0.03	0.000172± 0.000015	(8.7)
	208.01 ± 0.03	0.00079 ± 0.00002	(2.5)
	322.52 ± 0.03	0.00015 ± 0.00001	(6.7)
	332.35 ± 0.03	0.00015 ± 0.00001	(6.7)
	335.37 ± 0.03	0.000495± 0.00001	(2.0)
	368.65 ± 0.03	0.00022 ± 0.00002	(10.)
	662.40 ± 0.02	0.00036 ± 0.00002	(5.6)
95-Am-242	42.13 ± 0.01	45.6 ± 0.2	(0.44)
	44.52 ± 0.02	10.6 ± 0.4	(3.8)
95-Am-242m	48.63 ± 0.05	99.5	
	49.367 ± 0.004	0.19 ± 0.01	(5.3)
	66.898 ± 0.020	0.021 ± 0.001	(4.8)
	67.9	0.0073 ± 0.0002	(2.7)
	86.68 ± 0.03	0.04 ± 0.01	(30.)
	92.5	0.004 ± 0.001	(30.)
	109.6	0.024 ± 0.001	(4.2)
	111.1	0.003 ± 0.001	(30.)
	121.8	0.006 ± 0.0002	(3.3)
	135.17 ± 0.06	0.011 ± 0.001	(10.)
	136.1	0.0096 ± 0.0003	(3.1)
	152.75 ± 0.06	0.0014 ± 0.0003	(20.)
	153.84 ± 0.06	0.0046 ± 0.0001	(2.2)
	163.24 ± 0.04	0.024 ± 0.001	(4.2)
95-Am-243	43.53 ± 0.15	5.93 ± 0.13	(2.2)
	74.67 ± 0.15	68.2 ± 1.4	(2.1)
	86.79 ± 0.15	0.338 ± 0.007	(2.1)
	142.18 ± 0.15	0.12 ± 0.01	(8.3)
96-Cm-242	44.08 ± 0.03	0.0325 ± 0.0012	(3.7)
	101.93 ± 0.04	0.0025 ± 0.0004	(20.)
	157.42 ± 0.05	0.0014 ± 0.0002	(10.)
	561.02 ± 0.10	0.00015 ± 0.00004	(30.)
	605.04 ± 0.10	0.00011 ± 0.00003	(30.)
96-Cm-243	44.663 ± 0.005	0.12 ± 0.02	(20.)
	209.753 ± 0.002	3.29 ± 0.1	(3.0)
	228.184 ± 0.002	10.6 ± 0.3	(2.8)
	277.599 ± 0.002	14. ± 0.4	(2.9)
	285.460 ± 0.002	0.73 ± 0.02	(2.7)
96-Cm-244	42.824 ± 0.008	0.0248 ± 0.0006	(2.4)
	98.860 ± 0.013	0.0011 ± 0.0001	(10.)
	152.630 ± 0.020	0.00099	
98-Cf-252	43.399 ± 0.025	0.0148 ± 0.0009	(6.1)
	100.2	0.013	
	160. ± 5.	0.0019	

A-4: X-ray energies and intensities

Description of table entries:

1) element (column 1)

2) type of X-ray transition (column 1): only K X-rays are listed as the energies of other X-rays are too low for gamma-ray spectroscopy.

   The following notation for X-ray transitions is used (e.g. K α1 = Siegbahn notation, K-L_3 = associated initial - final shell vacancy):

K α1	...	K-L_3	K β2	...	K-N_2N_3	K β5	...	K-M_4M_5
K α2	...	K-L_2	K β3	...	K-M_2	K O	...	K-O_2O_3
K β1	...	K-M_3	K β4	...	K-N_4N_5	K P	...	K-P_2P_3

   Group designations: K β1' = K β1 + K β3 + K β5

   K β2' = K β2 + K β4 + K O + K P

3) Energies of individual X-rays and mean energies of groups (column 2).

4) X-ray intensities per 100 K-shell vacancies (column 3)

5) X-ray intensities per 100 decays of the nuclides given (columns 4-6)

   α = alpha decay β- = beta decay ec = electron capture

Source of data:

Table of Radioactive Isotopes, E. Browne, R.B. Firestone (V.S. Shirley, editor), publ. by John Wiley & Sons, USA, 1986. The tables used are:

(a) A-chain tables, pp. 208 ff.: for X-ray group energies and decay intensities (columns 4-6).

(b) X-ray tables, pp. C-19 to C-24: for notation and all other data.

element type	energy (keV)	intensity per 100 K-shell vacancies (left column), or per 100 decays of nuclide given	
81-Tl		83-Bi-212 α	
K α1	72.873	46.3 ±0.9	0.127 ±0.021
K α2	70.832	27.6 ±0.6	0.075 ±0.012
K β1	82.574	10.70 ±0.22	
K β3	82.115	5.59 ±0.11	
K β5	83.093	0.303±0.012	
K β1'	82.434		0.045 ±0.007
K β2	84.865	3.90 ±0.08	
K β4	85.134	0.09 ±0.04	
K O	85.444	0.67 ±0.07	
K β2'	85.185		0.0125±0.0021
82-Pb		81-Tl-208 β-	
K α1	74.969	46.2 ±0.9	3.60 ±0.11
K α2	72.805	27.7 ±0.6	2.14 ±0.07
K β1	84.938	10.70 ±0.22	
K β3	84.450	5.58 ±0.11	
K β5	84.470	0.312±0.012	
K β1	84.789		1.27 ±0.04
K β2	87.300	3.91 ±0.08	
K β4	87.580	0.09 ±0.04	
K O	87.911	0.70 ±0.07	
K P	88.003	0.017±0.002	
K β2'	87.632		0.367 ±0.013
83-Bi		82-Pb-212 β-	
K α1	77.107	46.2 ±0.9	17.70 ±0.6
K α2	74.815	27.7 ±0.6	10.5 ±0.4
K β1	87.349	10.70 ±0.21	
K β3	86.830	5.59 ±0.11	
K β5	87.892	0.321±0.013	
K β1'	87.190		6.27 ±0.22
K β2	89.784	3.93 ±0.08	
K β4	90.074	0.09 ±0.04	
K O	90.421	0.73 ±0.08	
K P	90.522	0.031±0.003	
K β2'	90.128		1.86 ±0.07
84-Po		83-Bi-212 β-	
K α1	79.290	46.1 ±0.9	0.10 ±0.03
K α2	76.863	27.7 ±0.6	0.060 ±0.016
K β1	89.807	10.70 ±0.21	
K β3	89.256	5.57 ±0.11	
K β5	90.388	0.330±0.013	
K β1'	89.639		0.035 ±0.010
K β2	92.317	3.95 ±0.08	
K β4	92.618	0.09 ±0.04	
K O	92.983	0.76 ±0.08	
K P	93.095	0.049±0.005	
K β2'	92.673		0.011 ±0.003

element type	energy (keV)	intensity per 100 K-shell vacancies (left column), or per 100 decays of nuclide given			
86-Rn			88-Ra-224 α		
K α1	83.787	46.0 ±0.9	0.20 ±0.06		
K α2	81.069	27.9 ±0.6	0.12 ±0.04		
K β1	94.868	10.60 ±0.21			
K β3	92.247	5.56 ±0.11			
K β5	95.449	0.349±0.014			
K β1'	94.966		0.072 ±0.020		
K β2	97.530	3.98 ±0.08			
K β4	97.853	0.10 ±0.05			
K O	98.257	0.81 ±0.08			
K P	98.389	0.094±0.010			
K β2'	97.907		0.023 ±0.007		
87-Fr			89-Ac-224 α		
K α1	86.105	45.8 ±0.9	0.28 ±0.04		
K α2	83.231	27.9 ±0.6	0.17 ±0.03		
K β1	97.474	10.70 ±0.21			
K β3	96.815	5.58 ±0.11			
K β5	98.069	0.358±0.014			
K β1'	97.272		0.101 ±0.015		
K β2	100.214	4.01 ±0.08			
K β4	100.548	0.10 ±0.05			
K O	100.972	0.84 ±0.09			
K P	101.118	0.114±0.012			
K β2'	100.599		0.032 ±0.005		
88-Ra			89-Ac-224 ec		90-Th-228 α
K α1	88.471	45.7 ±0.9	35. ±16.		0.0288±0.0019
K α2	85.431	28.0 ±0.6	22. ±10.		0.0175±0.0011
K β1	100.130	10.70 ±0.21			
K β3	99.432	5.59 ±0.11			
K β5	100.738	0.362±0.015			
K β1'	99.915		13. ±6.		0.0103±0.0007
K β2	102.948	4.04 ±0.08			
K β4	103.295	0.11 ±0.05			
K O	103.740	0.86 ±0.09			
K P	103.899	0.132±0.013			
K β2'	103.341		4.1 ±1.9		0.0034±0.0002
89-Ac			91-Pa-231 α		
K α1	90.886	45.5 ±0.9	0.78 ±0.03		
K α2	87.675	28.1 ±0.6	0.476 ±0.018		
K β1	102.841	10.70 ±0.21			
K β3	102.101	5.61 ±0.11			
K β5	103.462	0.371±0.015			
K β1'	102.613		0.280 ±0.011		
K β2	105.738	4.07 ±0.08			
K β4	106.098	0.11 ±0.05			
K O	106.563	0.89 ±0.09			
K P	106.738	0.146±0.015			
K β2'	106.137		0.092 ±0.004		

element type	energy (keV)	intensity per 100 K-shell vacancies (left column), or per 100 decays of nuclide given					
90-Th			89-Ac-228 β-		92-U-233 α		92-U-235 α
K α1	93.350	45.4 ±0.9	5.6	±1.3	0.0169	±0.0014	5.5 ±0.3
K α2	89.957	28.1 ±0.6	3.4	±0.8	0.0104	±0.0008	3.36 ±0.21
K β1	105.604	10.70 ±0.21					
K β3	104.819	5.61 ±0.11					
K β5	106.239	0.380 ±0.015					
K β1'	105.362		2.0	±0.5	0.0061	±0.0005	1.98 ±0.12
K β2	108.582	4.10 ±0.08					
K β4	108.955	0.11 ±0.05					
K O	109.442	0.90 ±0.09					
K P	109.630	0.160 ±0.016					
K β2'	108.990		0.67	±0.15	0.0020	±0.0002	0.66 ±0.04
91-Pa			90-Th-231 β-		90-Th-233 β-		93-Np-237 α
K α1	95.863	45.3 ±0.9	0.63	±0.05	0.83	±0.06	2.58 ±0.21
K α2	92.282	28.1 ±0.6	0.39	±0.03	0.51	±0.04	1.59 ±0.13
K β1	108.422	10.70 ±0.22					
K β3	107.595	5.64 ±0.11					
K β5	109.072	0.389 ±0.016					
K β1'	108.166		0.228	±0.019	0.301	±0.023	0.94 ±0.08
K β2	111.486	4.13 ±0.08					
K β4	111.870	0.12 ±0.06					
K O	112.380	0.93 ±0.10					
K P	112.575	0.156 ±0.016					
K β2'	111.897		0.076	±0.006	0.100	±0.008	0.31 ±0.03
92-U			91-Pa-232 β-		91-Pa-233 β-		91-Pa-234 β-
K α1	98.434	45.1 ±0.9	1.76	±0.07	16.	±3.	23.3 ±1.6
K α2	94.654	28.2 ±0.6	1.10	±0.04	10.2	±1.6	15.7 ±1.0
K β1	111.298	10.70 ±0.22					
K β3	110.421	5.65 ±0.11					
K β5	111.964	0.397 ±0.016					
K β1'	111.025		0.644	±0.024	6.0	±1.0	9.2 ±0.6
K β2	114.445	4.15 ±0.08					
K β4	114.844	0.12 ±0.06					
K O	115.377	0.97 ±0.10					
K P	115.580	0.159 ±0.016					
K β2'	114.866		0.217	±0.009	2.0	±0.3	3.11 ±0.21
92-U			93-Np-236 ec		94-Pu-239 α		94-Pu-241 α
K α1	98.434	45.1 ±0.9	17.8	±1.0	(5.90±0.06)E-3		(4.48±0.09)E-4
K α2	94.654	28.2 ±0.6	11.6	±0.6	(3.67±0.04)E-3		(2.80±0.07)E-4
K β1	111.298	10.70 ±0.22					
K β3	110.421	5.65 ±0.11					
K β5	111.964	0.397 ±0.016					
K β1'	111.025		6.5	±0.4	(2.25±0.02)E-3		(1.6 ±0.1)E-4
K β2	114.445	4.15 ±0.08					
K β4	114.844	0.12 ±0.06					
K O	115.377	0.97 ±0.10					
K P	115.580	0.159 ±0.016					
K β2'	114.866		2.20	±0.13	(5.59±0.06)E-4		(4.46±0.12)E-5

element type	energy (keV)	intensity per 100 K-shell vacancies (left column), or per 100 decays of nuclide given					
93-Np			92-U-237 β-		95-Am-241 α		
K α1	101.059	45.1 ±0.9	26.	±4.	(2.01±0.17)E-3		
K α2	97.069	28.3 ±0.6	16.	±3.	(1.26±0.11)E-3		
K β1	114.224	10.70 ±0.22					
K β3	113.303	5.65 ±0.11					
K β5	114.912	0.405±0.016					
K β1'	113.944		9.6	±1.5	(7.4 ±0.6)E-4		
K β2	117.463	4.17 ±0.08					
K β4	117.876	0.12 ±0.06					
K O	118.429	0.97 ±0.10					
K P	118.646	0.162±0.017					
K β2'	117.891		3.3	±0.5	(2.49±0.22)E-4		
94-Pu			93-Np-238 β-		93-Np-239 β-		95-Am-242 ec	
K α1	103.734	45.1 ±0.9	0.341	±0.014	23.9	±0.8	5.8	±1.2
K α2	99.525	28.4 ±0.6	0.214	±0.009	15.0	±0.5	3.6	±0.7
K β1	117.228	10.70 ±0.22						
K β3	116.244	5.44 ±0.11						
K β5	117.918	0.413±0.016						
K β1'	116.930		0.123	±0.005	8.6	±0.3	2.1	±0.4
K β2	120.540	4.18 ±0.08						
K β4	120.969	0.13 ±0.06						
K O	121.543	0.99 ±0.10						
K P	121.768	0.157±0.016						
K β2'	120.974		0.0426	±0.0019	2.98	±0.11	0.72	±0.15
94-Pu			96-Cm-243 α					
K α1	103.734	45.1 ±0.9	23.0	±0.6				
K α2	99.525	28.4 ±0.6	14.4	±0.4				
K β1	117.228	10.70 ±0.22						
K β3	116.244	5.44 ±0.11						
K β5	117.918	0.413±0.016						
K β1'	116.930		8.32	±0.24				
K β2	120.540	4.18 ±0.08						
K β4	120.969	0.13 ±0.06						
K O	121.543	0.99 ±0.10						
K P	121.768	0.157±0.016						
K β2'	120.974		2.87	±0.09				

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23 September 1991

To: Recipients of the Handbook of Nuclear Data for Safeguards

From: Meinhart Lammer
IAEA Nuclear Data Section

Subject: Comments on this preliminary issue

This preliminary issue is distributed to INDC members (G distr.), safeguards experts (CI+SQ distr.) and data experts (special distr.). However, only those who have the distribution code "SQ" on their label will receive future editions of the handbook. If you do not have that code on your label but wish to receive future issues, contact us at the address given on page 6.

The reason for the present wide distribution of this preliminary issue is that we need experts' advice, not only for a judgement of the quality of the data we have included, but particularly for the data not yet included and some open questions, which are collected in the appendices. Please, read page 7 of this handbook which lists more specifically the information and advice we ask you to give us. In addition we would like to ask INDC members to provide us with names of experts who could help us with the data that are not yet included (see Appendices A and C).

I thank you in advance for your help. Could you please send me your reply by the end of January 1992.

A-5: Thermal neutron cross sections, resonance integrals and related parameters

This table contains thermal neutron cross sections, Westcott g-factors and resonance integrals for capture and fission (if significant). All data are taken from [1] unless indicated by footnotes, as this source gives uncertainties which are not included in the more recent data files ENDF/B-6 (only sometimes included in the text information) or JENDL-3.

Description of table entries:

Cross section: thermal neutron cross section of the following type:

σ_0	2200 m/s cross section
σ	Maxwellian average cross section (kT = 0.0253 eV)
σr	cross section in a thermal reactor neutron spectrum
m	cross section leading to metastable state of product
g	cross section leading to ground state of product
m+g	sum cross section

g: Westcott g-factor for the deviation of the cross section from the 1/v shape for a Maxwellian neutron spectrum with kT=0.0253 eV

Res.Int.: infinite dilution resonance integral including the 1/v part

Source of data:

[1] S.F Mughabghab, Neutron Cross Sections Vol. 1: Resonance Parameters and Thermal Cross Sections, Part B: Z = 61-100; Academic Press, NY, 1984.

ENDF/B-6: the US Evaluated Nuclear Data File, version 6

JENDL-3: the Japanese Evaluated Nuclear Data Library, version 3

The evaluated data files of complete $\sigma(E)$ data, ENDF/B-6 and JENDL-3 are available from the 4 Data Centres (see Page 5) upon request.

Table A-5: Thermal neutron cross sections, resonance integrals and related parameters

Nuclide	CAPTURE				FISSION			
	Cross Section (b)		g	Res.Int. (b)	Cross Section (b)		g	Res.Int. (b)
90-Th-232	σ^0 7.37 ± 0.06		0.9982	85. ± 3.				
92-U-233	σ^0 45.5 ± 0.7		1.0040 [2]	137. ± 6.	σ^0 529.1 ± 1.2		0.9955±0.0015	760. ± 17.
92-U-234	σ^0 99.8 ± 1.3		0.9903	660. ± 70.				
92-U-235	σ^0 98.3 ± 0.8		0.9948 [3]	144. ± 6.	σ^0 582.6 ± 1.1		0.9761±0.0012	275. ± 5.
92-U-236	σ^0 5.11 ± 0.21			360. ± 15.				
92-U-237	σ 443. ± 167.			1200. ±200.				
92-U-238	σ^0 2.680 ± 0.019		1.0009	277. ± 3.				
93-Np-237	σ^0 175.9 ± 2.9		0.982	640. ± 50.				
93-Np-239	σr 68. ± 10.							
94-Pu-238	σ^0 540. ± 7.		0.9563	162. ± 15.	σ^0 17.9 ± 0.4		0.9562	33. ± 5.
94-Pu-239	σ^0 269.3 ± 2.9		1.1369 [4]	200. ± 20.	σ^0 748.1 ± 2.0		1.0553±0.0013	301. ± 10.
94-Pu-240	σ^0 289.5 ± 1.4		1.0264	8100. ±200.				
94-Pu-241	σ^0 358.2 ± 5.1		1.038	162. ± 8.	σ^0 1011.1 ± 6.2		1.046 ±0.006	570. ± 15.
94-Pu-242	σ^0 18.5 ± 0.5		1.0096	1115. ± 40.				
95-Am-241	σ^0(g) 533. ± 13.		to be comp.	1230. ±100.				
	σ^0(m) 54. ± 5.			195. ± 20.				
	σ^0(m+g) 587. [5]	± 12.	1.051	1425. ±100.	σ^0 3.20 ± 0.09		0.996	14.4± 1.0
95-Am-242g	σ^0 252.08 [1]			71.88 [1]	σ 2100. ± 200.			620.15 [1]
	σ^0 5500. [1]			391. [1]				1260. [1]
95-Am-242m	σ 2000. ± 600.			246. [6]	σ^0 6950. ± 280.		1.104	1800. ± 65.
95-Am-243	σ^0 75.1 ± 1.8		1.014	1820. ± 70.	σ 0.1983 ± 0.0043			9. ± 1.
96-Cm-242	σ 16. ± 5.			110. ± 20.	σ^0 5.064 [6]			20.0 [6]
96-Cm-243	σ^0 130. ± 10.		1.005	215. ± 20.	σ^0 617. ± 20.		1.0054	1570. ±100.
96-Cm-244	σ^0 15.2 ± 1.2		0.999	650. ± 30.	σ^0 1.04 ± 0.20		0.989	12.5± 2.5

[1] discrepancy between ENDFB/6 (1st value) and JENDL-3 (2nd value); no value given by Mughabghab [1]

[2] calculated from σ(abs) and g(abs), 574.7 ± 1.0 b and 0.9996±0.0011, respectively

[3] calculated from σ(abs) and g(abs), 680.9 ± 1.1 b and 0.9788±0.0008, respectively

[4] calculated from σ(abs) and g(abs), 1017.3 ± 2.9 b and 1.077 ±0.003, respectively

[5] Mughabghab's [1] value not in agreement with ENDF/B-6 (620 ± 13 b)

[6] value from JENDL-3; no values given in [1] and ENDF/B-6

to be comp. = to be computed from ENDF/B-6

A-6: Average number of neutrons emitted per fission ($\bar{\nu}$)

Average number of total and prompt neutrons

The average numbers of total neutrons for thermal neutron induced fission of U-233,235, Pu-239,241 and spontaneous fission of Cf-252 are taken from the most recent version of the internationally agreed standards file [1]. The prompt neutron data for the same reactions were calculated from the total and delayed neutron data.

For the other nuclides listed in Table A-6.1, the average numbers of total and prompt neutrons for thermal neutron induced and spontaneous fission, which are identical within their uncertainties, are taken from [2], which is the only and most recent source that contains all these data. In the evaluation [2], all data were normalised to $\bar{\nu}$ of U-235 thermal neutron induced fission and Cf-252 spontaneous fission. The normalisation values used in [2] are almost identical to the standard values from [1].

No evaluations of total or prompt $\bar{\nu}$ data from fission in a fast reactor or fission neutron spectrum are available. $\bar{\nu}$ data as a function of incident neutron energy are included in the large data files (e.g. ENDF/B-6 or JENDL-3).

Average numbers of delayed neutrons (total delayed neutron yield)

A recent OECD/NEA committee meeting recommended [5] the use of delayed neutron yields evaluated from direct measurements rather than those obtained from summation calculations. (In the latter method, delayed neutron yields are derived from individual delayed neutron precursor data and fission yields, and there the charge distribution, which is uncertain in many cases, has a significant effect on the results). Following this recommendation, the data of Tuttle [3], partially updated [5] by results of new measurements, are chosen for Tables A-6.1 and A-6.2. Recent results from summation calculations [4] are used for nuclides where no data are given in [3] or [5].

Source of data

[1] ENDF/B-6 Standards file 1990 (available from Nuclear Data Centres - see page 5 - upon request; when requested form NDS: documentation and data are in IAEA-NDS-88)

[2] N.E. Holden and M.S. Zucker, Int. Conf. on Nuclear Data for Basic and Applied Science, Santa Fe , New Mexico, USA, 13-17 May 1985; proceedings p.1631.

[3] R.J. Tuttle, INDC(NDS)-107 (1979) 29

[4] R.W. Mills, private communication, February 1991 (results to be published)

[5] J. Blachot et al., "Status of Delayed Neutron Data - 1990", report NEACRP-L-323 (1990).

ENDF/B-6: the US Evaluated Nuclear Data File, version 6

JENDL-3: the Japanese Evaluated Nuclear Data Library, version 3

The evaluated data files of complete $\bar{\nu}(E)$ data, as part of ENDF/B-6 and JENDL-3, are available from the 4 Nuclear Data Centres (see Page 5) upon request.

Table A-6.1: Average numbers of total, prompt and delayed neutrons from thermal neutron fission of U-233,5, Pu-239,41, Am-241, Cm-243,5 and spontaneous fission of Cm-242,4, Cf-252

nuclide	total	prompt	delayed
U -233	2.4946 ± 0.0040 [1]	2.4872 ± 0.0040 [1]	0.00667 ± 0.00029 [3]
U -235	2.4320 ± 0.0036 [1]	2.4153 ± 0.0036 [1]	0.0166 ± 0.0005 [5]
Pu-239	2.8815 ± 0.0052 [1]	2.8752 ± 0.0052 [1]	0.00654 ± 0.00026 [5]
Pu-241	2.9453 ± 0.0059 [1]	2.9301 ± 0.0059 [1]	0.0152 ± 0.0011 [3]
Am-241	3.22 ± 0.04 [2]	3.22 ± 0.04 [2]	0.00387 ± 0.00060 [4]
Cm-242	2.54 ± 0.02 [2]	2.54 ± 0.02 [2]	
Cm-243	3.43 ± 0.14 [2]	3.43 ± 0.14 [2]	
Cm-244	2.72 ± 0.02 [2]	2.72 ± 0.02 [2]	0.00342 ± 0.00070 [4]
Cm-245	3.75 ± 0.10 [2]	3.75 ± 0.10 [2]	0.00445 ± 0.00050 [4]
Cf-252	3.7676 ± 0.0049 [1]	3.7590 ± 0.0049 [1]	0.0086 ± 0.0010 [3]

Table A-6.2: Average numbers of delayed neutrons from fission in a fast reactor neutron spectrum

Th-232	0.0531 ± 0.0023 [3]
U -238	0.0439 ± 0.0010 [3] *)
Pu-240	0.0095 ± 0.0008 [3]
Pu-242	0.0221 ± 0.0026 [3]

*) In view of the large discrepancies among measurements, the NEACRP[5] recommends a range 0.043 to 0.047 rather than Tuttle's [3] value.

Table A-7: Prompt neutron multiplicity distributions P(ν)

There are only 2 sets of evaluated prompt neutron multiplicity distributions for thermal neutron induced and spontaneous fission known to us. The data are reproduced below.

1) P(ν) values for thermal neutron induced fission with uncertainties from: N.E.Holden and M.S.Zucker, Nucl.Sci.Eng. 98 (1988) 174

ν	U-233	U-235	Pu-239	Pu-241
0	0.0262 ± 0.0012	0.0317 ± 0.0015	0.0109 ± 0.0001	0.0108 ± 0.0005
1	0.1550 ± 0.0022	0.1720 ± 0.0014	0.0995 ± 0.0028	0.0895 ± 0.0014
2	0.3328 ± 0.0038	0.3363 ± 0.0031	0.2750 ± 0.0003	0.2660 ± 0.0017
3	0.3225 ± 0.0020	0.3038 ± 0.0004	0.3270 ± 0.0041	0.3313 ± 0.0041
4	0.1325 ± 0.0057	0.1268 ± 0.0036	0.2045 ± 0.0087	0.2140 ± 0.0039
5	0.0272 ± 0.0024	0.0266 ± 0.0026	0.0728 ± 0.0133	0.0749 ± 0.0050
6	0.0037 ± 0.0018	0.0026 ± 0.0009	0.0097 ± 0.0027	0.0112 ± 0.0024
7	0.0001 ± 0.0001	0.0002 ± 0.0001	0.0006 ± 0.0009	0.0023 ± 0.0013

2) P(ν) values for spontaneous fission without uncertainties from: N.E.Holden and M.S.Zucker,Int. Conf. on Nuclear Data for Basic and Applied Science, Santa Fe, New Mexico, USA, 13-17 May 1985; proceedings p.1631.

ν	Cm-242	Cm-244	Cf-252
0	0.02125	0.01501	0.00217
1	0.14674	0.11617	0.02556
2	0.32675	0.29984	0.12541
3	0.32683	0.33316	0.27433
4	0.13751	0.18378	0.30517
5	0.03738	0.04298	0.18523
6	0.00259	0.00879	0.06607
7	0.00076	0.00027	0.01414
8	0.00019		0.00186
9			0.00006

A-8: Delayed neutron six-group parameters

A recent OECD/NEA committee recommended [1] the group parameters from the summation calculations of Brady and England [2] because of the overall consistency of the data. On the other hand, some experts [3] felt that experimental results (like [4]) should be given greater weight than summation calculations. However, it was decided [1] that the overall differences were small enough that to recommend the data of [2] would give greater consistency without sacrificing accuracy [3].

Following this recommendation, we have adopted the group parameters of [2], but decided to give Keepin's [4] experimental data, which are still considered to be the best available [3], in addition for comparison. No evaluated group parameters for Cm-242,243,244 are presently available.

Description of table entries:

T1/2	delayed neutron group half-life
λ	delayed neutron group decay constant
α	ratio (delayed neutron group yield)/(total delayed neutron yield)
yield	delayed neutron group yield (in % per fission)

References

[1] J. Blachot et al., "Status of Delayed Neutron Data - 1990", report NEACRP-L-323 (1990).

[2] C.M. Brady and T.R. England, Nucl.Sci.Eng. 103 (1989) 135.

[3] R.W. Mills, private communication, April 1991

[4] G.R. Keepin, "Physics of Nuclear Kinetics", Addison-Wesley Publishing Co., Reading, Mass. (1965); tables on pages 86, 87 and 90.

1) Recommended data (C.M.Brady and T.R.England, Nucl.Sci.Eng. 103 (1989) 135)

group	λ(sec⁻¹)	α	yield (%)	λ(sec⁻¹)	α	yield (%)
	Th-232 fast			U-233 thermal		
1	0.0131	0.0364	0.1933	0.0129	0.0674	0.0450
2	0.0350	0.1259	0.669	0.0333	0.1927	0.1285
3	0.1272	0.1501	0.797	0.1163	0.1383	0.0922
4	0.3287	0.4406	2.340	0.2933	0.2798	0.1866
5	0.9100	0.1663	0.883	0.7943	0.1128	0.0752
6	2.8206	0.0808	0.429	2.3751	0.2091	0.1395
	U-235 thermal			U-238 fast		
1	0.0133	0.0380	0.0631	0.0136	0.0139	0.0610
2	0.0325	0.1918	0.318	0.0313	0.1128	0.495
3	0.1219	0.1638	0.272	0.1233	0.1310	0.575
4	0.3169	0.3431	0.570	0.3237	0.3851	1.691
5	0.9886	0.1744	0.290	0.9060	0.2540	1.115
6	2.9544	0.0890	0.148	3.0487	0.1031	0.453
	Pu-238 fast			Pu-239 thermal		
1	0.0133	0.0377	0.0177	0.0133	0.0306	0.02001
2	0.0312	0.2390	0.112	0.0301	0.2623	0.1715
3	0.1162	0.1577	0.074	0.1135	0.1828	0.1196
4	0.2888	0.3562	0.167	0.2953	0.3283	0.2147
5	0.8561	0.1590	0.075	0.8537	0.1482	0.0969
6	2.7138	0.0504	0.0237	2.6224	0.0479	0.0313
	Pu-240 fast			Pu-241 thermal		
1	0.0133	0.0320	0.0304	0.0137	0.0167	0.0254
2	0.0305	0.2529	0.240	0.0299	0.2404	0.365
3	0.1152	0.1508	0.143	0.1136	0.1474	0.224
4	0.2974	0.3301	0.314	0.3078	0.3430	0.521
5	0.8477	0.1795	0.171	0.8569	0.1898	0.288
6	2.8796	0.0547	0.0520	3.0800	0.0627	0.095
	Pu-242 fast			Am-241 thermal		
1	0.0136	0.0196	0.0433	0.0133	0.0305	0.0118
2	0.0302	0.2314	0.511	0.0300	0.2760	0.1068
3	0.1154	0.1256	0.278	0.1145	0.1531	0.0592
4	0.3042	0.3262	0.721	0.2949	0.3122	0.1208
5	0.8272	0.2255	0.498	0.8818	0.1825	0.0706
6	3.1372	0.0716	0.158	2.6879	0.0457	0.0177
	Cm-245 thermal			Cf-252 spontaneous		
1	0.0134	0.0222	0.00988	0.0136	0.0124	0.0107
2	0.0307	0.1788	0.0796	0.0291	0.3052	0.262
3	0.1130	0.1672	0.0744	0.1068	0.1813	0.156
4	0.3001	0.3706	0.1649	0.3024	0.2992	0.257
5	0.8340	0.2054	0.0914	0.8173	0.1729	0.149
6	2.7686	0.0559	0.0249	2.6159	0.0290	0.0249

2) Keepin's data (G.R.Keepin, "Physics of Nuclear Kinetics", 1965)

group	T1/2 (sec)	λ (sec^{-1})	α	yield (%)
	Th-232 fast			
1	56.03 ± 0.95	0.0124 ± 0.0002	0.034 ± 0.002	0.169 ± 0.012
2	20.75 ± 0.66	0.0334 ± 0.0011	0.150 ± 0.005	0.744 ± 0.037
3	5.74 ± 0.24	0.121 ± 0.005	0.155 ± 0.021	0.769 ± 0.108
4	2.16 ± 0.08	0.321 ± 0.011	0.446 ± 0.015	2.212 ± 0.110
5	0.571 ± 0.042	1.21 ± 0.090	0.172 ± 0.013	0.853 ± 0.073
6	0.211 ± 0.019	3.29 ± 0.30	0.043 ± 0.006	0.213 ± 0.031
	U-233 thermal			
1	55.00 ± 0.54	0.0126 ± 0.0003	0.086 ± 0.003	0.057 ± 0.003
2	20.57 ± 0.38	0.0337 ± 0.0006	0.299 ± 0.004	0.197 ± 0.009
3	5.00 ± 0.21	0.139 ± 0.006	0.252 ± 0.040	0.166 ± 0.027
4	2.13 ± 0.20	0.325 ± 0.030	0.278 ± 0.020	0.184 ± 0.016
5	0.615 ± 0.242	1.13 ± 0.40	0.051 ± 0.024	0.034 ± 0.016
6	0.277 ± 0.047	2.50 ± 0.42	0.034 ± 0.014	0.022 ± 0.009
	U-235 thermal			
1	55.72 ± 1.28	0.0124 ± 0.0003	0.033 ± 0.003	0.052 ± 0.005
2	22.72 ± 0.71	0.0305 ± 0.0010	0.219 ± 0.009	0.346 ± 0.018
3	6.22 ± 0.23	0.111 ± 0.004	0.196 ± 0.022	0.310 ± 0.036
4	2.30 ± 0.09	0.301 ± 0.011	0.395 ± 0.011	0.624 ± 0.026
5	0.610 ± 0.083	1.14 ± 0.15	0.115 ± 0.009	0.182 ± 0.015
6	0.230 ± 0.025	3.01 ± 0.29	0.042 ± 0.008	0.066 ± 0.008
	U-238 fast			
1	52.38 ± 1.29	0.0132 ± 0.0003	0.013 ± 0.001	0.054 ± 0.005
2	21.58 ± 0.39	0.0321 ± 0.0006	0.137 ± 0.002	0.564 ± 0.025
3	5.00 ± 0.19	0.139 ± 0.005	0.162 ± 0.020	0.667 ± 0.087
4	1.93 ± 0.07	0.358 ± 0.014	0.388 ± 0.012	1.599 ± 0.081
5	0.490± 0.023	1.41 ± 0.067	0.225 ± 0.013	0.927 ± 0.060
6	0.172± 0.009	4.02 ± 0.214	0.075 ± 0.005	0.309 ± 0.024
	Pu-239 thermal			
1	54.28 ± 2.34	0.0128 ± 0.0005	0.035 ± 0.009	0.021 ± 0.006
2	23.04 ± 1.67	0.0301 ± 0.0022	0.298 ± 0.035	0.182 ± 0.023
3	5.60 ± 0.40	0.124 ± 0.009	0.211 ± 0.048	0.129 ± 0.030
4	2.13 ± 0.24	0.325 ± 0.036	0.326 ± 0.033	0.199 ± 0.022
5	0.618± 0.213	1.12 ± 0.39	0.086 ± 0.029	0.052 ± 0.018
6	0.257± 0.045	2.69 ± 0.48	0.044 ± 0.016	0.027 ± 0.010
	Pu-240 fast			
1	53.56 ± 1.21	0.0129 ± 0.0004	0.028 ± 0.003	0.028 ± 0.003
2	22.14 ± 0.38	0.0313 ± 0.0005	0.273 ± 0.004	0.238 ± 0.016
3	5.14 ± 0.42	0.135 ± 0.011	0.192 ± 0.053	0.162 ± 0.044
4	2.08 ± 0.19	0.333 ± 0.031	0.350 ± 0.020	0.315 ± 0.027
5	0.511± 0.077	1.36 ± 0.205	0.128 ± 0.018	0.119 ± 0.018
6	0.172± 0.033	4.04 ± 0.782	0.029 ± 0.006	0.024 ± 0.005

Section B: Fission product nuclear data

The table below lists the fission products for which half-lives ($T_{½}$), γ-ray data and capture cross sections (σ) as well as branching fractions to isomeric states in decay (br) and neutron capture are given in this Section.

nuclide	$T_{½}$	br	γ-rays	σ	nuclide	$T_{½}$	br	γ-rays	σ
Kr [1])				+	Cs-135				+
Br-85		+			Cs-137	+		+	+
Kr-85m		+			Ba-140	+		+	
Kr-85	+		+	+	La-140	+		+	
Zr [1])				+	Ce-141	+		+	
Z -95	+	+	+	+	Pr-141				+
Nb-95m	+	+	+		Pr-143				+
Nb-95	+		+		Ce-144	+		+	+
Mo [1])				+	Pr-144	+		+	
Ru [1])				+	Nd [1])				+
Ru-103	+		+	+	Nd-147	+		+	+
Ru-106	+			+	Pm-147	+		+	+
Rh-106	+		+		Pm-148m	+	+	+	+
Sb-125	+		+		Pm-148	+		+	+
Xe [1])				+	Pm-149	+			+
I-131	+	+	+		Pm-151	+			+
Xe-131m	+	+	+		Sm [1])				+
I-133		+			Sm-151	+			+
Xe-133m	+	+			Sm-153	+			+
Xe-133	+		+	+	Eu-151				+
Cs-133				+	Eu-152				+
Cs-134	+	+	+	+	Eu-153				+
I-135	+	+			Eu-154	+	+	+	+
Xe-135m	+	+			Eu-155	+		+	+

[1]) Stable isotopes for mass spectrometric measurements

Nuclides with A=147-153 are included for calculating the formation of Eu-154.

B-1: Half-lives and decay branching

Table B-1.1: Half-lives and decay mode branching

Description of table entries:

units:	s	second	d	day
	m	minute	y	year (= 365.2422 days)
	h	hour		

rel err: relative error (in %)

decay mode:	β-	beta decay
	IT	isomeric transition
	ec	electron capture

branching: given for each decay mode (should sum up to 100%)

Source of data:

E. Browne, R.B. Firestone: Table of Radioactive Isotopes (V.S. Shirley, ed.), John Wiley & Sons, N.Y., 1986.
Updates to this handbook from the Berkeley decay data file (data derived from ENSDF), E. Browne, private communication, 1986/87.

Table B-1.2: Branching to daughters

Branching fractions are given for some important daughter products. The column "branching" shows the selected value. Other values are given in the column "others" for comparison.

References:

[1] T.R. England, private communication: preliminary evaluated fission yields with status of 15 Sept.1989 (decay data for each mass chain given at top of tables).

[2] K. Tasaka et al: JNDC Nuclear Data Library of Fission Products, 2nd version, report JAERI-1320 (Sept.1990)

[3] E. Browne, R.B. Firestone: Table of Radioactive Isotopes (V.S. Shirley, ed.), John Wiley & Sons, N.Y., 1986.
Updates to this book from the Berkeley decay data file (data derived from ENSDF), E. Browne, private communication, 1986/87.

[4-8] Nuclear Data Sheets (NDS): revised A-chains

[4] W. Tepel, A=85, NDS 30 (1980) 501

[5] P. Luksch, A=95, NDS 38 (1983) 1

[6] R.L. Auble, A=131, NDS 17 (1976) 573

[7] Yu.V. Sergankov et al, A=133, NDS 49 (1986) 639

[8] Yu.V. Sergankov, A=135, NDS 49 (1987) 205

nuclide	half-life units	value	rel err	decay mode	branching (percent/decay)
36-Kr- 85	y	10.720 ±0.020	(0.19)	β-	100.000
40-Zr- 95	d	64.02 ±0.04	(0.06)	β-	100.000
41-Nb- 95m	d	3.608 ±0.033	(0.92)	IT β-	97.50 ±0.10 2.50 ±0.10
41-Nb- 95	d	34.970 ±0.030	(0.09)	β-	100.000
44-Ru-103	d	39.254 ±0.008	(0.02)	β-	100.000
44-Ru-106	y	1.020 ±0.003	(0.29)	β-	100.000
45-Rh-106	s	29.80 ±0.08	(0.27)	β-	100.000
51-Sb-125	y	2.730 ±0.030	(1.1)	β-	100.000
53-I -131	d	8.0400±0.0010	(0.01)	β-	100.000
54-Xe-131m	d	11.90 ±0.10	(0.84)	IT	100.000
54-Xe-133m	d	2.19 ±0.03	(1.4)	IT	100.000
54-Xe-133	d	5.245 ±0.006	(0.11)	β-	100.000
55-Cs-134	y	2.062 0.005	(0.24)	β- ec	99.9997±0.0001 0.0003±0.0001
53-I -135	h	6.55 ±0.03	(0.46)	β-	100.000
54-Xe-135m	m	15.65 ±0.10	(0.64)	IT β-	99.996 0.004
54-Xe-135	h	9.104 ±0.020	(0.22)	β-	100.000
55-Cs-137	y	30.00 ±0.20	(0.67)	β-	100.000
56-Ba-140	d	12.746 ±0.010	(0.08)	β-	100.000
57-La-140	d	1.6780±0.0002	(0.01)	β-	100.000
58-Ce-141	d	32.500 ±0.010	(0.03)	β-	100.000
58-Ce-144	d	284.90 ±0.20	(0.07)	β-	100.000
59-Pr-144	m	17.28 ±0.05	(0.29)	β-	100.000
60-Nd-147	d	10.980 ±0.010	(0.09)	β-	100.000
61-Pm-147	y	2.6230±0.0002	(0.01)	β-	100.000
61-Pm-148m	d	41.29 ±0.11	(0.27)	IT β-	4.60 ±0.50 95.40 ±0.50
61-Pm-148	d	5.370 ±0.009	(0.17)	β-	100.000
61-Pm-149	d	2.2110±0.0020	(0.09)	β-	100.000

nuclide	half-life units	half-life value	half-life rel err	decay mode	branching (percent/decay)
61-Pm-151	d	1.1830±0.0016	(0.14)	β-	100.000
62-Sm-151	y	90.0 ±6.0	(6.7)	β-	100.000
62-Sm-153	d	1.9460±0.0041	(0.21)	β-	100.000
63-Eu-154	y	8.590 ±0.010	(0.12)	ec β-	0.020±0.010 99.980±0.010
63-Eu-155	y	4.960 ±0.010	(0.2)	β-	100.000

Table B-1.2: Branching to daughters

nuclide	daughter	branching (percent/decay)	Ref.	others
35-Br- 85	36-Kr- 85	0.	[1,3]	0.16 ± 0.01 [4]
36-Kr- 85m	36-Kr- 85	21.0 ± 0.6	[3,4]	19.979 [1], 21.1 [2]
40-Zr- 95	41-Nb- 95m	1.11 ± 0.12 [1])	[5]	1.0 [1], 0.90 [2]
53-I -131	54-Xe-131m	1.10 [1])	[2]	1.086±0.013 [6], 1.4 [1]
53-I -133	54-Xe-133m	2.88 ± 0.03 [1])	[7]	2.8 [1], 2.88 [2]
53-I -135	54-Xe-135m	15.7 ± 0.3 [1])	[8]	14.7 [1], 16.57 [2]

[1]) Branching to ground state = 100 - branching to metastable state

B-2: Gamma ray energies and emission probabilities

Description of table entries:

1st column: fission product nuclide

2nd column: γ-ray energies and their errors in keV.

3rd column: γ-ray emission probabilities and their errors in percent per decay and relative errors (in %) in brackets.

4th column: " syst err" = systematic (relative) error contributions (in %) from conversion of relative to absolute intensities for each nuclide (included in the errors given in the 3rd column).

Source of data:

E. Browne, R.B. Firestone: Table of Radioactive Isotopes (V.S. Shirley, ed.), John Wiley & Sons, N.Y., 1986.
Updates to this handbook from the Berkeley decay data file (data derived from ENSDF), E. Browne, private communication, 1986/87.

nuclide	energy (keV)	emission probability (percent per decay)	syst err
36-Kr- 85	513.996 ±0.016	0.434 ±0.010 (2.3)	2.27
40-Zr- 95	235.680 ±0.020	0.294 ±0.016 (5.5)	0.37
	724.1990±0.0050	44.15 ±0.90 (2.0)	
	756.729 ±0.012	54.50 ±0.20 (0.37)	
41-Nb- 95m	235.680 ±0.020	24.9 ±1.1 (4.3)	4.3
41-Nb- 95	765.7890±0.0088	99.790 ±0.020 (0.02)	0.02
44-Ru-103	53.2770±0.0087	0.376 ±0.018 (4.9)	1.12
	294.950 ±0.019	0.2500±0.0084 (3.4)	
	443.777 ±0.012	0.3250±0.0089 (2.8)	
	497.054 ±0.010	88.7 ±2.5 (2.8)	
	557.022 ±0.014	0.83 ±0.17 (20.)	
	610.299 ±0.014	5.64 ±0.19 (3.4)	
45-Rh-106	511.8640±0.0031	20.70 ±0.60 (2.9)	2.9
	616.181 ±0.021	0.738 ±0.031 (4.2)	
	621.917 ±0.036	9.81 ±0.57 (5.8)	
	873.468 ±0.055	0.429 ±0.029 (6.7)	
	1050.360 ±0.048	1.526 ±0.078 (5.1)	
	1128.042 ±0.021	0.398 ±0.014 (3.5)	
	1562.219 ±0.048	0.1580±0.0077 (4.9)	
	1766.090 ±0.079	0.0270±0.0022 (8.1)	
	1796.931 ±0.054	0.0240±0.0013 (5.7)	
	1927.281 ±0.095	0.0130±0.0008 (5.9)	
	1988.595 ±0.093	0.0240±0.0015 (6.4)	
	2112.599 ±0.088	0.0340±0.0020 (5.9)	
	2366.06 ±0.15	0.0220±0.0013 (6.1)	
	2406.07 ±0.13	0.0140±0.0008 (6.4)	
51-Sb-125	35.4910±0.0005	6.01 ±0.19 (3.2)	1.00
	172.626 ±0.021	0.1820±0.0040 (2.2)	
	176.316 ±0.010	6.79 ±0.15 (2.2)	
	380.416 ±0.013	1.520 ±0.034 (2.2)	
	427.875 ±0.010	29.44 ±0.66 (2.2)	
	463.367 ±0.010	10.45 ±0.23 (2.2)	
	600.500 ±0.022	17.78 ±0.40 (2.2)	
	606.633 ±0.014	5.02 ±0.11 (2.2)	
	635.890 ±0.012	11.32 ±0.25 (2.2)	
	671.381 ±0.012	1.800 ±0.044 (2.4)	
53-I -131	80.1840±0.0070	2.621 ±0.058 (2.2)	0.99
	284.2980±0.0083	6.06 ±0.14 (2.2)	
	364.4830±0.0080	81.3 ±1.8 (2.2)	
	636.9740±0.0090	7.27 ±0.16 (2.2)	
	642.7070±0.0081	0.2190±0.0049 (2.2)	
	722.8910±0.0076	1.804 ±0.040 (2.2)	
54-Xe-131m	163.9310±0.0068	1.960 ±0.059 (3.0)	3.0
54-Xe-133	80.9890±0.0047	37.0 ±1.0 (2.7)	2.7
55-Cs-134	475.357 ±0.020	1.465 ±0.042 (2.9)	1.00
	563.2370±0.0077	8.39 ±0.17 (2.1)	
	569.321 ±0.013	15.43 ±0.35 (2.2)	
	604.7100±0.0084	97.6 ±1.0 (1.0)	
	795.867 ±0.014	85.44 ±0.96 (1.1)	

nuclide	energy (keV)	emission probability (percent per decay)			syst err
55-Cs-134 (cont'd)	801.951 ±0.015	8.73	±0.20	(2.2)	
	1038.592 ±0.019	1.000	±0.022	(2.2)	
	1167.944 ±0.011	1.804	±0.039	(2.2)	
	1365.185 ±0.014	3.040	±0.068	(2.2)	
55-Cs-137	661.6600±0.0030	85.210	±0.068	(0.08)	0.08
56-Ba-140	29.987 ±0.033	13.6	±1.2	(10.)	0.90
	132.718 ±0.029	0.202	±0.017	(8.5)	
	162.705 ±0.032	6.21	±0.14	(2.2)	
	304.867 ±0.019	4.300	±0.094	(2.2)	
	423.720 ±0.025	3.12	±0.15	(4.8)	
	437.585 ±0.024	1.929	±0.043	(2.2)	
	467.572 ±0.031	0.146	±0.012	(8.4)	
	537.310 ±0.036	24.39	±0.33	(1.4)	
57-La-140	109.4070±0.0064	0.200	±0.014	(7.1)	0.08
	131.1130±0.0072	0.439	±0.086	(20.)	
	173.5290±0.0085	0.129	±0.020	(20.)	
	241.9540±0.0081	0.473	±0.028	(5.9)	
	266.5490±0.0080	0.452	±0.025	(5.5)	
	328.7570±0.0089	20.74	±0.42	(2.0)	
	397.6620±0.0090	0.105	±0.033	(30.)	
	432.523 ±0.029	2.986	±0.060	(2.0)	
	487.026 ±0.018	45.95	±0.92	(2.0)	
	751.661 ±0.021	4.27	±0.30	(7.1)	
	815.783 ±0.020	23.64	±0.47	(2.0)	
	867.83 ±0.13	5.59	±0.11	(2.0)	
	919.548 ±0.033	2.681	±0.054	(2.0)	
	925.189 ±0.020	7.03	±0.14	(2.0)	
	950.86 ±0.21	0.541	±0.019	(3.5)	
	1596.54 ±0.14	95.400	±0.076	(0.08)	
	2348.19 ±0.14	0.849	±0.017	(2.0)	
	2521.72 ±0.14	3.444	±0.075	(2.2)	
	2547.39 ±0.24	0.1030	±0.0028	(2.7)	
	2899.75 ±0.45	0.0650	±0.0019	(2.9)	
	3119.21 ±0.71	0.0250	±0.0009	(3.5)	
58-Ce-141	145.4400±0.0028	48.44	±0.39	(0.8)	0.80
58-Ce-144	80.1030±0.0079	1.13	±0.11	(10.)	1.44
	133.5380±0.0076	11.09	±0.47	(4.3)	
59-Pr-144	696.543 ±0.013	1.342	±0.014	(1.0)	1.04
	1489.212 ±0.038	0.272	±0.010	(3.6)	
	2185.747 ±0.038	0.701	±0.028	(4.0)	
60-Nd-147	91.104 ±0.013	27.9	±1.1	(3.9)	3.9
	275.385 ±0.013	0.801	±0.059	(7.4)	
	319.414 ±0.013	1.95	±0.14	(6.9)	
	398.155 ±0.016	0.871	±0.065	(7.5)	
	439.910 ±0.016	1.20	±0.10	(8.0)	
	531.013 ±0.016	13.09	±0.89	(6.8)	
61-Pm-147	121.258 ±0.043	0.0020	±0.0001	(3.9)	3.9
61-Pm-148m	75.70 ±0.10	1.0210	±0.0076	(0.75)	0.75
	98.479 ±0.017	2.473	±0.066	(2.7)	
	189.645 ±0.016	1.091	±0.026	(2.4)	
	288.124 ±0.016	12.48	±0.26	(2.1)	

nuclide	energy (keV)	emission probability (percent per decay)			syst err
61-Pm-148m (cont'd)	311.634	±0.015	3.897	±0.080 (2.1)	
	414.071	±0.013	18.59	±0.39 (2.1)	
	432.763	±0.017	5.33	±0.11 (2.1)	
	501.279	±0.016	6.75	±0.14 (2.1)	
	550.274	±0.015	94.5	±2.0 (2.1)	
	599.757	±0.016	12.53	±0.27 (2.1)	
	611.270	±0.015	5.46	±0.12 (2.1)	
	629.962	±0.016	88.63	±0.66 (0.75)	
	725.704	±0.014	32.72	±0.68 (2.1)	
	915.348	±0.015	17.13	±0.35 (2.1)	
	1013.827	±0.015	20.17	±0.42 (2.1)	
61-Pm-148	550.274	±0.015	22.00	±0.66 (3.0)	2.25
	611.270	±0.015	1.021	±0.031 (3.0)	
	914.850	±0.016	11.46	±0.34 (3.0)	
	1465.120	±0.018	22.20	±0.50 (2.3)	
63-Eu-154	123.1000	±0.0039	40.5	±2.4 (6.0)	5.6
	188.274	±0.012	0.227	±0.015 (6.4)	
	247.9670	±0.0074	6.60	±0.40 (6.0)	
	401.316	±0.027	0.209	±0.014 (6.6)	
	444.519	±0.018	0.507	±0.031 (6.2)	
	478.292	±0.041	0.217	±0.014 (6.5)	
	557.627	±0.026	0.256	±0.016 (6.3)	
	582.061	±0.027	0.841	±0.053 (6.3)	
	591.811	±0.023	4.84	±0.29 (6.0)	
	625.263	±0.019	0.314	±0.020 (6.3)	
	676.594	±0.022	0.1400	±0.0089 (6.4)	
	692.486	±0.017	1.69	±0.10 (5.9)	
	715.828	±0.022	0.176	±0.012 (6.8)	
	723.356	±0.022	19.7	±1.2 (6.0)	
	756.808	±0.022	4.34	±0.26 (6.1)	
	815.585	±0.017	0.464	±0.029 (6.3)	
	845.417	±0.029	0.550	±0.036 (6.5)	
	850.687	±0.029	0.229	±0.014 (6.3)	
	873.230	±0.018	11.45	±0.68 (5.9)	
	892.785	±0.030	0.462	±0.029 (6.3)	
	904.101	±0.022	0.823	±0.052 (6.4)	
	996.329	±0.018	10.29	±0.61 (5.9)	
	1004.775	±0.021	17.9	±1.1 (5.9)	
	1047.370	±0.034	0.134	±0.015 (10.)	
	1118.293	±0.043	0.1030	±0.0067 (6.5)	
	1128.507	±0.037	0.267	±0.017 (6.2)	
	1140.752	±0.030	0.216	±0.014 (6.4)	
	1241.393	±0.043	0.1310	±0.0080 (6.2)	
	1245.84	±0.10	0.896	±0.054 (6.1)	
	1274.543	±0.026	35.5	±2.1 (6.0)	
	1493.80	±0.10	0.654	±0.042 (6.5)	
	1593.00	±0.20	1.03	±0.12 (10.)	
	1596.582	±0.020	1.83	±0.14 (7.5)	
63-Eu-155	45.2970	±0.0017	1.282	±0.094 (7.3)	6.5
	60.0150	±0.0017	1.14	±0.12 (10.)	
	86.0660	±0.0047	0.151	±0.031 (20.)	
	86.5420	±0.0020	33.6	±2.2 (6.5)	
	105.3120	±0.0020	20.6	±1.4 (6.8)	

B-3: Thermal neutron capture cross sections and resonance integrals

The main references used for fission product cross section data are the evaluations by Gryntakis [1] and Mughabghab [2,3]. The more recent data files ENDF/B-6 or JENDL-3 could not be used because they do not contain data uncertainties (except in the text information for some nuclides in ENDF/B-6). The compilation by De Corte [4] was not used (except in one case) because recommended data are not given for all fission products.

The thermal cross sections in [1] agree with those in [2] or [3] in almost all cases, and the values are taken from [1] (more recent) unless indicated by footnotes.

The agreement for resonance integrals is not so good. In cases of differences the data in Table B-3 were selected by comparison to ENDF/B-6 and JENDL-3 and/or by one of the following criteria (special cases are indicated by footnotes):

The values of [1] were chosen when:
- no resonance integral is given in [2] or [3], or
- more recent measurements were included in [1], or
- the resonance integral given in [2] and [3] was calculated from resonance parameters, but did not include more recent measurements.

The values of [2] or [3] were chosen when:
- more recent measurements were included, or
- the value in [1] was deduced from old measurements only, and the value in [2] or [3] was calculated from resonance parameters (indicated by "C") which often included more recent measurements.

Description of table entries:

cross section: thermal neutron cross section of the following type:

σ_0	2200 m/s cross section
σ	Maxwellian average cross section (kT = 0.0253 eV)
σr	cross section in a thermal reactor neutron spectrum
m	cross section leading to metastable state of product
g	cross section leading to ground state of product
m+g	sum cross section

resonance integral: infinite dilution resonance integral including the 1/v part

Ref.	source of tabulated resonance integral
C	calculated from resonance parameters

Source of data:

[1] G. Gryntakis et al: Thermal Neutron Cross-Sections and Infinite Dilution Resonance Integrals, in "Handbook on Nuclear Activation Data", IAEA Technical Report Series No. 273 (1987), page 199.

[2] S.F Mughabghab et al., Neutron Cross Sections Vol. 1: Resonance Parameters and Thermal Cross Sections, Part A: Z = 1-60; Academic Press, NY, 1981.

[3] S.F Mughabghab, Neutron Cross Sections Vol. 1: Resonance Parameters and Thermal Cross Sections, Part B: Z = 61-100; Academic Press, NY, 1984.

[4] F. De Corte et al., J. Radioanal. Nucl. Chem. 133 (1989) 43.

ENDF/B-6: the US Evaluated Nuclear Data File, version 6

JENDL-3: the Japanese Evaluated Nuclear Data Library, version 3 (see JAERI-1320 for fission products)

The evaluated data files of complete $\sigma(E)$ data, ENDF/B-6 and JENDL-3 are available from the 4 Nuclear Data Centres (see Page 5) upon request.

Table B-3: Thermal neutron capture cross sections and resonance integrals

nuclide		cross section (b)		resonance integral (b)		Ref.
36-Kr-82	σ	30.0	± 10.0	C 190.0	± 20.0	[1]
83	σ	180.0	± 30.0	C 183.0	± 25.0	[2]
84	σ (m)	0.090	± 0.013	2.4		[1]
	σ (g)	0.042	± 0.004	0.8		[1]
	σ (m+g)	0.110	± 0.015	3.2	± 0.5	[1]
85	σ	1.66	± 0.2	1.8	± 1.0	[1,2]
86	σ	0.003	± 0.002	0.1	± 0.04	[1]
40-Zr-90	σ	0.011	± 0.005	C 0.14		[2]
91	σ	1.24	± 0.25	6.8	± 1.3	[1]
92	σ	0.22	± 0.06	0.63	± 0.11	[1]
93	σ	2.6	± 1.4	20.0	± 10.0	[1]
94	σ	0.0499	± 0.0024	0.30	± 0.07	[1]
95	σ°	0.49		6.5	± 1.4	[1]
96	σ	0.0229	± 0.0010	5.6	± 0.9	[1]
42-Mo-95	σ	14.0	± 0.5	C 109.0	± 5.0	[2]
96	σ	0.5	± 0.2	24.0	± 4.0	[1]
97	σ	2.1	± 0.5	C 14.0	± 3.0	[2]
98	σ°	0.130	± 0.006	7.3	± 1.8	[1]
100	σ	0.199	± 0.003	3.75	± 0.15	[2]
44-Ru-100	σ°	5.0	± 0.6	11.0	± 0.7	[1]
101	σ°	3.4	± 0.9	88.0	± 17.0	[1]
102	σ°	1.21	± 0.07	4.2	± 0.1	[2]
103	σ	7.71		60.0	± 20.0	[1]
104	σ°	0.32	± 0.02	4.3	± 0.1	[2]
106	σ	0.146	± 0.045	1.8	± 0.4	[1]
54-Xe-130	σ° (m)	0.45	± 0.10	C 1.17		[1]
	σ° (g)	6.0	± 1.0	C 13.72		[1]
	σ° (m+g)	6.45	± 1.0	C 14.89		[1]
131	σ°	85.0	± 10.0	900.0	± 100.0	[2]
132	σ° (m)	0.050	± 0.010	0.9	± 0.2	[1,2]
	σ° (m+g)	0.450	± 0.060	4.6	± 0.6	[1,2]
133g	σr	190.0	± 90.0			
134	σ° (m)	0.003	± 0.0003	0.1		[1]
	σ° (m+g)	0.265	± 0.020	0.3		[1]
135g	σ°	(2.65 ± 0.11) E+06		C 7600.0	± 500.	[2]
136	σ°	0.26	± 0.02	0.74	± 0.21	[1,2]
55-Cs-133	σ° (m)	2.5	± 0.2	30.0	± 6.0	[1]
	σ° (m+g)	29.0	± 1.5	422.0	± 23.0	[1]
134g	σr	140.0	± 12.0			
135	σ	8.7	± 0.5	66.0	± 8.0	[1]
137g	σr (g)	0.110	± 0.033			
58-Ce-144g	σ	1.0	± 0.1	2.6	± 0.3	[1,2]
59-Pr-141	σ° (m)	3.9	± 0.3			
	σ° (m+g)	11.5	± 0.3	17.8	± 3.5	[1]
143	σ	90.0	± 10.0	190.0	± 25.0	[2]

Table B-3: Thermal neutron capture cross sections and resonance integrals

nuclide	cross section (b)				resonance integral (b)			Ref.	
60-Nd-142	σ	18.7	±	0.7	8.5	±	1.0	[1]	
143	σ°	325.0	±	10.0	136.0	±	35.0	[1]	
144g	σ	3.6	±	0.3	5.0	±	1.0	[1]	
145	σ°	42.0	±	2.0	255.0	±	40.0	[1]	
146	σ°	1.4	±	0.1	2.7	±	0.4	[1]	
147	σ	440.0	±	150.0	540.0	±	150.0	[1]	
148	σ°	2.5	±	0.2	14.0	±	1.5	[1,2]	
150	σ°	1.2	±	0.2	14.5	±	2.0	[1,2]	
61-Pm-147	σ (m)	85.0	±	5.0	910.0	±	265.0	[1]	1)
	σ (g)	96.0	±	2.0	1320.0	±	85.0	[1]	
	σ (m+g)	181.0	±	7.0	2230.0	±	70.0	[1]	2)
148m	σ	22000.0	±	2500.0	3600.0	±	2400.0	[1,3]	
148g	σr	2000.0	±	1000.0					
149	σ	1400.0	±	300.0	825.0	±	50.0	[1]	
151	σ	173.0			1400.0	±	400.0	[1]	
62-Sm-147	σ	64.0	±	5.0	650.0	±	50.0	[1]	
148	σ	2.7	±	0.6	27.0	±	14.0	[1,3]	
149	σ	41000.0	±	2000.0	3700.0	±	400.0	[1]	
150	σ°	102.0	±	5.0	358.0	±	50.	[3]	
151	σ	15000.0	±	1800.0	3100.0	±	500.0	[1]	
152	σ°	206.0	±	6.0	2960.0	±	150.0	[1]	
153	σ°	420.0	±	180.0 3)	3700.0	±	2000.0	[1]	
154	σ°	7.74	±	0.46 4)	33.3	±	3.0	[4]	4)
63-Eu-151	σ (m2)	4.2	±	2.0					
	σ (m1)	3211.0	±	82.0	1823.0	±	146.0	[1]	
	σ (g)	5935.0	±	73.0	3552.0	±	264.0	[1]	
	σ (total)	9146.0	±	109.0	5367.0	±	263.0	[1]	
152	σr	2313.0							
153	σ°	312.0	±	7.0 5)	1420.0	±	100.0	[3]	5)
154g	σ°	1500.0	±	400.0	1500.0	±	450.0	[1]	
155	σr	4040.0	±	125.0 6)	1680.0	±	300.0	[1]	6)
	σ	3950.0	±	125.0 6)	C 23200.0	±	300.0	[3]	6)

1) Original value in [1] = 1045 ± 265 b, adjusted here (within the error limits) to give the correct sum (m+g).

2) The higher value of [1] is supported by the data from JENDL-3 (2199 b) and ENDF/B-6 (2197 b), whereas [3] gives 2064 ± 100 b.

3) [3] used, as uncertainty is given. Other values: 334.5 b [1], 420.2 b (JENDL-3), 330 b (ENDF/B-6).

4) Taken from [4] because of discrepancies between [1] and [3].

5) [1] gives 603 and 3414 b respectively, but recent evaluations ([4], ENDF/B-6) support the lower values.

6) Both sets of data given for comparison. Other values: ENDF/B-6: same as [3], JENDL-3: 4071 b and 6755 b respectively.

The tables contain yield sets from the US and UK evaluated fission yield files, which result from the presently largest evaluation efforts. This is in accordance with the recommendations of two Specialists' Meetings on the evaluation of fission product yields (Studsvik, Sweden, 11-15 Sept 1987, Vienna, Austria, 27-29 Sept 1989) that not a single set of fission yields should be recommended. A third file of fission yield data from China is presently being revised; it is expected that it can be included in a later version of this handbook.

Fission yields are given for thermal neutron fission of U-233, U-235, Pu-239 and Pu-241, and for fast neutron fission of Th-232 and U-238.

Tables C-1 to C-6 contain cumulative and chain yields ≥ 0.01-0.001 %. In addition, the most important ternary fission yields are presented. Cumulative yields are given separately only if they differ significantly from the respective chain yields, or for some important fission products to show the (even small) difference.

Tables C-7.1 to C-7.6 show selected independent yields. The description of these tables is given on page C-7.1.

Description of table entries:

FP: Chain yields are indicated by "A=". Otherwise the nuclide is listed for which the cumulative yield is given.

The fission yield values are given in percent per fission and tabulated in 2 different representations as extracted from the files. **Users are asked to inform us which one they prefer.** For the final version of the handbook the representation will be uniform.

US file: fixed point numbers and relative errors (in % of value);

UK file: floating point numbers and absolute errors.

Source of data:

US file: T.R. England, private communication: preliminary evaluated fission yields with status of 15 Sept.1989. The final yield sets will be included in the ENDF/B-6 file.

UK file: M.F. James, R.W. Mills, D.R. Weaver: "UKFY2", the new UK library of independent and cumulative fission product yields, in ENDF-6 format (1991). The file UKFY2 contains also several other tables of fission yield data and discrepances. These as well as the methods and outline of the evaluation are also available in printed form as reports AEA-TRS-1015, AEA-TRS-1018 and AEA-TRS-1019 (1991).

The US file (as part of ENDF/B-6) will be and the UK file is available on magnetic tape from the Data Centres (see page 5) upon request.

Table C-1: Th-232 fast fission chain yields and selected cumulative yields

FP	US file	error(%)	UK file	error
H-3			7.8498- 3	3.0654- 3
He-3			7.8498- 3	3.0654- 3
He-4			1.2003- 1	4.6873- 2
A=77	0.01295	8.	1.0937- 2	1.7127- 3
A=78	0.04533	8.	3.2313- 2	8.1180- 3
A=79	0.07765	11.	8.8674- 2	2.1989- 2
A=80	0.1971	16.	2.3003- 1	5.4815- 2
A=81	0.4746	11.	5.3859- 1	1.2408- 1
A=82	1.0913	16.	1.2196+ 0	2.5545- 1
A=83	2.1848	2.0	2.2570+ 0	2.5565- 1
A=84	4.0460	2.0	5.2135+ 0	3.8619- 1
Kr-85	0.8371	1.4	1.0265+ 0	1.3214- 1
A=85	4.1876	1.4	4.8010+ 0	6.1864- 1
A=86	6.6311	2.0	6.4262+ 0	5.4932- 1
A=87	7.1176	2.8	6.4653+ 0	3.3456- 1
A=88	7.2993	2.0	6.9103+ 0	2.6492- 1
A=89	7.5127	2.8	7.3605+ 0	5.2985- 1
A=90	7.9899	4.0	7.2875+ 0	2.8339- 1
A=91	7.3305	2.0	6.8435+ 0	6.1089- 1
A=92	6.8935	2.8	7.0911+ 0	2.0380- 1
A=93	6.7002	4.0	6.4263+ 0	3.7388- 1
A=94	5.5770	4.0	5.3052+ 0	2.1349- 1
A=95	5.6724	2.0	5.5669+ 0	1.6501- 1
A=96	4.4316	6.	4.9887+ 0	2.4723- 1
A=97	4.4343	2.0	4.5199+ 0	9.9122- 2
A=98	3.6987	6.	3.5665+ 0	1.7797- 1
A=99	2.9530	2.0	2.9378+ 0	8.5531- 2
A=100	1.3775	6.	1.7328+ 0	3.5035- 1
A=101	0.7207	11.	8.4799- 1	2.0276- 1
A=102	0.3715	11.	3.6927- 1	9.2444- 2
A=103	0.1561	4.0	1.5406- 1	9.1892- 3
A=104	0.09122	11.	1.0458- 1	2.1156- 2
A=105	0.05168	2.8	7.1078- 2	1.5530- 2
A=106	0.05337	6.	5.2899- 2	3.8177- 3
A=107	0.05159	11.	5.3157- 2	1.0745- 2
A=108	0.06223	16.	5.4851- 2	1.1075- 2
A=109	0.06640	4.0	5.5902- 2	8.4837- 3
A=110	0.07201	16.	6.1451- 2	1.2449- 2
A=111	0.07184	8.	6.7619- 2	6.4966- 3
A=112	0.07850	6.	7.5785- 2	6.7444- 3
A=113	0.07745	4.0	7.1159- 2	1.4430- 2
A=114	0.07447	16.	6.7074- 2	1.3595- 2
A=115	0.07720	2.8	6.3327- 2	3.4572- 3
A=116	0.07512	16.	6.3593- 2	1.6043- 2
A=117	0.07461	2.8	6.3274- 2	1.5973- 2
A=118	0.06407	11.	6.2535- 2	1.5794- 2
A=119	0.05823	16.	6.1341- 2	1.5501- 2
A=120	0.05530	16.	5.9770- 2	1.5108- 2
A=121	0.04932	6.	5.7796- 2	1.4615- 2
A=122	0.03718	16.	5.5497- 2	1.4039- 2
A=123	0.02988	16.	5.2961- 2	1.3407- 2
A=124	0.02695	16.	5.0521- 2	1.2794- 2
A=125	0.03424	11.	4.9554- 2	1.2553- 2
A=126	0.04897	16.	5.5129- 2	1.3918- 2
A=127	0.08241	6.	8.2144- 2	7.3113- 3
A=128	0.1859	16.	1.8676- 1	3.7978- 2
A=129	0.3211	4.0	4.1996- 1	8.9897- 2

Table C-1: Th-232 fast fission chain yields and selected cumulative yields

FP	US file	error(%)	UK file	error
A=130	0.9292	11.	8.1745- 1	1.6759- 1
Xe-131m	0.02274	4.0	1.8575- 2	6.1896- 4
A=131	1.6246	2.0	1.7104+ 0	5.6992- 2
A=132	2.9675	1.4	2.8133+ 0	8.5099- 2
Xe-133m	0.1126	4.0	1.2886- 1	5.2472- 3
A=133	4.0218	2.0	4.4722+ 0	1.8211- 1
A=134	5.3638	2.0	5.6428+ 0	2.6870- 1
Xe-135m	0.8222	4.0	8.5327- 1	3.8975- 2
Xe-135	5.5483	2.0	5.4034+ 0	2.4540- 1
A=135	5.5483	2.0	5.4038+ 0	2.4542- 1
A=136	5.6339	2.0	5.8281+ 0	2.2499- 1
A=137	5.8797	4.0	5.9519+ 0	3.4195- 1
A=138	6.4900	6.	6.2937+ 0	1.9981- 1
A=139	6.9521	2.0	6.9609+ 0	3.4740- 1
A=140	7.8758	2.0	7.7679+ 0	2.4097- 1
A=141	7.4890	2.8	7.2765+ 0	2.2639- 1
A=142	6.5544	2.8	6.5180+ 0	1.7529- 1
A=143	6.6732	2.0	6.5140+ 0	2.2051- 1
A=144	7.9552	2.8	7.6904+ 0	3.3811- 1
A=145	5.3667	2.0	5.1055+ 0	3.5624- 1
A=146	4.5793	2.8	3.7956+ 0	4.2974- 1
A=147	2.9444	4.0	3.0773+ 0	1.2182- 1
A=148	2.0181	2.8	1.9679+ 0	1.1046- 1
A=149	1.0889	4.0	1.1525+ 0	9.4856- 2
A=150	0.3546	16.	9.5269- 1	1.5341- 1
A=151	0.3657	6.	4.1491- 1	4.2958- 2
A=152	0.07690	16.	2.8279- 1	5.9605- 2
A=153	0.06828	8.	2.0629- 1	2.1016- 2
A=154	0.00705	23.	4.7343- 2	9.6460- 3
A=155	0.00371	23.	1.0920- 2	2.2121- 3
A=156	0.00272	11.	2.5093- 3	3.0956- 4
A=157	0.00096	23.	7.7649- 4	1.9631- 4

Table C-2: U-233 thermal fission chain yields and selected cumulative yields

FP	US file	error(%)	UK file	error
H-2			8.5100- 4	8.3162- 5
H-3			9.6943- 3	1.0362- 3
He-3			9.6943- 3	1.0362- 3
He-4			2.1979- 1	1.4117- 2
A=75	0.00798	23.	7.0058- 3	1.8305- 3
A=76	0.01383	23.	1.7082- 2	4.4000- 3
A=77	0.02593	16.	3.8195- 2	3.1740- 3
A=78	0.05382	16.	6.2314- 2	4.2599- 3
A=79	0.1436	16.	1.2567- 1	6.3380- 3
A=80	0.2332	16.	2.4926- 1	8.3760- 3
A=81	0.3677	4.	3.7159- 1	1.3238- 2
A=82	0.5854	2.8	5.8513- 1	1.3681- 2
A=83	1.0144	1.0	1.0113+ 0	2.2218- 2
A=84	1.6894	1.0	1.7398+ 0	4.0018- 2
Kr-85	0.5311	0.35	4.9812- 1	1.7511- 2
A=85	2.2548	1.4	2.1209+ 0	3.4881- 2
A=86	2.8435	1.4	2.8937+ 0	3.9204- 2
A=87	4.0150	1.4	4.0253+ 0	5.9407- 2
A=88	5.4649	1.4	5.4774+ 0	7.4785- 2
A=89	6.3370	1.4	6.2457+ 0	7.5378- 2
A=90	6.7882	1.4	6.6774+ 0	7.1792- 2
A=91	6.4973	1.0	6.5884+ 0	6.7086- 2
A=92	6.5477	1.0	6.5976+ 0	6.6997- 2
A=93	6.9730	1.0	6.9828+ 0	7.6612- 2
A=94	6.8286	1.4	6.8186+ 0	7.5828- 2
Zr-95	6.3480	2.	6.3868+ 0	7.1301- 2
Nb-95m	0.06352	2.	1.1869- 4	4.4299- 5
A=95	6.3482	1.0	6.3875+ 0	7.1298- 2
A=96	5.6709	1.0	5.7496+ 0	5.8873- 2
A=97	5.5156	1.0	5.6180+ 0	5.3188- 2
A=98	5.1886	1.0	5.1419+ 0	5.4344- 2
A=99	4.9096	1.4	4.9072+ 0	6.0025- 2
A=100	4.4584	1.4	4.3164+ 0	4.4675- 2
A=101	3.1711	1.4	3.1379+ 0	2.9579- 2
A=102	2.4027	1.0	2.4311+ 0	2.5519- 2
A=103	1.5745	2.	1.5607+ 0	2.9392- 2
A=104	0.9801	2.	9.7559- 1	1.4400- 2
A=105	0.4958	2.8	5.0045- 1	1.2670- 2
A=106	0.2462	2.	2.5039- 1	7.1505- 3
A=107	0.1145	4.	1.1537- 1	3.6657- 3
A=108	0.07576	4.	7.9515- 2	2.6969- 3
A=109	0.03806	23.	4.7716- 2	7.9163- 3
A=110	0.03866	4.	3.8955- 2	4.2029- 3
A=111	0.02171	6.	2.5071- 2	2.9411- 3
A=112	0.01329	8.	1.3867- 2	1.2996- 3
A=113	0.01354	11.	1.4651- 2	3.2300- 3
A=114	0.01284	11.	1.5951- 2	3.5365- 3
A=115	0.01487	6.	1.7929- 2	2.6805- 3
A=116	0.01316	16.	1.7571- 2	3.4999- 3
A=117	0.01404	11.	1.5081- 2	1.1092- 3
A=118	0.01534	11.	1.5587- 2	1.1472- 3
A=119	0.01843	16.	1.5914- 2	1.3363- 3
A=120	0.02167	8.	1.7602- 2	1.2951- 3
A=121	0.02329	8.	1.8501- 2	1.4768- 3
A=122	0.04063	8.	1.9474- 2	1.2316- 3
A=123	0.06001	23.	2.5537- 2	3.4414- 3
A=124	0.07393	16.	3.2311- 2	2.3792- 3

Table C-2: U-233 thermal fisson chain yields and selected cumulative yields

FP	US file	error(%)	UK file	error
A=125	0.1177	8.	1.1988- 1	1.4655- 2
A=126	0.2255	8.	2.4977- 1	4.7806- 2
A=127	0.5543	11.	4.9065- 1	1.1208- 1
A=128	0.8369	8.	8.9566- 1	2.1644- 1
A=129	1.5847	16.	1.7944+ 0	3.4227- 1
A=130	2.0862	11.	2.5132+ 0	4.5705- 1
Xe-131m	0.05046	2.8	3.8429- 2	1.4856- 3
A=131	3.6016	0.7	3.5244+ 0	1.3612- 1
Te-132	4.7568	2.8	4.5176+ 0	1.3355- 1
A=132	4.9503	0.7	4.7696+ 0	1.0017- 1
Xe-133m	0.2104	23.	2.0797- 1	1.4319- 2
Xe-133	6.0519	2.	6.0010+ 0	1.4399- 1
A=133	6.0519	1.0	6.0011+ 0	1.4399- 1
A=134	6.3023	0.7	6.1715+ 0	2.5620- 1
I-135	4.9964	2.8	4.4074+ 0	4.5380- 1
Xe-135m	1.5522	32.	1.5508+ 0	1.8900- 1
Xe-135	6.2798	2.	5.8748+ 0	3.0315- 1
A=135	6.2873	1.4	5.8996+ 0	3.0433- 1
A=136	6.7667	1.0	7.5466+ 0	5.2029- 1
Cs-137	6.8097	0.7	6.4113+ 0	1.3699- 1
A=137	6.8140	0.7	6.4240+ 0	1.3692- 1
A=138	5.9053	2.	5.8998+ 0	2.0960- 1
A=139	6.3143	2.8	6.4176+ 0	2.6794- 1
Ba-140	6.4056	2.8	6.4431+ 0	2.0573- 1
La-140	6.4299	2.	6.4675+ 0	2.0632- 1
A=140	6.4299	1.4	6.4676+ 0	2.0632- 1
A=141	6.4871	2.8	6.4787+ 0	1.5775- 1
A=142	6.6743	1.4	6.6823+ 0	1.6622- 1
A=143	5.9078	0.7	5.7751+ 0	1.0127- 1
Ce-144	4.6860	2.	4.6003+ 0	1.0358- 1
A=144	4.6864	0.7	4.6018+ 0	1.0361- 1
A=145	3.4156	0.7	3.3620+ 0	7.6564- 2
A=146	2.5577	0.7	2.5007+ 0	6.2359- 2
A=147	1.7383	2.8	1.7850+ 0	5.2083- 2
A=148	1.2852	0.7	1.2771+ 0	3.4852- 2
A=149	0.7770	2.8	7.6446- 1	2.8927- 2
A=150	0.5009	1.0	4.9272- 1	1.1989- 2
A=151	0.3153	2.	3.3534- 1	1.8080- 2
A=152	0.2133	2.8	1.9586- 1	8.7134- 3
A=153	0.1036	6.	1.2564- 1	2.0394- 2
A=154	0.04661	2.8	4.6206- 2	2.1036- 3
A=155	0.02137	16.	2.2659- 2	3.7475- 3
A=156	0.01282	6.	1.1268- 2	1.3385- 3
A=157	0.00642	8.	6.7451- 3	8.6510- 4
A=158	0.00205	23.	2.5387- 3	5.3834- 4
A=159	0.00089	6.	9.5767- 4	1.1855- 4

Table C-3: U-235 thermal fission chain yields and selected cumulative yields

FP	US file	error(%)	UK file	error
H-1			1.6549- 3	1.5529- 4
H-2			8.4000- 4	5.5894- 5
H-3			9.9825- 3	3.2132- 4
He-3			9.9825- 3	3.2132- 4
He-4			1.6731- 1	5.9310- 3
A=77	0.00795	8.	7.9250- 3	6.5951- 4
A=78	0.02077	8.	2.0514- 2	1.1925- 3
A=79	0.04392	6.	4.7242- 2	3.7286- 3
A=80	0.1278	6.	1.2755- 1	5.3360- 3
A=81	0.1914	4.	1.9682- 1	9.0222- 3
A=82	0.3233	2.8	3.2329- 1	8.0753- 3
A=83	0.5355	0.5	5.5055- 1	8.8026- 3
A=84	0.9996	0.7	1.0955+ 0	3.1452- 2
Kr-85	0.2856	0.35	2.6865- 1	6.5631- 3
A=85	1.3170	0.35	1.2399+ 0	3.1888- 2
A=86	1.9621	0.5	2.0156+ 0	1.7994- 2
A=87	2.5549	0.5	2.5992+ 0	3.1560- 2
A=88	3.5718	0.7	3.5694+ 0	7.4456- 2
A=89	4.7618	1.0	4.6920+ 0	7.8590- 2
A=90	5.7750	1.0	5.7621+ 0	6.8311- 2
A=91	5.8365	0.7	5.8314+ 0	5.3611- 2
A=92	6.0272	0.7	6.0380+ 0	5.2660- 2
A=93	6.3589	0.7	6.4244+ 0	7.5142- 2
A=94	6.4953	0.7	6.3869+ 0	7.7664- 2
A=95	6.4946	0.7	6.5224+ 0	5.4827- 2
A=96	6.3403	1.0	6.2876+ 0	6.0498- 2
A=97	5.9858	0.7	6.0740+ 0	4.8841- 2
A=98	5.7813	0.7	5.7137+ 0	5.1966- 2
A=99	6.1072	1.0	6.1602+ 0	4.8112- 2
A=100	6.2823	0.7	6.2406+ 0	5.8290- 2
A=101	5.1803	1.0	5.1516+ 0	5.3110- 2
A=102	4.2966	1.0	4.2883+ 0	3.7348- 2
A=103	3.0323	1.0	3.0328+ 0	3.5145- 2
A=104	1.8807	1.0	1.8742+ 0	1.6756- 2
A=105	0.9633	1.4	9.5904- 1	1.2418- 2
A=106	0.4011	1.0	4.0760- 1	9.3519- 3
A=107	0.1460	2.8	1.3910- 1	5.4314- 3
A=108	0.05392	4.	5.7084- 2	2.8645- 3
A=109	0.03098	6.	2.8311- 2	2.4546- 3
A=110	0.02535	4.	2.5236- 2	1.9374- 3
A=111	0.04216	2.	2.9016- 2	6.2813- 3
A=112	0.01296	4.	1.7642- 2	8.8727- 4
A=113	0.01399	4.	1.5950- 2	8.0211- 4
A=114	0.01163	4.	1.2877- 2	6.4732- 4
A=115	0.01207	2.8	1.1053- 2	5.7781- 4
A=116	0.01308	4.	1.6060- 2	8.0713- 4
A=117	0.01283	4.	1.3854- 2	1.5532- 3
A=118	0.01130	8.	1.3634- 2	2.0616- 3
A=119	0.01275	8.	1.5085- 2	1.4777- 3
A=120	0.01327	11.	1.4643- 2	1.6044- 3
A=121	0.01311	6.	1.2521- 2	5.1397- 4
A=122	0.01547	8.	1.8101- 2	1.1727- 3
A=123	0.01585	2.8	1.5705- 2	9.1021- 4
A=124	0.02677	8.	3.1543- 2	2.6584- 3
A=125	0.03105	2.8	2.7729- 2	1.6630- 3
A=126	0.05874	8.	6.0190- 2	5.5927- 3
A=127	0.1264	4.	1.2332- 1	4.8147- 3

Table C-3: U-235 thermal fission chain yields and selected cumulative yields

FP	US file	error(%)	UK file	error
A=128	0.3496	2.8	3.2839- 1	7.8900- 3
A=129	0.7522	6.	7.7648- 1	3.1439- 2
A=130	1.8109	2.	1.8013+ 0	5.2113- 2
Xe-131m	0.04049	1.4	3.1303- 2	3.4167- 4
A=131	2.8920	0.5	2.8822+ 0	3.1460- 2
A=132	4.3149	0.35	4.2666+ 0	4.2121- 2
Xe-133m	0.1894	2.	1.9069- 1	2.0291- 3
Xe-133	6.6989	0.5	6.6046+ 0	7.0026- 2
A=133	6.6989	0.35	6.6046+ 0	7.0026- 2
A=134	7.8762	0.5	7.7551+ 0	8.8568- 2
I-135	6.2784	1.4	6.2727+ 0	1.6961- 1
Xe-135m	1.1055	1.4	1.1468+ 0	5.2914- 2
Xe-135	6.5407	0.7	6.5343+ 0	1.4751- 1
A=135	6.5412	0.35	6.5355+ 0	1.4753- 1
A=136	6.3159	0.35	6.4911+ 0	1.0679- 1
A=137	6.1894	0.5	6.0860+ 0	7.2890- 2
A=138	6.7108	0.7	6.7471+ 0	8.3243- 2
A=139	6.3633	1.0	6.4452+ 0	9.7962- 2
A=140	6.2084	0.5	6.2832+ 0	6.1155- 2
A=141	5.8221	1.0	5.8744+ 0	7.7017- 2
A=142	5.8315	0.5	5.8377+ 0	5.1242- 2
A=143	5.9461	0.35	5.9430+ 0	4.6790- 2
A=144	5.4943	0.5	5.4717+ 0	3.7988- 2
A=145	3.9273	0.35	3.9248+ 0	3.1219- 2
A=146	2.9938	0.35	2.9861+ 0	2.3598- 2
A=147	2.2452	0.7	2.2708+ 0	2.2394- 2
A=148	1.6728	0.35	1.6765+ 0	1.4996- 2
A=149	1.0788	1.0	1.0506+ 0	1.6618- 2
A=150	0.6528	0.5	6.5000- 1	6.5016- 3
A=151	0.4171	1.0	4.1652- 1	6.6569- 3
A=152	0.2668	1.0	2.5916- 1	6.2100- 3
A=153	0.1584	2.8	1.5137- 1	5.8895- 3
A=154	0.07439	1.0	7.2875- 2	2.1907- 3
A=155	0.03220	4.	3.2386- 2	9.4184- 4
A=156	0.01491	2.8	1.2702- 2	5.9872- 4
A=157	0.00629	8.	6.3132- 3	4.3694- 4
A=158	0.00334	11.	2.8186- 3	5.3159- 4
A=159	0.00101	6.	1.0620- 3	6.3918- 5

Table C-4: U-238 fast fission chain yields and selected cumulative yields

FP	US file	error(%)	UK file	error
H-3			1.0601- 2	4.1398- 3
He-3			1.0601- 2	4.1398- 3
He-4			1.6210- 1	6.3302- 2
A=78	0.01123	23.	7.4434- 3	1.8530- 3
A=79	0.03271	23.	1.7992- 2	4.4391- 3
A=80	0.04718	32.	4.2588- 2	1.0194- 2
A=81	0.1083	16.	9.3712- 2	2.2162- 2
A=82	0.2134	16.	2.0548- 1	4.5852- 2
A=83	0.3943	1.4	4.0010- 1	1.9650- 2
A=84	0.8222	1.4	7.5646- 1	1.0773- 1
Kr-85	0.1482	2.	1.4782- 1	2.1760- 2
A=85	0.7409	1.0	6.9113- 1	1.0185- 1
A=86	1.2906	1.0	1.3171+ 0	6.2639- 2
A=87	1.6184	1.0	1.5425+ 0	8.6912- 2
A=88	2.0374	1.4	2.1661+ 0	9.1809- 2
A=89	2.7702	1.4	2.7554+ 0	7.5837- 2
A=90	3.2401	1.4	3.2453+ 0	9.0825- 2
A=91	4.0799	2.	4.0124+ 0	1.2243- 1
A=92	4.3029	2.8	4.2288+ 0	1.4261- 1
A=93	4.9174	2.	5.3407+ 0	2.0655- 1
A=94	4.7158	2.8	4.8627+ 0	1.9674- 1
Nb-95m	0.05143	1.0	1.6827- 7	6.0480- 8
A=95	5.1434	1.0	5.0804+ 0	8.4254- 2
A=96	6.0036	4.	5.8581+ 0	2.7747- 1
A=97	5.5675	0.7	5.6357+ 0	5.3598- 2
A=98	5.8716	1.0	5.6220+ 0	2.6816- 1
A=99	6.1640	1.4	6.1914+ 0	8.6608- 2
A=100	6.6830	1.0	6.5698+ 0	3.0999- 1
A=101	6.1872	1.4	6.6702+ 0	3.5178- 1
A=102	6.4248	1.0	6.4309+ 0	4.0079- 1
A=103	6.2707	1.0	6.0882+ 0	1.0252- 1
A=104	5.0205	1.0	4.8431+ 0	2.4114- 1
A=105	4.0488	2.	3.7544+ 0	1.3485- 1
A=106	2.4828	1.4	2.6332+ 0	1.6037- 1
A=107	1.4773	8.	1.8174+ 0	1.1661- 1
A=108	0.6009	16.	5.3713- 1	8.7256- 2
A=109	0.2420	11.	1.5520- 1	1.5959- 2
A=110	0.1385	16.	9.9780- 2	1.3778- 2
A=111	0.07016	2.	6.4678- 2	2.2633- 3
A=112	0.05556	4.	5.3462- 2	3.3692- 3
A=113	0.04510	11.	3.0645- 2	6.9822- 3
A=114	0.03856	16.	3.3967- 2	6.8435- 3
A=115	0.03675	4.	3.7936- 2	2.3160- 3
A=116	0.03875	11.	3.5214- 2	8.9222- 3
A=117	0.03721	11.	3.3532- 2	8.4981- 3
A=118	0.04176	11.	3.2153- 2	8.1043- 3
A=119	0.03801	11.	3.1534- 2	7.6713- 3
A=120	0.03704	11.	2.9952- 2	7.3298- 3
A=121	0.03902	11.	2.8301- 2	3.3509- 3
A=122	0.03927	11.	3.4508- 2	8.4300- 3
A=123	0.04214	16.	4.3917- 2	1.0676- 2
A=124	0.04443	11.	6.1202- 2	1.4736- 2
A=125	0.04766	6.	9.3633- 2	1.4577- 2
A=126	0.05301	6.	9.1961- 2	1.7886- 2
A=127	0.1346	4.	1.5713- 1	1.0182- 2
A=128	0.4607	6.	2.8527- 1	5.5118- 2
A=129	0.9512	4.	6.2055- 1	2.9639- 2

Table C-4: U-238 fast fission chain yields and selected cumulative yields

FP	US file	error(%)	UK file	error
A=130	1.8734	6.	1.3556+ 0	2.2551- 1
Xe-131m	0.04611	1.4	3.5873- 2	6.4063- 4
A=131	3.2936	1.0	3.3031+ 0	5.8988- 2
A=132	5.1543	1.0	5.0611+ 0	7.5160- 2
Xe-133m	0.1908	2.8	1.9499- 1	3.9718- 3
A=133	6.7729	0.7	6.7695+ 0	1.3789- 1
A=134	7.7501	2.	7.6992+ 0	2.1650- 1
I-135	6.9553	2.	6.4908+ 0	1.7309- 1
Xe-135m	1.0383	2.8	1.0181+ 0	2.6901- 2
A=135	6.9824	0.7	6.5072+ 0	1.7279- 1
A=136	6.9943	2.8	6.9236+ 0	2.3977- 1
A=137	6.0240	0.7	5.8192+ 0	8.4925- 2
A=138	5.7311	1.4	6.0560+ 0	1.5485- 1
A=139	5.6515	1.0	5.7589+ 0	2.1979- 1
A=140	5.8151	0.7	5.7201+ 0	4.7052- 2
A=141	5.3257	2.	5.8538+ 0	2.0532- 1
A=142	4.5699	1.0	4.8593+ 0	1.4487- 1
A=143	4.5960	0.7	4.8229+ 0	3.1578- 2
A=144	4.5279	0.7	4.4629+ 0	6.0560- 2
A=145	3.7882	0.7	3.8362+ 0	1.2400- 1
A=146	3.4279	0.7	3.5796+ 0	1.1171- 1
A=147	2.5793	0.7	2.6550+ 0	1.6336- 2
A=148	2.1013	0.7	2.2837+ 0	3.1786- 2
A=149	1.6170	1.0	1.6810+ 0	5.4466- 2
A=150	1.2662	1.0	1.3156+ 0	4.2872- 2
A=151	0.7961	1.0	8.0984- 1	1.1326- 2
A=152	0.5270	1.0	5.5650- 1	3.1463- 2
A=153	0.4116	2.	3.4346- 1	1.0294- 2
A=154	0.2154	1.0	2.3905- 1	1.6706- 2
A=155	0.1370	11.	1.2268- 1	1.0437- 2
A=156	0.07597	2.	6.3167- 2	9.4750- 4
A=157	0.03961	16.	3.1938- 2	6.0303- 3
A=158	0.01770	16.	1.6271- 2	3.0672- 3
A=159	0.00827	16.	8.2913- 3	9.1253- 4
A=160	0.00334	23.	3.0963- 3	5.5144- 4

Table C-5: Pu-239 thermal fission chain yields and selected cumulative yields

FP	US file	error(%)	UK file	error
H-1			4.0800- 3	3.7370- 4
H-2			1.4201- 3	1.6240- 4
H-3			1.4659- 2	5.5795- 4
He-3			1.4728- 2	5.5795- 4
He-4			2.2239- 1	4.0949- 3
A=77	0.00709	11.	7.0474- 3	1.1177- 3
A=78	0.02792	11.	1.6915- 2	4.1668- 3
A=79	0.04351	2.	3.9550- 2	9.5501- 3
A=80	0.1137	16.	9.1062- 2	2.0953- 2
A=81	0.1790	16.	1.9143- 1	2.5127- 2
A=82	0.2204	23.	2.4464- 1	3.7053- 2
A=83	0.2968	0.5	2.8801- 1	8.8764- 3
A=84	0.4797	1.0	4.9061- 1	1.9982- 2
Kr-85	0.1257	1.4	1.2575- 1	3.8201- 3
A=85	0.5770	0.35	5.5093- 1	1.2428- 2
A=86	0.7658	0.5	7.8579- 1	1.6907- 2
A=87	1.0051	0.5	9.7459- 1	3.5680- 2
A=88	1.3198	1.0	1.3070+ 0	3.4070- 2
A=89	1.7068	2.	1.6586+ 0	3.0788- 2
A=90	2.0457	1.4	1.9567+ 0	3.5504- 2
A=91	2.4370	1.4	2.4327+ 0	3.1500- 2
A=92	2.9916	0.7	3.0293+ 0	5.6405- 2
A=93	3.7734	0.7	3.9275+ 0	1.1566- 1
A=94	4.2973	1.0	4.2654+ 0	8.2055- 2
Zr-95	4.8089	1.4	4.9051+ 0	8.7107- 2
Nb-95m	0.04822	2.	5.3737- 5	1.9661- 5
A=95	4.8096	1.0	4.9054+ 0	8.7110- 2
A=96	4.8650	1.4	4.9376+ 0	1.2981- 1
A=97	5.4050	1.0	5.3055+ 0	6.9313- 2
A=98	5.8380	1.0	5.9973+ 0	3.6001- 1
A=99	6.1990	1.4	6.1628+ 0	4.9547- 2
A=100	6.9097	2.8	7.0104+ 0	4.2493- 1
A=101	6.0076	1.4	6.1870+ 0	2.0670- 1
A=102	6.0994	1.4	6.1045+ 0	2.9105- 1
A=103	7.0048	2.	6.9526+ 0	6.9325- 2
A=104	6.0704	1.0	6.0789+ 0	2.0470- 1
A=105	5.6203	2.	5.7675+ 0	1.4644- 1
Ru-106	4.3282	2.	4.1853+ 0	6.6632- 2
A=106	4.3286	2.	4.1867+ 0	6.6653- 2
A=107	3.2953	4.	3.1784+ 0	1.2748- 1
A=108	2.1402	4.	2.0581+ 0	8.7767- 2
A=109	1.7442	8.	1.5174+ 0	1.7462- 1
A=110	0.6364	6.	6.2540- 1	3.1346- 2
A=111	0.2925	2.	3.0547- 1	6.4167- 3
A=112	0.1278	2.8	1.2756- 1	7.1511- 3
A=113	0.08053	2.8	8.1070- 2	3.9745- 3
A=114	0.05929	2.8	5.3936- 2	2.6982- 3
A=115	0.04096	4.	4.9492- 2	4.9587- 3
A=116	0.04947	8.	4.5748- 2	2.2885- 3
A=117	0.04674	8.	4.5742- 2	2.2882- 3
A=118	0.03579	8.	4.5703- 2	3.2012- 3
A=119	0.03773	8.	4.8738- 2	3.3941- 3
A=120	0.03390	11.	4.3292- 2	5.9678- 3
A=121	0.03813	8.	5.5613- 2	1.0250- 2
A=122	0.05356	11.	6.9616- 2	3.4722- 3
A=123	0.04487	16.	9.5035- 2	9.3811- 3
A=124	0.09394	16.	1.2816- 1	6.3835- 3

Table C-5: Pu-239 thermal fission chain yields and selected cumulative yields

FP	US file	error(%)	UK file	error
A=125	0.1127	8.	2.0542- 1	3.7979- 2
A=126	0.2508	6.	3.1286- 1	4.4461- 2
A=127	0.5763	8.	4.6080- 1	2.4214- 2
A=128	0.7381	11.	8.2855- 1	4.9415- 2
A=129	1.3847	4.	1.4022+ 0	6.6701- 2
A=130	2.0548	11.	2.3693+ 0	1.3625- 1
Xe-131m	0.05409	2.	4.2009- 2	6.2247- 4
A=131	3.8621	0.5	3.8659+ 0	5.7278- 2
Te-132	5.1539	2.	5.0881+ 0	8.2130- 2
A=132	5.4160	0.5	5.2620+ 0	5.7269- 2
Xe-133m	0.2318	16.	2.1467- 1	6.4737- 3
A=133	7.0262	0.5	6.9026+ 0	9.4077- 2
A=134	7.6876	0.5	7.5653+ 0	1.3588- 1
I-135	6.4123	2.8	6.1927+ 0	3.5440- 1
Xe-135m	1.7089	32.	1.5756+ 0	1.4748- 1
Xe-135	7.6237	1.0	7.2269+ 0	1.6582- 1
A=135	7.6338	0.7	7.2390+ 0	1.6605- 1
A=136	7.0228	1.0	7.0764+ 0	1.8648- 1
Cs-137	6.6202	0.5	6.4025+ 0	1.1652- 1
A=137	6.6253	0.5	6.4065+ 0	1.1651- 1
A=138	6.1369	1.0	6.1215+ 0	1.3912- 1
A=139	5.6319	2.8	5.6638+ 0	1.3895- 1
Ba-140	5.3644	1.4	5.2854+ 0	5.2550- 2
A=140	5.3724	1.0	5.2944+ 0	5.2531- 2
A=141	5.2556	2.	5.2033+ 0	7.1682- 2
A=142	4.9418	0.7	5.0462+ 0	7.8925- 2
A=143	4.4216	0.5	4.4631+ 0	6.5883- 2
Ce-144	3.7454	1.0	3.7512+ 0	3.7314- 2
A=144	3.7457	0.35	3.7516+ 0	3.7317- 2
A=145	2.9952	0.35	3.0532+ 0	4.8365- 2
A=146	2.4626	0.35	2.5010+ 0	3.9729- 2
A=147	2.0071	1.0	2.0536+ 0	3.4709- 2
A=148	1.6449	0.5	1.6893+ 0	2.5261- 2
A=149	1.2195	0.7	1.2539+ 0	2.5012- 2
A=150	0.9680	0.35	9.8246- 1	1.5716- 2
A=151	0.7485	1.4	7.6279- 1	1.9807- 2
A=152	0.5779	1.0	5.8719- 1	2.4012- 2
A=153	0.3638	6.	3.9636- 1	3.2467- 2
A=154	0.2617	1.4	2.7913- 1	1.1457- 2
A=155	0.1679	11.	2.0566- 1	3.1505- 2
A=156	0.1248	4.	1.0706- 1	6.0120- 3
A=157	0.07471	6.	7.5258- 2	7.5826- 3
A=158	0.04215	16.	3.9542- 2	7.6434- 3
A=159	0.02081	6.	2.1348- 2	1.9257- 3
A=160	0.00984	16.	1.0171- 2	1.8704- 3

Table C-6: Pu-241 thermal fission chain yields and selected cumulative yields

FP	US file	error(%)	UK file	error
H-3			1.4100- 2	5.7041- 3
He-3			1.4100- 2	5.7041- 3
He-4			2.0347- 1	8.6421- 2
A=77	0.00204	23.	8.2662- 3	5.5254- 3
A=78	0.00923	6.	1.5317- 2	1.0116- 2
A=79	0.01576	16.	2.7826- 2	1.7990- 2
A=80	0.03079	16.	4.9836- 2	3.1041- 2
A=81	0.06544	16.	8.7020- 2	5.1789- 2
A=82	0.1400	8.	1.5152- 1	8.3767- 2
A=83	0.2024	1.4	2.0152- 1	1.6955- 2
A=84	0.3537	2.	3.8324- 1	3.3728- 2
Kr-85	0.08345	2.8	7.9500- 2	5.6703- 3
A=85	0.4086	1.4	3.6487- 1	2.6557- 2
A=86	0.5984	2.	6.2398- 1	5.0673- 2
A=87	0.7604	2.	7.5125- 1	4.3364- 2
A=88	0.9958	1.4	9.9836- 1	7.0942- 2
A=89	1.2504	2.8	1.1933+ 0	6.8099- 2
A=90	1.5447	1.4	1.4911+ 0	8.8966- 2
A=91	1.8867	1.4	1.7149+ 0	1.2356- 1
A=92	2.3142	1.4	2.2986+ 0	1.7168- 1
A=93	3.0019	1.4	3.0593+ 0	2.1565- 1
A=94	3.4201	1.4	3.3474+ 0	2.6785- 1
Nb-95m	0.03948	2.8	5.9929- 6	3.6114- 6
A=95	3.9478	1.4	3.9514+ 0	1.4060- 1
A=96	4.4236	1.4	4.4239+ 0	3.4865- 1
A=97	4.8325	1.4	4.8437+ 0	1.6851- 1
A=98	5.0818	2.	5.1714+ 0	3.6776- 1
A=99	5.9990	2.	5.6603+ 0	2.1853- 1
A=100	6.3220	2.	5.9293+ 0	6.4645- 1
A=101	6.2876	2.	5.9969+ 0	4.8127- 1
A=102	6.7213	2.	6.3908+ 0	5.1013- 1
A=103	6.8410	2.8	7.1151+ 0	2.3859- 1
A=104	7.2531	2.	6.9131+ 0	5.4353- 1
A=105	5.0897	2.8	6.0538+ 0	4.7262- 1
A=106	6.1468	2.	6.2168+ 0	4.8874- 1
A=107	5.0137	8.	5.1663+ 0	6.2036- 1
A=108	3.8660	8.	4.0848+ 0	4.9215- 1
A=109	2.6207	4.	2.7318+ 0	4.6293- 2
A=110	1.3598	8.	1.2742+ 0	3.4084- 1
A=111	0.5886	2.8	5.0913- 1	1.4956- 1
A=112	0.2202	2.8	2.0685- 1	3.8989- 2
A=113	0.1531	4.	1.6477- 1	1.0338- 1
A=114	0.07654	23.	1.2290- 1	7.8432- 2
A=115	0.03894	11.	9.2324- 2	6.0036- 2
A=116	0.03087	32.	6.9978- 2	4.6205- 2
A=117	0.02459	16.	5.3164- 2	3.5524- 2
A=118	0.02573	32.	4.1742- 2	2.8092- 2
A=119	0.02573	32.	3.8158- 2	2.5763- 2
A=120	0.02551	23.	5.0047- 2	3.3261- 2
A=121	0.02572	32.	9.2421- 2	3.0891- 2
A=122	0.02572	32.	1.0595- 1	1.5259- 2
A=123	0.02652	32.	1.3729- 1	4.6180- 2
A=124	0.03189	32.	1.8277- 1	6.1761- 2
A=125	0.04707	8.	2.6125- 1	8.8605- 2
A=126	0.08179	23.	3.7071- 1	1.2679- 1
A=127	0.2523	11.	5.8113- 1	3.3562- 2
A=128	0.3775	23.	7.9153- 1	2.8209- 1

Table C-6: Pu-241 thermal fission chain yields and selected cumulative yields

FP	US file	error(%)	UK file	error
A=129	0.8162	23.	1.2169+ 0	4.3364- 1
A=130	1.8147	11.	1.8213+ 0	6.1803- 1
Xe-131m	0.04338	4.	3.3233- 2	1.2398- 3
A=131	3.0985	1.4	3.0600+ 0	1.1416- 1
Te-132	4.5010	2.8	4.0549+ 0	1.1058- 1
A=132	4.5617	1.4	4.0741+ 0	1.1050- 1
Xe-133m	0.1890	4.	1.8883- 1	1.0734- 2
A=133	6.7302	0.7	6.5245+ 0	3.7032- 1
A=134	7.9100	1.4	7.5698+ 0	7.1647- 1
I-135	6.9479	2.8	7.0414+ 0	3.8898- 1
Xe-135m	1.1801	16.	1.2391+ 0	9.5623- 2
Xe-135	7.1712	2.	7.2497+ 0	3.7593- 1
A=135	7.1717	1.0	7.2509+ 0	3.7599- 1
A=136	7.0862	1.4	6.9502+ 0	9.2766- 1
A=137	6.6543	0.7	6.0706+ 0	1.2578- 1
A=138	6.6066	1.0	6.3769+ 0	4.6857- 1
A=139	6.2225	2.	5.6561+ 0	1.1520+ 0
A=140	5.7644	1.4	5.7459+ 0	1.8479- 1
A=141	4.9034	1.4	4.8718+ 0	1.7299- 1
A=142	4.7469	1.0	5.2317+ 0	1.4998- 1
A=143	4.5788	0.7	4.3576+ 0	1.6224- 1
A=144	4.2278	0.7	4.0616+ 0	1.5802- 1
A=145	3.2634	1.0	3.0967+ 0	1.6861- 1
A=146	2.7670	0.7	2.6395+ 0	1.3020- 1
A=147	2.2840	1.4	2.2710+ 0	1.2781- 1
A=148	1.9331	0.7	1.8635+ 0	9.2143- 2
A=149	1.4732	1.4	1.4510+ 0	9.1824- 2
A=150	1.2096	1.0	1.1504+ 0	6.8769- 2
A=151	0.9111	1.4	8.4045- 1	1.0834- 1
A=152	0.7172	1.4	7.9962- 1	6.8621- 2
A=153	0.5402	4.	4.9445- 1	1.2954- 1
A=154	0.3789	2.	4.0133- 1	6.7184- 2
A=155	0.2410	8.	3.8165- 1	1.4862- 1
A=156	0.1720	2.8	3.0924- 1	1.1749- 1
A=157	0.1353	4.	2.7407- 1	2.3853- 2
A=158	0.09183	23.	1.8882- 1	6.8985- 2
A=159	0.04800	4.	1.3369- 1	4.7854- 2
A=160	0.02041	23.	1.0311- 1	3.6487- 2
A=161	0.00846	4.	7.3507- 2	2.5727- 2
A=162	0.00183	16.	5.1603- 2	1.0143- 2
A=163	0.00066	16.	2.6243- 2	1.8730- 2
A=164	0.00021	16.	1.3897- 2	9.6876- 3
A=165	6.6200- 5	16.	7.0689- 3	4.8636- 3

C-7: Selected independent fission product yields

Description of table entries:

The format is the same as for tables C-1 to C-6, except:

type: i independent yield of fission product listed

c "cumulative" yield of fission product listed when shielded from beta decay by a stable or long lived precursor; the yield value given is the sum of the independent yields of the nuclide listed and it's short lived precursors which are also shielded (e.g.: the "cumulative" yield of Kr-82 is the sum of independent yields of Br-82m, Br-82 and Kr-82, all shielded by stable Se-82)

Only those yield values are listed that exceed 0.01 % of the corresponding chain yields in one of the files. According to this criterion, the independent yields of the following fission products, although requested by safeguards experts, are insignificant and not included in any of the tables:

Mo-92, Mo-94, Xe-128, Xe-129, Nd-142, Pm-148m, Pm-148, Sm-148, Eu-151, Eu-152.

The table below summarises the yield values (and types) which are significant and included in Tables C-7.1 to C-7.6.

FP	Th-232	U-233	U-235	U-238	Pu-239	Pu-241
Kr-82	c	c	c		c	c
Kr-85	i	i	i	i	i	i
Nb-95m					i	
Nb-95					i	
Mo-96	c	c	c		c	c
Xe-130		c	c		c	
Xe-133m		i	i	i	i	i
Xe-133		i	i	i	i	i
Cs-134		i			i	
Xe-135m	i	i	i	i	i	i
Xe-135	i	i	i	i	i	i
Nd-144		c			c	
Sm-150		c	c		c	
Eu-154		i			i	

FP	type	US file	error(%)	UK file	error
Kr-82	c	0.000100	45.	2.1820- 4	6.5079- 5
Kr-85	i	0.00061	64.	4.1648- 3	1.3840- 3
Mo-96	c	0.00018	45.	1.6302- 5	6.1480- 6
Xe-135m	i	0.00824	64.	1.9861- 2	7.6668- 3
Xe-135	i	0.00280	64.	7.0986- 3	2.7402- 3

Table C-7.2: U-233 thermal fission

FP	type	US file	error(%)	UK file	error
Kr-82	c	0.00084	16.	5.4364- 3	1.5061- 3
Kr-85	i	0.1007	23.	5.8668- 2	2.1605- 2
Mo-96	c	0.00557	64.	5.7508- 3	2.0968- 3
Xe-130	c	0.00258	2.8	4.2361- 3	1.6746- 3
Xe-133m	i	0.0426	64.	3.6740- 2	1.4031- 2
Xe-133	i	0.0160	6.	1.8674- 2	7.1319- 3
Cs-134	i	0.00039	64.	1.7696- 3	6.5262- 4
Xe-135m	i	0.818	64.	8.6765- 1	2.3637- 1
Xe-135	i	0.4657	11.	6.0045- 1	1.6358- 1
Nd-144	c	0.00040	64.	1.5305- 3	5.2393- 4
Sm-150	c	0.00055	64.	1.5940- 3	5.9166- 4
Eu-154	i	0.0000030	64.	1.1652- 5	4.4849- 6

Table C-7.3: U-235 thermal fission

FP	type	US file	error(%)	UK file	error
Kr-82	c	0.000056	11.	3.4324- 4	8.4800- 5
Kr-85	i	0.0281	16.	5.5940- 3	2.0703- 3
Mo-96	c	0.00055	64.	4.9985- 4	1.8084- 4
Xe-130	c	0.00023	16.	9.0564-10	3.2724-10
Xe-133m	i	0.00192	64.	5.4056- 4	1.9448- 4
Xe-133	i	0.000663	6.	1.5465- 3	5.5642- 4
Xe-135m	i	0.1826	6.	1.7458- 1	6.0751- 2
Xe-135	i	0.0798	6.	8.7551- 2	3.0467- 2
Sm-150	c	0.000030	64.	7.6019- 5	2.7848- 5

Table C-7.4: U-238 fast fission

FP	type	US file	error(%)	UK file	error
Kr-85	i	0.00017	64.	6.5407- 4	2.4367- 4
Xe-133m	i	0.00122	64.	3.2078- 5	1.1258- 5
Xe-133	i	0.00057	64.	5.3525- 6	1.8786- 6
Xe-135m	i	0.0158	64.	1.2058- 2	4.4736- 3
Xe-135	i	0.0112	64.	4.3094- 3	1.5989- 3

Table C-7.5: Pu-239 thermal fission

FP	type	US file	error(%)	UK file	error
Kr-82	c	0.001027	2.8	1.7142- 3	4.7322- 4
Kr-85	i	0.0130	64.	1.0604- 2	3.7819- 3
Nb-95m	i	0.00013	64.	5.3737- 5	1.9661- 5
Nb-95	i	0.00056	64.	2.3240- 4	8.5029- 5
Mo-96	c	0.00361	64.	3.7460- 3	1.3320- 3
Xe-130	c	0.004105	2.0	1.1217- 3	3.9350- 4
Xe-133m	i	0.0364	64.	1.6478- 2	5.9917- 3
Xe-133	i	0.01023	8.	4.5937- 3	1.6703- 3
Cs-134	i	0.000494	64.	5.6422- 4	2.0396- 4
Xe-135m	i	0.766	64.	6.1576- 1	1.9382- 1
Xe-135	i	0.4452	11.	4.1913- 1	1.3193- 1
Nd-144	c	0.00029	64.	4.2206- 4	1.4210- 4
Sm-150	c	0.00115	64.	1.6415- 3	5.7760- 4
Eu-154	i	0.000021	64.	2.8031- 5	1.0277- 5

Table C-7.6: Pu-241 thermal fission

FP	type	US file	error(%)	UK file	error
Kr-82	c	0.000257	64.	2.8486- 4	1.6153- 4
Kr-85	i	0.00228	64.	2.2070- 3	1.3704- 3
Mo-96	c	0.0124	45.	5.6065- 4	3.4735- 4
Xe-133m	i	0.00056	64.	9.6265- 4	5.9235- 4
Xe-133	i	0.000227	64.	3.9875- 4	2.4537- 4
Xe-135m	i	0.159	64.	1.4771- 1	9.1944- 2
Xe-135	i	0.0645	8.	6.1184- 2	3.8086- 2

Appendix A:

Information requested by safeguards experts for inclusion in this handbook

An IAEA working group consisting of staff of the Nuclear Data Section (NDS) and the Department of Safeguards was formed to develop guidelines for the preparation of a Handbook of Nuclear Data for Safeguards, which NDS offered to prepare with the aid of nuclear data files and evaluations available through its international data centres network and co-operating experts' groups. The working group drew up a first list of data to be included in the handbook and combined it with a questionnaire on the scope of the handbook and some specific questions on certain data types.

This questionnaire was sent to many safeguards experts all over the world, asking them for their replies, comments and additional requirements. Many replies were received and it turned out that, in addition to nuclear data, a number of non-nuclear and macroscopic data as well as graphical presentations were requested. Details on the replies received are given in [1-3]. The following **Tables App-1 to App-4** summarize the data requested.

For the sake of completeness of the handbook, NDS agreed to include also non-nuclear and macroscopic data. However, the availability of such data and the detailed form of their presentation in the handbook remain still to be established. The same questions are also still open for some types of microscopic nuclear data, especially when energy spectra of gammas or particles are requested as a function of time or of incident particle or gamma-ray energy. Details on open questions or problems are given in **Appendix C.**

The following decisions were made: The handbook should contain only non bulky sets of microscopic nuclear data that are readily available and can be tabulated. Reference should be given to more complete data libraries and their availability. Prior to the publication of the final edition, a draft version (this preliminary issue) should be sent to data and safeguards experts for review of the data and to answer open questions collected in **Appendix C.**

Finally, safeguards users have not yet defined and calculated their data accuracy requirements. This is not so relevant for the production of the handbook in it's present form, but will be important if the accuracy of the data is considered to be not sufficient. An appropriate way for the calculation and justification of accuracy requirements are sensitivity studies as outlined in Appendix C of reference [1] and in Appendix B of reference [3].

References:

[1] M. Lammer: "Nuclear Data for Safeguards: Availability, Status and Requirements", paper presented at the 4th AGM on Evaluation of the Quality of Safeguards Non-Destructive Assay Measurement Data, Vienna, 19-23 November 1984; distributed as internal paper INDC/P(84)-52.

[2] M. Lammer, paper INDC/P(86)-48 for the 15th INDC meeting (Vienna, 16-20 June 1986): summary of replies received to the questionnaire.

[3] M. Lammer: "Nuclear Data for Safeguards: Status and Information Needs", paper presented at the IAEA Consultants' Meeting on Evaluation of the Quality of Safeguards Neutron Coincidence Measurements, Vienna, 24-28 November 1986; published as report INDC(NDS)-187 (1986).

Abbreviations used in the tables

dn	delayed neutron data (including: time dependent energy spectra)
d_γ	delayed gamma data (including: time dependent energy spectra)
E(n)	energy spectrum of prompt neutrons
fast	fission neutron spectrum (specifically Cf-252)
M(n)	multiplicity distribution of prompt neutrons
$M(\gamma)$	multiplicity distribution of prompt gammas
T1/2	total half-life
T_{sf}	partial half-life for spontaneous fission
T_α	partial half-life for α-decay
X-rays	(in table A.1) energies and intensities of X-rays
$Y(\gamma)$	prompt γ-ray yields and correlations in fission
α-rays	α particle energies and intensities
γ-rays	(in table A.1) energies and intensities of γ-rays
$\bar{\nu}_p$	average number of prompt neutrons emitted per fission
$\hat{\sigma}_c$	thermal reactor spectrum averaged neutron capture cross-section
$\hat{\sigma}_f$	thermal reactor spectrum averaged neutron fission cross-section
$\sigma_c(E)$	capture cross section } { as function of incident neutron energy
$\sigma_f(E)$	fission cross section } { (point or group data)

Table App-1: Actinides

nuclide	T1/2 1)	T_α	T_{sf}	X-rays 1)	γ-rays 1)	$\hat{\sigma}_f$ 2)	$\hat{\sigma}_c$ 2)	$\sigma_f(E)$ 3)	$\sigma_c(E)$ 3)	$\bar{\nu}_p$	α decay	M(n)	E(n) 4)	$M(\gamma)$ 4)	$Y(\gamma)$ 4)	dn	d_γ 4)
Th-232	+	+	+	+		fast	+	+	+	+	+	+	+	+	+	+	+
Th-234	+			+	+												
Pa-231	+			+	+												
Pa-233	+			+	+												
Pa-234	+			+	+												
U-232	+	+		+	+						+						
U-233	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
U-234	+	+	+	+	+		+				+						
U-235	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
U-236	+	+	+	+	+		+				+						
U-237	+			+	+	+	+										
U-238	+	+	+	+	+	fast	+	+	+	+	+	+	+	+	+	+	+
Np-237	+	+	+		+	+	+										
Np-239	+				+		+										
Pu-236	+	+									+						
Pu-238	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Pu-239	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Pu-240	+	+	+	+	+	fast	+	+	+	+	+	+	+	+	+	+	+
Pu-241	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Pu-242	+	+	+	+	+	fast	+	+	+	+	+	+	+	+	+	+	+
Am-241	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Am-242	+		+			+	+	+	+								
Am-242m	+		+			+	+	+	+								
Am-243	+	+	+	+		+	+										
Cm-242	+	+	+	+		+	+			+	+	+	+	+	+		
Cm-243	+	+	+	+		+	+			+	+	+	+	+	+		
Cm-244	+	+	+	+		+	+			+	+	+	+	+	+		
Cf-252	+	+	+	+						+	+	+	+	+	+		

1) Includes data for daughter products of α-decay chains

2) Represented by few group cross sections, e.g.: σ(2200), Maxwellian average, resonance integral, fission spectrum average

3) Not included in printed handbook; will be available on computer file.

4) Not included in first version of the handbook.

Table App-2: Fission products

Data to be included are:

- complete sets of chain yields and independent or cumulative yields of the fission products below from thermal neutron fission of U-233,235, Pu-239,241, and from fast neutron fission of Th-232 and U-238;
- decay and cross section data as indicated in the table below;
- branching fractions to isomeric states in decay and neutron capture.

nuclide	$T_{1/2}$	γ-rays	$\hat{\sigma}_c$ [2]	nuclide	$T_{1/2}$	γ-rays	$\hat{\sigma}_c$ [2]
Kr [1]			+	Ba-140	+	+	
Kr-85	+		+	La-140	+	+	
Zr [1]			+	Ce-141	+	+	
Zr-95	+	+		Ce-144	+	+	+
Nb-95m	+	+		Pr-141			+
Nb-95	+	+		Pr-144	+	+	
Mo [1]			+	Nd [1]			+
Ru [1]			+	Nd-147	+	+	+
Ru-103	+	+		Pm-147	+		+
Ru-106	+	+	+	Pm-148m	+		+
Rh-106		+		Pm-148	+		+
Sb-125	+	+		Pm-149	+		+
I-131	+	+		Pm-151	+		+
Xe [1]			+	Sm [1]			+
Xe-133	+		+	Sm-151	+		+
Xe-135	+		+	Sm-153	+		+
Cs-133			+	Eu-153			+
Cs-134	+	+	+	Eu-154	+	+	+
Cs-137	+	+	+	Eu-155	+	+	+

[1]) Stable isotopes for mass spectrometric measurements

[2]) Reactor spectrum average cross section, represented by e.g. σ(2200) or Maxwellian average σ and resonance integral

Nuclides with A=147-153 are included for calculating the formation of Eu-154.

γ-rays of Ru-103, Sb-125, I-131, Ce-141 and Eu-155 may interfere with those of other fission products (depending on cooling time).

Table App-3: Reactions with light nuclei:

a) (n,x) reaction cross-sections with x = charged particles relevant for neutron counters for the following target nuclei:

   H, D, He-3,4, Li-6, Be-9, B-10, Cd-113

b) (α,n) cross-sections vs. E_α (reaction threshold below $E_\alpha \approx 7$ MeV) for:

   Li, Li-6,7, Be-9, B, B-10,11, C, C-13, N, O, O-17,18, F-19, Ne-23, Mg, Al-27, Si, P-31, S, Cl, K, Ca.

c) (γ,n) cross-sections for Be-9, D_2O and other materials still to be specified.

Table App-4: Non-neutron and macroscopic data, additional presentations

a) γ-ray attenuation coefficients as function of γ-ray energy for different nuclear fuel, construction and shielding materials (still to be defined in detail);

b) Spontaneous fission rates and neutron yields per gram of isotope.

c) (α,n) yields per gram of compound for oxides, carbides, fluorides and alloys.

d) Thick target (α,n) yields per α vs. α-energy for C, O, F and Al.

e) Same as above, but with α-spectra from the α-decay of the isotopes of U, Pu etc.

f) Data for isotopic neutron sources (yield/g, yield/Ci, energy spectra, average energy, etc).

g) Photoabsorption cross sections, fluorescent yields for fissile and fertile materials.

h) "Twin-target yields" for UF_6.

i) Specific heat generation rates (watts/gram) for the Pu and Am isotopes.

j) Physical and chemical data for typical nuclear materials (density, stoichiometric data, solubility etc. of U, Pu, UO_2, PuO_2 etc.)

k) Efficiency for typical γ-detectors.

l) Graphical presentations of gamma spectra from typical fresh and spent fuel.

m) (possibly) list of gamma rays sorted by increasing energy.

n) natural isotopic abundance of U and fission products (Table App-2).

Appendix B: Planned structure of the final issue of this handbook

Part I: Basic microscopic nuclear data

- Section A: Actinide nuclear data
- Section B: Fission product nuclear data
- Section C: Fission yield data

Part II: Supplementary nuclear data

(proposals for possible inclusion; some tables could be included in Part I; see also Appendix C: Open questions and problems)

- Thermal g- and s- factors of actinides
- Actinide group cross sections
- Energy dependent prompt neutron data
- Energy dependent prompt gamma-ray data
- Thermal g- and s- factors of fission products
- Delayed neutron precursor data
- Gamma-rays sorted by energy

Part III: Reactions with light nuclei

Part IV: Macroscopic and non-nuclear data

Part V: Graphs

(this part could include graphs supplementing tables in other parts of the handbook; see also Appendix C: Open questions and problems)

Appendix C: Open questions and problems

Most of the questions refer to the replies received from safeguards experts which are summarised in Appendix A (data in Tables App-1 to App-4) and to which the reader should refer. Although in some cases we have already made a (preliminary) decision and included the data (e.g. the tabulation of neutron reaction cross sections), we still ask experts to reply to the questions.

1. Data for fast reactors

So far only needs for the safeguarding of thermal reactors have been expressed. Question: Can requirements for fast reactors be defined already at present? If yes: what are they?

2. Equilibrium decay data

Most of the actinides present in nuclear fuel are produced during irradiation in a reactor. A reactor fuel lifetime is not sufficient to reach secular equilibrium with daughter products. We assume that also the naturally occurring Th-232 and Uranium isotopes are separated from (at least a part of) their daughters during the fuel fabrication process. In this event, equilibrium decay data for actinides are not needed, but a reply by **safeguards experts** whether this conclusion is correct would be useful.

3. Representation of neutron reaction cross sections

The replies to the questionnaire on nuclear data needs for safeguards reflected diverting opinions on the question whether one-group, few-group or energy-dependent cross section data should be included.

3.a The options for spectrum averaged cross sections for thermal reactors are:

- one-group or few-group data
- sets of one-group data for different typical reactor spectra.

Questions to **safeguards** and **reactor physics experts:**

Are one-group data, calculated from σ_0 (with g-factors) or σ and I sufficient? If so, for which nuclides (fission products, actinides?)

Few-group data: which group structure?

Are fission neutron spectrum averaged cross section data relevant?

Which are "typical" reactor spectra? By which parameters can they be described?

Who could be in a position to calculate the sets of one-group data?

Questions to **data experts:**

Availability of evaluated sets of Westcott g-factors for different Maxwellian temperatures.

Availability of evaluated fast reactor or fission neutron spectrum avarage cross sections.

3.b For representing $\sigma(E)$ data the following options exist:

- point cross section data
- multigroup cross section data
- resonance parameters.

We do not consider to tabulate $\sigma(E)$ data in the handbook, since such data can only be used in large computer codes anyway. The 4 Nuclear Data Centres (see Page 5) have such files for distribution upon request. On the other hand, we could reproduce plots of selected cross section curves for illustration, if time permits. **Questions:**

Would this be desirable?

If yes, for which nuclides?

4. Prompt fission neutron multiplicity distributions

Designated by M(n) in Table App-1 and by P(ν) in Table A-7. Table A-7 contains only a limited set of evaluated P(ν) data. **Question to data experts:** are there any other sources of these data?

5. Energy dependence of prompt fission neutron data

$\bar{\nu}$ and P(ν) are requested as a function of neutron energy.

Questions to safeguards experts:

Are these data really needed? If yes:

In which way should they be represented?
- formulae describing the energy dependence (would be the most convenient way of representation);
- point-wise data (would not be tabulated but, if available, be distributed as data file upon request);
- as graphs.

Questions to data experts:

Which formulae describing the energy dependences do exist (references)?

Are point data available (references)?

6. Spectra of prompt fission neutrons

Spectra are hard to represent in numerical form. Any choice depends on the way these data are used (e.g. in calculations). Graphs serve only for illustration. Again, incident neutron energy dependent numerical data will not be included in the handbook, but can be distributed as data files, if they exist. **Questions:**

- How is the spectrum information used?
- In which form should it be represented (graphs, tables, formulae)?
- Are evaluations of such data available? (**data experts**)

7. Delayed neutron data

Here the problems are: the numerical representation of spectra and a way of describing the time and, possibly, incident neutron energy dependence of the data. **Data experts** are asked to propose a solution.

Again, the **question** to **safeguards experts** is, how these multi-dimensional data (energy-time dependence) are used.

8. Prompt and delayed γ-ray data.

The problems and questions are similar to those for prompt and delayed neutrons.

9. Reactions with light nuclei (Table App-3)

Evaluations of these data do exist in handbooks and files, but we have no information on any specific sources. Recommendations by **data experts** on the best available data are needed.

10. γ-ray attenuation coefficients

We have no information on the existence of experimental results or evaluations of them. However, calculated values for pure elements exist and will be included later since there was strong support in the replies to the questionnaire.

Three problems still remain:

- existence and availability of experimental data;
- definition of typical composite absorbers, for which attenuation coefficients should be measured;
- stimulation of such measurements.

Here the assistance of **all interested users and experts** is needed to find solutions. Also, a recommendation by **data experts** on the best presently available data (evaluated or calculated) is needed.

11. Other non-neutron and macroscopic data (Table App-4, items b-n)

Information on these items does exist and can hopefully be made available to NDS (e.g. neutron source properties).

However, some **more information** on the needs has to be given on the following items of Table App-4:

- availability and/or best data: all items except m;
- representation: all items except i,j,m,n;
- further specifications (nuclides, source, meaning, etc.) for the following items: b,e,i ... which isotopes?
  c ..... exact specifications of compounds
  e,j ..... specify "etc"
  f ..... which neutron sources?
  g ..... which materials exactly?
  h ..... definition
  k,l ..... specify "typical"