

Activation Product Decay Data: UKPAD6.10



Authors **A L Nichols, R J Perry**

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Contact Details Technical Services
Serco
Winfrith Technology Centre
Dorchester
Dorset
DT2 8DH
Telephone 01305 851200
Facsimile 01305 851105

ray.perry@serco.com

www.serco.com/technicalservices

	Name	Signature	Date
Author(s)	R J Perry		11/03/10
Reviewed by	C J Dean		11/3/2010
Approved by	B D Turland		16/3/2010

Executive Summary

The latest version of the UK Activation Product Decay Data Library (UKPADD6.10) is described in this report, as assembled for general use in March 2010.

The decay data of various radionuclides have been evaluated on the basis of a series of well-defined specifications. These radionuclides are predominantly activation products of immediate relevance to the European Fusion Programme and to the operation, decommissioning and disposal of fission-based reactor facilities, along with various standards that are commonly used to calibrate gamma-ray spectrometers. Recommended data include half-lives, branching fractions, alpha, beta and gamma-ray energies and emission probabilities, total decay energies, mean alpha, beta and gamma energies, internal conversion coefficients, and all associated uncertainties. Computer based files have been generated, including lists of the references used to produce the proposed decay schemes and comments that identify any observed inadequacies. The evaluated data have been processed through the COGEND code to yield complete and verified evaluated decay data files in ENDF-6 format. Verification has included processing with the codes STANEF, CHECKR and FIZCON, and confirming the overall consistency of the energy release by summing the emission by quanta and comparing with the total emission by decay mode.

All evaluations for UKPADD6.10 were carried out by Dr A L Nichols¹ whilst COGEND processing and verification were performed by SERCO.

Data for 11 nuclides have been newly evaluated or re-evaluated for UKPADD6.10 during the course of 2009/10. These evaluations were sponsored by the Culham Centre for Fusion Energy (ex-UK Atomic Energy Authority, Fusion, Culham) in support of the European Fusion Programme.

Historically, the evaluation work and assembly of the files has also been funded by BNFL plc, Sellafield, and the UK Department of Trade and Industry and Euratom (UK Atomic Energy Authority/Euratom Fusion Association).

¹ Consultant and Visiting Researcher, Faculty of Engineering and Physical Sciences, University of Surrey, Guildford, Surrey GU2 7XH

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I Introduction

The UK Activation Product Decay Data Library was first released in 1977 as UKPADD1 (1). Improvements in the available decay data through various spectroscopic measurements led to a comprehensive evaluation of the decay data for 236 radionuclides. These improved data were released as UKPADD2 in 1993 (2). A significant fraction of the UKPADD2 decay-data library was incorporated into version 2 of the Joint Evaluated File JEF-2.2 (3). Subsequent reviews of JEF-2.2 data highlighted the need for further developments in the recommended data for fission and fusion applications. Hence, UKPADD6 was developed and released in 1999 (4).

A continuing programme of decay data evaluation has been underway with the aim of producing and maintaining the recommended libraries of relevant nuclear data. This long-term initiative has led to significant improvements and extensions of the UKPADD library. Since the beginning of 1999, the evaluation programme has been sponsored primarily by the UK Atomic Energy Authority (UKAEA) in support of the European Fusion Programme. Specific nuclides requiring improved decay data have been identified by R A Forrest (formerly of UKAEA Fusion, Culham) and A L Nichols (5). Over the period from 1999 to early 2009, a further 174 radionuclides were newly evaluated or re-evaluated, and details of these evaluations were published in a series of UK Nuclear Science Forum papers (6, 7, 8, 9, 10, 11, 12, 13, 14). All evaluations have been carried out by A L Nichols. UKPADD libraries are made available to the international community via the NEA Data Bank, and new evaluations are also submitted for possible inclusion in the JEFF-3 decay data library.

The most recent version of the UKPADD library (UKPADD6.10), released in March 2010, is described in this paper. This latest library contains evaluations for 589 radionuclides.

Data for 11 nuclides have been newly evaluated or re-evaluated in preparation for the release of UKPADD6.10. These evaluations were carried out by Dr A L Nichols and sponsored by the Culham Centre for Fusion Energy (ex-UK Atomic Energy Authority, Fusion, Culham) in support of the European Fusion Programme. The evaluation procedure and contents of UKPADD6.10 are summarized in the following sections.

2 Decay Data

UKPADD6.10 contains recommended data for the following parameters (see also Section 4):

- (i) half-lives,
- (ii) total decay energies (Q-values),
- (iii) branching fractions,
- (iv) alpha-particle energies and emission probabilities,
- (v) beta-particle energies, emission probabilities and transition types (also equivalent data for β^+ /electron-capture (EC) transitions),
- (vi) gamma-ray energies, emission probabilities and internal-conversion coefficients,
- (vii) neutron energies and emission probabilities,
- (viii) spontaneous fission data including prompt gamma-ray spectra.

The spin and parity of the decaying nuclide are defined, and uncertainties have been assigned to all evaluated data. Other data in UKPADD6.10 (mean energies, discrete electrons and mean X-rays) were derived from the above data by using the processing code COGEND (15). The component contributions to the average energies (light particle, electromagnetic and heavy particle) are derived from the evaluated input data by COGEND. The code also contains data libraries of fluorescence yields, Auger-electron energies, mean x-ray energies and electron-wave-function ratios from which capture ratios can be calculated.

The library has been generated in ENDF-6 format (16). There is a general information section for each nuclide which contains:

- (i) name of the evaluator and date of the evaluation (month and year),
- (ii) list of references used to construct the recommended data set,
- (iii) detailed comments associated with the evaluation,
- (iv) consistency check of the evaluated data.

The recommended decay data are contained within the main data section. Every effort has been made to produce consistent and comprehensive data sets. When necessary, theoretical internal conversion coefficients have been used in conjunction with the evaluated gamma-ray data. X-ray data were derived from the energy and emission probability data held within COGEND (17, 18).

All of the energy data are in eV, and the absolute emission probabilities are expressed as fractions of the decay (calculated from the spectral normalisation factor and relative emission probabilities). The data in UKPADD6.10 are listed as described in Reference 16, and summaries of the contents of the updated library are given in Tables 1 and 2.

The consistency of the recommended data has been determined by calculating the percentage deviation between the effective Q-value and the calculated Q-value:

$$\text{effective Q-value} = \sum_{i=1}^{\text{all BF}} Q_i \cdot \text{BF}_i \quad (1)$$

where Q_i and BF_i are the Q-value and branching fraction of the i^{th} decay mode (i.e. weighted sum of the evaluated Q-values of the radionuclide),

$$\text{calculated Q-value} = \sum_i^{\text{all } \alpha} E_{\alpha_i} P_{\alpha_i} + \sum_j^{\text{all } \beta} E_{\beta_j} P_{\beta_j} + \sum_k^{\text{all } \gamma} E_{\gamma_k} P_{\gamma_k} + \sum_l^{\text{all x-rays}} E_{x_l} P_{x_l} + \text{etc.} \quad (2)$$

where $E_{\alpha_i}, E_{\beta_j}, E_{\gamma_k}, E_{x_l}, \text{etc.}$, and $P_{\alpha_i}, P_{\beta_j}, P_{\gamma_k}, P_{x_l}, \text{etc.}$

are the energies and emission probabilities of the i^{th} alpha particle, j^{th} beta particle, k^{th} gamma ray, l^{th} x ray, etc. of the individual decay process.

The percentage deviations of the data in the UKPADD6.10 library are given in Table 1. Percentage deviations above 5% would be regarded as high and imply a poorly defined decay scheme; a value of less than 5% indicates the construction of a reasonably consistent decay scheme.

3 Evaluation Procedure

3.1 Overview

An initial decay scheme was constructed for each radionuclide from a suitable combination of the various data sources. The evaluation procedure was as follows:

- (i) assess the status of the existing data,
- (ii) identify data discrepancies,
- (iii) evaluate and recommend decay data.

The emission probabilities have been expressed as the absolute probability of the transition (α , β , conversion electron, X-ray or γ ray) per decay. All available measurements were generally taken into account during an evaluation, including experimental data from laboratory reports and written private communications. Comprehensive statements of the precise evaluation procedure were prepared after each assessment, as well as details of any changes made to the reported data. Under specific circumstances, the evaluations involved the determination of a weighted mean for each parameter. No individual measurement was allowed to contribute more than 50% to the sum of weights when more than one value of the same parameter was reported, and the uncertainty of the datum was increased if necessary. If the set of accepted experimental data proved to be inconsistent, one of several possibilities was adopted:

- (i) recommend the unweighted mean,
- (ii) reject some measured values on the basis of objective or subjective judgements (e.g. inappropriate calibration procedure or ill-defined measurement techniques employed by the metrologist),
- (iii) change the weights.

An appropriate method of changing weights was preferred rather than outright rejection of data. Any serious problems encountered during an evaluation are described in the Comments Section associated with each nuclide in the library. If the resulting decay scheme has any outstanding problems, a statement was made to the effect that better measurements are required.

3.2 Procedures and Consistency Checks

The following procedures and consistency checks form the basis of the evaluation strategy used to update and improve the UKPADD library.

- (i) Every effort was made to ensure that there was a reasonable emission-probability balance between the population and de-population of all excited levels in the decay scheme.
- (ii) All decay modes of each radioactive nuclide were completely specified in terms of both the branching ratios and the Q-values. The Q-value, defined as the energy difference between the initial and final states, takes account of the energies of any metastable states which are involved in the decay.
- (iii) The sum of all α , β^- , β^+ /electron-capture and isomeric gamma-emission probabilities were consistent with the corresponding branching fractions.

- (iv) Gamma-ray emission probabilities must be the photon probabilities per disintegration and were listed as percentages in the data files. This means that relative photon probabilities were normalised in a consistent manner.
- (v) Internal-conversion coefficients for gamma-ray transitions were consistent with both the photon and total transition probabilities, i.e. (photon + conversion electron) emission probabilities = total transition probability.
- (vi) When the internal conversion of a gamma-ray transition was significant, theoretical internal-conversion coefficients were adopted if experimental data were unavailable. This procedure ensured that the transition energy was appropriately shared between the electromagnetic and electron components.
- (vii) The nature of the beta transition was taken into account in the calculation of mean beta energies from the evaluated end points. This information was inferred from the spin and parity assignments proposed for the levels involved.
- (viii) Energies and emission probabilities of conversion electrons, Auger electrons, X rays and annihilation radiation were derived in a consistent manner.
- (ix) Uncertainties were estimated for all of the parameters incorporated into UKPADD6.
- (x) Each evaluation was fully documented. The evaluated ENDF-6 files include a descriptive section that includes comments on inconsistencies and any assumptions made by the evaluator to deal with such problems.

3.3 Production Procedure

- (i) The evaluation is undertaken and the initial input data are prepared by the evaluator.
- (ii) The evaluation is converted into a form suitable for input to COGEND.
- (iii) The COGEND input data are checked against the original evaluation.
- (iv) The COGEND code is run and the input file and ENDF-6 output file are sent to the evaluator for checking.
- (v) Any corrections and improvements are defined by the evaluator, and COGEND is rerun until he/she is satisfied with the results.

COGEND generates an ENDF-6 format file. The computer codes STANEF (19), CHECKR (19) and FIZCON (20) are applied to the file. Any diagnostic reports from these codes are reported to the evaluator who directs any further changes necessary.

4 Activation Product Decay Data Library, UKPADD6.10

4.1 Changes Since the Last Release

4.1.1 New Evaluations

The European Fusion Programme requires improved decay data files for specific nuclides. Inadequate decay data files have been identified by R A Forrest (formerly of UKAEA Fusion, Culham), on the basis of their relative activities and gamma-dose rates as a function of time (21). Over 750 radionuclides were assessed, and a set of 338 nuclides were recommended for new measurements and re-evaluation with various degrees of priority.

Eleven nuclides were evaluated or re-evaluated during 2009/10 (Table 3), and decay data prepared in ENDF-6 format. One aim was to improve the quality of these particular decay data files, and so enhance the credibility of the UKPADD and JEFF-3 databases for nuclear applications.

The resulting quality of the recommended decay data was based on the subjective judgement of the evaluator and a well-defined consistency check of the proposed data set, as outlined in the Comments Sections of the files. All such extensive comments have been assembled in Appendix 1 for each evaluation, and cite a significant number of specific references by first-named author. However, these references are not listed in this report as they are too numerous for such an exercise, and the reader is referred to the Comments Section of the relevant ENDF-6 decay-data file of each specific radionuclide for full details.

A reasonable segment of the gamma decay for 83-Bi-205 occurs via internal pair production for gamma-transition energies above 1022 keV (judged as significant above 1107 keV). At present, this behaviour cannot be handled and modelled by the COGEND code, and is not accommodated satisfactorily within the ENDF-6 format. Therefore, the relevant gamma-ray energies and internal pair-production coefficients have been included in the Comments Section of the resulting file.

Overall, the recommended decay data exhibit good to excellent consistency when Q-values and branching fraction data are compared with the discrete emission data (i.e., gamma rays, X-rays, Auger and conversion electrons, and EC and beta-particle transitions; see Table 1).

4.1.2 Consistency Checks

All the files within UKPADD6.10 were checked using CHECKR7.02 (19) and FIZCON (20).

Six nuclides produced a warning statement when processed through CHECKR that the material number (MAT) was inconsistent with the ZA number (Cs-123, Cs-123m, Tb-146, Tb-146m, Tl-193 and Tl-193m). This warning arose because the MAT numbers for these nuclides exceed the standard ENDF-6 numbering scheme. For example, the first stable isotope of Tl is Tl-203 which is assigned the MAT number 8125. The MAT number for Tl-193 is 3*10 less than this value, i.e. 8095. Thus the first two digits do not match the Z number and produce the warning message from CHECKR.

FIZCON produced diagnostic messages for a number of nuclides, as described below.

elis not in range 0.00000E+00 to 0.00000E+00

This message is present for all metastable nuclides. The parameter ELIS is the excitation energy (16), and is non-zero for metastable nuclides. FIZCON checks that this parameter is between zero and EMAX, the upper energy of the evaluation. EMAX is zero for decay data files, and therefore the message does not apply to decay data files and can be ignored.

ft value too small

This message occurred for Mg-28, Br-77, Rb-93, Y-97m, Rh-104, Ag-115m, Cd-107, I-138, Ho-160, Ta-177, Os-180, Ir-190, Hg-190 and Pb-201. FIZCON checks that the ft value for beta transitions is within certain limits dependent on the transition type. Although beta transitions that fail this test had been individually assessed at the time of evaluation, the evaluator believed that this condition could not be averted.

total energy release sumup failure

Evaluations have been derived theoretically for 35 fission products important at short cooling times in decay-heat calculations (see Section 4.2). The theoretical spectra are given only in continuum form, resulting in the associated antineutrino energy not being included in the files except as part of the Q value for the decay mode. This causes the total energy sum-up test to fail. There is no practicable way to prevent this process happening, and FIZCON prints the following message.

```
warning: continuum spectrum for beta-radiation.  
         fizcon cannot calculate antineutrino energy  
         for total energy release.
```

Two additional nuclides also failed the total energy sum-up test (In-116 and Po-208), although the discrepancy is rather small for Po-208 (-0.0380%). The reasons for these two failures are not clear.

gamma ray needed, source mode= 4

This message was present for Li-8 and indicates that the discrete energy of the single alpha particle (plus recoil) is less than the Q value for the decay mode and thus an associated gamma emission is expected. As there are no gamma data present, this warning is issued.

Various messages relating to energy sum-up discrepancies were also obtained for the incomplete evaluations of Cs-136m, Pm-155 and Ho-163. Further details of these evaluations are given in Section 4.2 below.

4.2 Contents of the Library

The UKPADD6.10 evaluated decay data library has been assembled in the internationally-accepted ENDF-6 format adopted for nuclear applications, as described in Reference 16. Comprehensive decay scheme data are presented for 589 radionuclides.

A General Information/Descriptive Data Section is defined for each nuclide (MF=1, MT=451) that contains the following information:

- (i) radionuclide, date of evaluation, name of evaluator, date of distribution (month, year) and most recent date of issue (year, month and day);

- (ii) library name (UKPADD6.10), file identifier (material number), data type (radioactive decay data) and format type (ENDF-6);
- (iii) list of references used to determine the recommended data set;
- (iv) detailed comments concerning the evaluation;
- (v) specific decay data not contained in the main decay data section, including beta-particle transition parameters;
- (vi) consistency check of the recommended data set.

The recommended decay data are contained within the primary data section (MF=8, MT=457). These data are:

- (i) spin and parity of the decaying radionuclide;
- (ii) half-life;
- (iii) average energy per disintegration for three general radiation types (light particles, electromagnetic radiations and heavy particles), followed by the individual components of these types for evaluations since September 2002;
- (iv) decay modes, Q-values and branching fractions;
- (v) radiation decay data, including gamma-ray, beta-particle, electron-capture, alpha-particle, neutron, discrete electron and x-ray transitions;
- (vi) spontaneous fission decay data.

The decay parameters of the majority of radionuclides in UKPADD6.10 have been reasonably well defined in the published literature, and were evaluated with good precision and confidence to produce consistent decay schemes.

Various decay parameters and continuum spectra have been theoretically derived for 35 neutron-rich nuclides deemed to be important at short cooling times in decay-heat calculations (denoted by # in Table 1). While each of these fission products contributes significantly to the decay heat of irradiated fuel (> 0.01 of the fractional cumulative yield), they have proved extremely difficult (if not impossible) to prepare, isolate and study experimentally. The US ENDF/B-VI decay-data library contains files of theoretical data for 33 of these nuclides (22), and they were considered as possible candidates for incorporation into UKPADD, with supportive data from Takahashi *et al.* (23) and Audi *et al.* (24). Furthermore, the relevant data for nine other radionuclides proved insufficient to evaluate and recommend complete decay schemes at the time of their evaluation. These nine troublesome radionuclides are discussed in more detail below - references associated with these particular comments are not defined in the reference list of this report, but can be found in the original database.

He-8

He-8 undergoes beta-particle and neutron decay. While a reasonably consistent decay scheme can be assembled, the neutron emissions are less well defined and constitute an incomplete decay scheme.

Li-9

Li-9 undergoes beta-particle and neutron decay. The latter emissions are relatively complex and poorly characterised, resulting in the formulation of an incomplete decay scheme.

V-54

There are major difficulties in defining the population-depopulation transitions of the 834.8- and 3159.3-keV nuclear levels. Furthermore, it is assumed that no beta transitions occur to the nuclear levels at 834.8, 3159.3, 3222.2 and 3436.8 keV, despite contrary evidence from gamma-ray measurements.

Sb-129m

A significant number of gamma-ray transitions can not be satisfactorily incorporated into the proposed decay scheme, and the calculated normalisation factor for the gamma rays is judged to be a poor estimate.

Cs-136m

Cs-136m has only been detected from an analysis of Cs X-rays following the proton irradiation of lanthanum. No decay data have been reported, although this metastable level at 600 keV has been postulated on the basis of the equivalent observed decay of I-136m. A decay scheme can not be proposed with such a lack of information.

Pm-155

A complete and consistent decay scheme can not be sensibly derived from the detailed TAGS (total absorption gamma-ray spectrometry) studies of Greenwood *et al.* (1997) because of the significant lack of discrete gamma-ray and gamma-gamma coincidence measurements reported in the open literature. While the TAGS spectrum indicates the existence and population of at least 37 nuclear levels of Sm-155, only five gamma-ray emissions have been characterised (by Greenwood *et al.*, 1982). Unpublished gamma-ray studies at the University of Idaho and INEL have been mentioned in relatively vague terms, and good agreement was claimed between these unreported measurements and the simulated spectra (through TAGS) up to a nuclear level energy of 1362.1 keV. Sixteen additional "pseudolevels" were also postulated by Greenwood *et al.* (1997) in order to explain the TAGS spectrum.

There are a very large number of uncertainties associated with the decay of Pm-155, and extensive gamma-ray studies are required to assist greatly in the evolution of a comprehensive and consistent decay scheme. Many features of the decay scheme need to be explored and clarified (particularly the emission probabilities of all the gamma rays, and the beta-particle energies and emission probabilities).

Ho-163

Ho-163 undergoes electron capture decay through the M and higher shells (N, O, etc.). The models in COGEND and the checking code FIZCON assume that this form of decay will involve capture from the innermost K and L shells. Hence, ENDF-6 data can not be generated using COGEND, nor checked by FIZCON. Fractional atomic shell electron capture probabilities calculated using the EC-CAPTURE code yield: $P(K) = 0.0$, $P(L) = 0.0$, $P(M) = 0.1967$, $P(N) = 0.6688$ and $P(O) = 0.1346$ for the 2.650-keV decay to the ground state of Dy-163. Auger and X-ray data need to be determined separately.

Au-198m

The significant 333-keV gamma ray observed in the decay of Au-198m can not be satisfactorily placed in the proposed decay scheme. There is also a lack of gamma-ray data to produce a satisfactory decay scheme.

Tl-201

There are difficulties in defining the emission probabilities and (M1+E2) mixing ratios of the low-energy 1.56- and 5.87-keV gamma rays, and there are significant uncertainties in these data. The emission probabilities of these low-energy transitions were derived from the various assumptions based on population/de-population of the relevant nuclear levels, an estimated emission probability for the 26.28-keV gamma ray, and zero EC decay to the 26.28-keV nuclear level and ground state of Hg-201. The nature of the low-energy gamma-ray emissions and their

high internal conversion prevented confident recommendations for a number of the transitions in the TI-201 decay scheme.

There are 589 full evaluations in UKPADD6.10, of which 35 files are assembled from theoretical data and 9 are defined as being incomplete data sets. The remaining 545 radionuclides have been evaluated to give reasonably consistent decay schemes. All of the data files are judged to be suitable for a wide range of applications in the nuclear industry and for research purposes.

5 Conclusions

Sets of recommended decay scheme and emission probability data have been derived for a series of radionuclides identified predominantly as activation products and calibrants. The resulting evaluated data sets represent significant improvements in the quality of the derived decay parameters.

Data for 11 nuclides have been newly evaluated or re-evaluated in 2009/10, and exhibit good to excellent consistency. A number of radionuclides remain to be evaluated in greater detail as documented by Forrest (21). Most of these remaining radionuclides that merit comprehensive decay-data evaluation possess extremely complex decay schemes, with significant numbers of unplaced gamma rays. The expectation is that suitable evaluations would only be feasible at a relatively slow rate of file production owing to their complexity.

All of the evaluated decay data have been assembled with other files from previous versions of UKPADD to create the UKPADD6.10 library in ENDF-6 format (589 radionuclides, as listed in Table 1). Rigorous consistency checks have been undertaken to confirm the validity and completeness of the data before releasing the updated library. Comprehensive details of each evaluation can be found within the Comments Section of each individual ENDF-6 file.

The structure of all the evaluated files has been updated to ensure the files are consistent with modern standards and can be assimilated into JEFF-3 and future libraries. UKPADD6.10 is available via the NEA Data Bank, and all the decay data comprising UKPADD6.10 have been submitted for possible inclusion in the JEFF-3 Decay Data Library.

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Table 1. Decay Data Summary

Nuclide	Evaluation Date	T _{1/2}	Decay Modes	Q % Deviation
1-H - 3	OCT82	12.330y	β ⁻	0.0000
2-He- 6	OCT82	0.808s	β ⁻	0.0000
2-He- 8	FEB03	0.122s	β ⁻ (0.88), β ⁻ⁿ (0.12)	Incomplete
3-Li- 8	APR92	0.838s	β ^{-α}	0.0419
3-Li- 9	APR92	0.178s	β ⁻ (0.505), β ⁻ⁿ (0.495)	Incomplete
4-Be- 7	OCT82	53.240d	EC	0.0111
4-Be- 8	APR92	7.000E-17s	α	-0.0092
4-Be- 10	OCT82	1.600E+06y	β ⁻	0.0000
4-Be- 11	DEC90	13.810s	β ⁻ (0.97), β ^{-α} (0.03)	0.0915
5-B - 12	OCT82	0.020s	β ⁻ (0.9842), β ^{-α} (0.0158)	0.0002
5-B - 13	FEB03	0.017s	β ⁻ (0.99724), β ⁻ⁿ (0.00276)	0.0244
6-C - 14	OCT82	5.730E+03y	β ⁻	0.0000
6-C - 15	OCT82	2.449s	β ⁻	-0.0733
7-N - 13	DEC94	9.965m	EC	0.0000
7-N - 16	JAN02	7.130s	β ⁻ (0.9999880), β ^{-α} (1.2000E-05)	0.0577
7-N - 17	JAN02	4.170s	β ⁻ (0.05), β ⁻ⁿ (0.9499750), β ^{-α} (2.5000E-05)	0.0700
8-O - 19	OCT82	26.910s	β ⁻	-0.1655
9-F - 18	DEC94	1.828h	EC	0.0000
9-F - 20	OCT82	11.030s	β ⁻	0.0051
9-F - 21	OCT05	4.158s	β ⁻	0.0666
10-Ne- 23	OCT82	37.200s	β ⁻	0.0183
11-Na- 22	OCT92	2.603y	EC	0.0018
11-Na- 24	OCT92	14.965h	β ⁻	0.0068
11-Na- 24m	NOV82	0.020s	β ⁻ (0.005), IT (0.995)	0.0003
11-Na- 25	OCT82	59.600s	β ⁻	0.1602
11-Na- 26	NOV82	1.080s	β ⁻	-0.0077
12-Mg- 27	NOV82	9.458m	β ⁻	0.0001
12-Mg- 28	NOV82	20.9h	β ⁻	0.1597
13-Al- 26	NOV82	7.200E+05y	EC	0.0250
13-Al- 26m	DEC94	6.345s	EC	0.0000
13-Al- 28	NOV82	2.241m	β ⁻	0.0022
13-Al- 29	NOV82	6.560m	β ⁻	-0.0207
13-Al- 30	NOV82	3.650s	β ⁻	-0.0638
14-Si- 31	NOV82	2.620h	β ⁻	-0.0014
14-Si- 32	NOV82	330.0y	β ⁻	0.0000
15-P - 32	NOV82	14.270d	β ⁻	0.0000



Nuclide	Evaluation Date	T _{1/2}	Decay Modes	Q % Deviation
15-P - 33	NOV82	25.4d	β-	0.0000
15-P - 34	DEC94	12.4s	β-	-0.0062
16-S - 35	NOV82	87.5d	β-	0.0000
16-S - 37	NOV82	4.990m	β-	-0.0801
17-Cl- 34	DEC94	1.526s	EC	0.0000
17-Cl- 34m	DEC94	32.1m	EC (0.52), IT (0.48)	-0.0474
17-Cl- 36	SEP01	3.070E+05y	β- (0.981), EC (0.019)	0.0001
17-Cl- 38	DEC82	37.2m	β-	-0.0079
17-Cl- 38m	NOV82	0.715s	IT	-0.0640
17-Cl- 39	OCT05	55.6m	β-	-0.0153
18-Ar- 37	DEC82	35.0d	EC	-0.0007
18-Ar- 39	DEC82	269.0y	β-	0.0000
18-Ar- 41	JAN83	1.827h	β-	-0.0384
18-Ar- 42	DEC82	33.00y	β-	0.0000
19-K - 38	DEC94	7.610m	EC	0.0013
19-K - 38m	DEC94	0.924s	EC	0.0000
19-K - 40	DEC82	1.280E+09y	β- (0.893), EC (0.107)	-0.0011
19-K - 42	FEB83	12.370h	β-	0.0066
19-K - 43	DEC82	22.2h	β-	-0.0474
19-K - 44	MAR90	22.130m	β-	0.1283
20-Ca- 41	DEC82	1.030E+05y	EC	0.0035
20-Ca- 45	JAN92	162.7d	β-	0.0000
20-Ca- 47	APR92	4.538d	β-	0.1213
20-Ca- 49	DEC82	8.720m	β-	-0.0229
21-Sc- 44	JAN83	3.927h	EC	0.0171
21-Sc- 44m	JAN83	2.442d	EC (0.0123), IT (0.9877)	0.0391
21-Sc- 45m	NOV07	0.325s	IT	-0.0903
21-Sc- 46	OCT92	83.790d	β-	-0.0028
21-Sc- 46m	FEB83	18.7s	IT	0.4710
21-Sc- 47	DEC91	3.346d	β-	0.0017
21-Sc- 48	FEB83	1.820d	β-	0.0226
21-Sc- 49	DEC82	57.2m	β-	0.0000
21-Sc- 50	JAN92	1.708m	β-	-0.0075
21-Sc- 50m	JAN92	0.350s	β- (0.0125), IT (0.9875)	-0.0276
22-Ti- 45	APR92	3.080h	EC	0.0022
22-Ti- 51	JAN92	5.8m	β-	0.0073
23-V - 48	FEB83	15.974d	EC	-0.2125
23-V - 49	FEB83	330.0d	EC	0.0029
23-V - 52	JAN92	3.745m	β-	-0.0006



Nuclide	Evaluation Date	T _{1/2}	Decay Modes	Q % Deviation
23-V - 53	APR92	1.620m	β-	-0.2563
23-V - 54	APR92	49.8s	β-	Incomplete
24-Cr- 49	JAN83	41.9m	EC	-0.0171
24-Cr- 51	AUG89	27.706d	EC	0.0053
24-Cr- 55	FEB92	3.540m	β-	0.0000
25-Mn- 53	NOV93	3.680E+06y	EC	0.0042
25-Mn- 54	DEC91	312.3d	EC	-0.0001
25-Mn- 56	JAN92	2.579h	β-	-0.0179
25-Mn- 58	APR97	1.087m	β-	-0.3450
25-Mn- 58m	APR97	2.7s	β-	0.1037
26-Fe- 53	JAN92	8.510m	EC	-0.2021
26-Fe- 53m	JAN92	2.580m	IT	0.1882
26-Fe- 55	JAN92	2.735y	EC	-0.0020
26-Fe- 59	DEC91	44.502d	β-	-0.0172
26-Fe- 60	JAN94	1.500E+06y	β-	0.0000
26-Fe- 63	DEC00	6.1s	β-	0.0119
27-Co- 55	FEB92	17.530h	EC	0.0305
27-Co- 56	APR92	77.260d	EC	0.5072
27-Co- 57	JAN92	271.790d	EC	0.0020
27-Co- 58	JUL91	70.860d	EC	-0.0023
27-Co- 58m	JUL91	8.940h	IT	-0.3171
27-Co- 60	DEC91	5.272y	β-	0.0053
27-Co- 60m	JAN94	10.470m	β- (0.0025), IT (0.9975)	0.0838
28-Ni- 57	JAN92	1.487d	EC	-0.0314
28-Ni- 59	DEC91	7.600E+04y	EC	-0.0056
28-Ni- 63	JUL90	99.0y	β-	0.0000
28-Ni- 65	DEC91	2.520h	β-	0.0352
28-Ni- 66	AUG93	2.267d	β-	0.0000
28-Ni- 67	JUL01	21.0s	β-	0.0093
29-Cu- 62	FEB92	9.750m	EC	0.0001
29-Cu- 64	JAN92	12.70h	β- (0.3886), EC (0.6114)	-0.0007
29-Cu- 66	JAN92	5.1m	β-	0.0166
29-Cu- 67	AUG93	2.579d	β-	0.0171
30-Zn- 63	MAR91	38.4m	EC	0.0286
30-Zn- 65	JAN90	244.260d	EC	-0.0075
30-Zn- 69	NOV05	56.4m	β-	0.0000
30-Zn- 69m	NOV05	13.780h	β- (0.00033), IT (0.99967)	-0.0071
31-Ga- 67	NOV08	3.261d	EC	-0.0255
31-Ga- 70	NOV07	21.140m	β- (0.9959), EC (0.0041)	-0.0002

Nuclide	Evaluation Date	T _{1/2}	Decay Modes	Q % Deviation
31-Ga- 77	JUL99	13.0s	β-	-0.4724
32-Ge- 71	OCT07	11.430d	EC	-0.0402
32-Ge- 71m	JAN08	0.0204s	IT	-0.0361
32-Ge- 73m	JUN06	0.5s	IT	-0.3557
32-Ge- 75	DEC07	1.380h	β-	-0.0284
32-Ge- 75m	DEC07	48.00s	β- (0.00033), IT (0.99967)	-0.033
32-Ge- 80	FEB05	27.0s	β-	-0.0204
33-As- 73	JUN06	80.3d	EC	-0.0344
33-As- 74	OCT90	17.780d	β- (0.34), EC (0.66)	-0.2919
33-As- 76	NOV06	1.092d	β-	0.0406
33-As- 82	JUL99	20.0s	β-	-0.0231
33-As- 82m	JUL99	13.6s	β-	-0.7379
33-As- 85	SEP97	2.040s	β- (0.78), β-n (0.22)	0.0988
34-Se- 75	JAN90	119.640d	EC	-0.1033
34-Se- 77m	JUL06	17.550s	IT	-0.1025
34-Se- 79	OCT07	3.770E+05y	β-	0.0000
34-Se- 79m	JUN01	3.9m	IT (0.99944), β- (0.00056)	-0.0743
34-Se- 81	AUG03	18.390m	β-	0.0027
34-Se- 81m	AUG03	57.280m	β- (0.00068), IT (0.99932)	0.1410
35-Br- 72	AUG03	1.310m	EC	-0.2821
35-Br- 72m	AUG03	10.6s	IT	0.2164
35-Br- 77	DEC09	2.3765d	EC(gd) (0.9794), EC(m) (0.0206)	0.0255
35-Br- 79m	FEB90	4.880s	IT	-0.0283
35-Br- 80	SEP90	17.6m	β- (0.917), EC (0.083)	-0.0134
35-Br- 80m	SEP90	4.410h	IT	-0.1960
35-Br- 82	DEC89	1.472d	β-	0.0729
35-Br- 82m	DEC89	6.090m	β- (0.024), IT (0.976)	0.5001
35-Br- 87	NOV98	55.7s	β- (0.9749), β-n (0.0251)	-0.1976
35-Br- 88	OCT97	16.5s	β- (0.933), β-n (0.067)	0.2554
35-Br- 89	OCT97	4.370s	β- (0.859), β-n (0.141)	0.0534
35-Br- 90	MAR97	1.9s	β- (0.754), β-n (0.246)	0.1331
35-Br- 91	SEP97	0.538s	β- (0.80), β-n (0.20)	0.0274
36-Kr- 79	JAN90	1.460d	EC	-0.0466
36-Kr- 79m	JAN90	50.0s	IT	-0.0728
36-Kr- 81	MAY94	2.100E+05y	EC	-0.0300
36-Kr- 81m	MAY94	13.2s	EC (2.5000E-05), IT (0.9999750)	0.0187
36-Kr- 83m	OCT08	1.83h	IT	-0.6199
36-Kr- 85	APR94	10.730y	β-	-0.0001
36-Kr- 85m	APR94	4.480h	β- (0.789), IT (0.211)	0.0483



Nuclide	Evaluation Date	T _{1/2}	Decay Modes	Q % Deviation
37-Rb- 83	OCT93	86.2d	EC(gd) (0.25), EC(m) (0.75)	-0.0760
37-Rb- 84	FEB94	33.5d	β- (0.032), EC (0.968)	0.0319
37-Rb- 84m	AUG93	20.4m	IT	0.1151
37-Rb- 86	APR94	18.630d	β- (0.9999480), EC (5.2000E-05)	0.0049
37-Rb- 86m	APR94	1.017m	IT	0.0034
37-Rb- 89	AUG01	15.4m	β-	-0.0750
37-Rb- 93	FEB03	5.8s	β- (0.986), β-n (0.014)	-0.0182
37-Rb- 94	JUN98	2.702s	β- (0.899), β-n (0.101)	-0.0527
37-Rb- 95	FEB98	0.381s	β- (0.914), β-n (0.086)	-0.2394
38-Sr- 83	OCT93	1.350d	EC	0.3553
38-Sr- 83m	OCT93	4.950s	IT	-0.0428
38-Sr- 85	FEB92	64.849d	EC	-0.0051
38-Sr- 85m	FEB92	1.127h	EC (0.134), IT (0.866)	0.0031
38-Sr- 87m	OCT06	2.816h	EC (0.003), IT (0.997)	-0.0120
38-Sr- 89	JAN91	50.520d	β-(gd) (0.9999040), β-(m) (9.6400E-05)	0.0000
38-Sr- 90	MAY94	28.869y	β-	0.0000
38-Sr- 92	JUN01	2.710h	β-	-0.0061
38-Sr- 94	SEP03	1.255m	β-	0.0259
39-Y - 87	JUL06	3.325d	EC	0.0077
39-Y - 87m	JUL06	13.370h	EC (0.0157), IT (0.9843)	-0.0408
39-Y - 88	MAR90	106.630d	EC	0.0531
39-Y - 89m	JAN91	16.050s	IT	0.0024
39-Y - 90	NOV07	2.667d	β-	0.0089
39-Y - 90m	NOV07	3.190h	β- (2.1000E-05), IT (0.999979)	-0.002
39-Y - 91	APR94	58.7d	β-	0.0000
39-Y - 91m	APR94	49.720m	IT	-0.0041
39-Y - 96	FEB96	5.370s	β-	-0.0151
39-Y - 96m	FEB96	9.620s	β-	0.0079
39-Y - 97	FEB05	3.750s	β- (0.99945), β-n (0.00055)	0.0105
39-Y - 97m	FEB05	1.170s	β- (0.9925), IT (0.007), β-n (0.0005)	-0.0227
39-Y - 97n	FEB05	0.142s	β- (0.016), IT (0.984)	-0.0264
39-Y - 98	FEB97	0.590s	β- (0.9973), β-n (0.0027)	-0.0432
39-Y - 98m	FEB97	2.0s	β- (0.9656), β-n (0.0344)	-0.2944
39-Y - 99	NOV97	1.477s	β- (0.983), β-n (0.017)	-0.0741
39-Y -104	MAR98	0.130s	β- (0.912230), β-n (0.087769)	#
39-Y -105	MAR98	0.150s	β- (0.80247), β-n (0.19753)	#
40-Zr- 88	MAY94	83.4d	EC	0.0149



Nuclide	Evaluation Date	T _{1/2}	Decay Modes	Q % Deviation
40-Zr- 89	JAN91	3.267d	EC(gd) (0.0013), EC(m) (0.9987)	0.0513
40-Zr- 89m	JAN91	4.180m	EC (0.0666), IT (0.9334)	-0.0317
40-Zr- 90m	NOV07	0.808s	IT	-0.0421
40-Zr- 93	OCT08	1.53E+06y	β-(gd) (0.03), β-(m) (0.97)	0.0000
40-Zr- 95	NOV90	64.030d	β-(gd) (0.989), β-(m) (0.011)	-0.0121
40-Zr- 99	AUG03	2.2s	β-(gd) (0.632), β-(m) (0.368)	-0.0510
40-Zr-105	JAN98	0.6s	β- (0.986), β-n (0.014)	#
40-Zr-106	MAR98	0.9s	β- (0.984760), β-n (0.015242)	#
40-Zr-107	MAR98	0.240s	β- (0.962870), β-n (0.037127)	#
41-Nb- 90	NOV07	14.590h	EC(gd) (0.019), EC(m) (0.981)	-0.0108
41-Nb- 90m	NOV07	18.810s	IT	0.0185
41-Nb- 90n	NOV07	6.220E-03s	IT	0.0158
41-Nb- 91	APR94	680.016y	EC	-0.0021
41-Nb- 91m	APR94	60.9d	IT (0.976), EC (0.024)	-0.1628
41-Nb- 92	SEP93	3.500E+07y	EC	0.0187
41-Nb- 92m	SEP93	10.150d	EC	-0.0254
41-Nb- 93m	OCT08	16.120y	IT	-0.2611
41-Nb- 94	JAN90	1.998E+04y	β-	-0.0014
41-Nb- 94m	JAN90	6.260m	β- (0.005), IT (0.995)	-0.0290
41-Nb- 95	NOV90	34.975d	β-	0.0025
41-Nb- 95m	NOV90	3.608d	β- (0.034), IT (0.966)	-0.0661
41-Nb- 96	OCT05	23.350h	β-	0.0239
41-Nb-100	DEC96	1.4s	β-	0.0733
41-Nb-100m	DEC96	2.9s	β-	-0.0167
41-Nb-109	MAR98	0.190s	β- (0.87347), β-n (0.12653)	#
42-Mo- 93	MAR90	3.011E+03y	EC(gd) (0.15), EC(m) (0.85)	-0.0074
42-Mo- 93m	MAR90	6.850h	EC (0.0012), IT (0.9988)	0.0162
42-Mo- 99	OCT90	2.748d	β-(gd) (0.119), β-(m) (0.881)	-0.0098
42-Mo-103	AUG01	1.132m	β-	-0.0096
42-Mo-109	MAR98	0.5s	β- (0.9947), β-n (0.0053)	#
42-Mo-111	MAR98	0.5s	β- (0.9897), β-n (0.0103030)	#
42-Mo-112	MAR98	1.0s	β- (0.97921), β-n (0.0207880)	#
43-Tc- 97	FEB96	2.600E+06y	EC	-0.0047
43-Tc- 97m	FEB96	90.2d	IT	0.0621
43-Tc- 98	JUL08	4.300E+06y	β-	0.0097
43-Tc- 99m	JUL90	6.010h	β- (3.7000E-05), IT (0.9999630)	0.0470
43-Tc-113	MAR98	0.130s	β- (0.928140), β-n (0.071864)	#
43-Tc-114	MAR98	0.2s	β- (0.934640), β-n (0.065358)	#
43-Tc-115	MAR98	0.270s	β- (0.85663), β-n (0.14337)	#



Nuclide	Evaluation Date	T _{1/2}	Decay Modes	Q % Deviation
43-Tc-116	MAR98	0.120s	β ⁻ (0.87777), β ⁻ⁿ (0.12223)	#
43-Tc-99	JUL90	2.113E+05y	β ⁻	0.0000
44-Ru-103	MAY90	39.260d	β ⁻ (gd) (0.0115), β ⁻ (m) (0.9885)	-0.0914
44-Ru-115	MAR98	0.7s	β ⁻ (0.997720), β ⁻ⁿ (0.002276)	#
44-Ru-116	MAR98	1.7s	β ⁻ (0.989190), β ⁻ⁿ (0.010811)	#
44-Ru-117	MAR98	0.340s	β ⁻ (0.979490), β ⁻ⁿ (0.020509)	#
44-Ru-118	MAR98	0.7s	β ⁻ (0.958910), β ⁻ⁿ (0.041092)	#
44-Ru-119	JAN02	0.190s	β ⁻ (0.95642), β ⁻ⁿ (0.04358)	#
45-Rh-101	NOV08	3.2y	EC	-0.0017
45-Rh-101m	NOV08	4.35d	EC (0.9256), IT (0.0744)	-0.0119
45-Rh-102	DEC90	2.902y	EC	-0.4531
45-Rh-102m	DEC90	208.0d	β ⁻ (0.20), EC (0.75), IT (0.05)	0.0748
45-Rh-103m	MAY94	56.115m	IT	-0.3866
45-Rh-104	JUN90	42.3s	β ⁻ (0.9955), EC (0.0045)	0.0233
45-Rh-104m	JUN90	4.340m	β ⁻ (0.0013), IT (0.9987)	-0.1843
45-Rh-105	JAN94	1.474d	β ⁻	-0.0546
45-Rh-105m	JAN94	40.0s	IT	-0.0461
45-Rh-106	AUG96	30.1s	β ⁻	-0.0243
45-Rh-106m	AUG96	2.2h	β ⁻	-0.0487
45-Rh-110	SEP03	28.5s	β ⁻	0.0172
45-Rh-110m	SEP03	3.2s	β ⁻	0.1721
45-Rh-111	SEP04	12.0s	β ⁻	0.0125
45-Rh-118	MAR98	0.320s	β ⁻ (0.970830), β ⁻ⁿ (0.029167)	#
45-Rh-120	MAR98	0.170s	β ⁻ (0.940720), β ⁻ⁿ (0.059282)	#
45-Rh-121	MAR98	0.250s	β ⁻ (0.86432), β ⁻ⁿ (0.13568)	#
46-Pd-103	MAY94	16.980d	EC(gd) (0.00026), EC(m) (0.99974)	-0.0398
46-Pd-107	NOV93	6.500E+06y	β ⁻	0.0000
46-Pd-107m	NOV93	21.3s	IT	0.0330
46-Pd-109	MAR98	13.460h	β ⁻ (gd) (0.00046), β ⁻ (m) (0.99954)	0.0090
46-Pd-109m	FEB98	4.710m	IT	0.0367
46-Pd-112	JAN97	20.3h	β ⁻	-0.0306
46-Pd-113	OCT04	1.517m	β ⁻ (gd) (0.050), β ⁻ (m) (0.950)	-0.1194
46-Pd-113m	OCT04	0.3s	IT	0.3404
46-Pd-121	MAR98	0.6s	β ⁻ (0.99728), β ⁻ⁿ (0.0027220)	#
47-Ag-105	JAN94	41.3d	EC	-0.0536
47-Ag-105m	JAN94	7.230m	EC (0.0034), IT (0.9966)	-0.6547
47-Ag-106	JAN94	24.0m	β ⁻ (0.005), EC (0.995)	-0.0051
47-Ag-106m	JAN94	8.460d	EC	0.9682
47-Ag-107m	JAN97	44.1s	IT	-0.0525



Nuclide	Evaluation Date	T _{1/2}	Decay Modes	Q % Deviation
47-Ag-108	OCT90	2.4m	β ⁻ (0.971), EC (0.029)	0.0204
47-Ag-108m	JAN92	418.010y	EC (0.913), IT (0.087)	-0.0190
47-Ag-109m	JUL06	39.7s	IT	-0.0051
47-Ag-110	NOV91	24.7s	β ⁻ (0.997), EC (0.003)	-0.0009
47-Ag-110m	NOV91	249.791d	β ⁻ (0.9873), IT (0.0127)	-0.3356
47-Ag-111	JUL94	7.450d	β ⁻	0.0002
47-Ag-111m	JUL94	1.080m	β ⁻ (0.005), IT (0.995)	-0.1750
47-Ag-114	OCT98	4.7s	β ⁻	-0.1883
47-Ag-114m	OCT98	1.500E-03s	IT	0.0039
47-Ag-115	MAY98	20.5m	β ⁻ (gd) (0.88), β ⁻ (m) (0.12)	0.0434
47-Ag-115m	FEB03	18.6s	β ⁻ (gd) (0.767), β ⁻ (m) (0.023), IT (0.21)	0.1918
48-Cd-107	FEB03	6.520h	EC(gd) (0.00064), EC(m) (0.99936)	-0.0289
48-Cd-109	MAR90	1.267y	EC	0.0330
48-Cd-111m	NOV09	48.74m	IT	-0.0121
48-Cd-113	DEC07	7.800E+15y	β ⁻	0.0000
48-Cd-113m	DEC07	14.600y	β ⁻ (0.9988), IT (0.0012)	0.0000
48-Cd-115	AUG08	2.228d	β ⁻ (gd) (0.0000007), β ⁻ (m) (0.9999993),	0.0269
48-Cd-115m	AUG08	44.45d	β ⁻ (gd) (0.999897), β ⁻ (m) (0.000103)	-0.0407
49-In-111	JAN91	2.805d	EC(gd) (0.9999140), EC(m) (8.6000E-05)	0.0372
49-In-111m	JAN91	7.9m	IT	-0.0507
49-In-112	JAN97	14.7m	β ⁻ (0.44), EC (0.56)	0.1052
49-In-112m	JAN97	20.7m	IT	-0.1202
49-In-113m	FEB91	1.658h	IT	0.0014
49-In-114	FEB92	1.198m	β ⁻ (0.995), EC (0.005)	-0.0031
49-In-114m	FEB92	50.0d	EC (0.035), IT (0.965)	-0.1894
49-In-114n	FEB92	0.043s	IT	-0.0062
49-In-115	MAR90	4.410E+14y	β ⁻	0.0000
49-In-115m	MAY94	4.486h	β ⁻ (0.0505), IT (0.9495)	0.0066
49-In-116	JAN92	14.2s	β ⁻	0.6261
49-In-116m	JAN92	54.6m	β ⁻	0.1921
49-In-116n	JAN92	2.170s	IT	0.0632
50-Sn-110	DEC00	4.1h	EC	0.0064
50-Sn-113	FEB91	115.0d	EC(gd) (0.0001), EC(m) (0.9999)	0.0204
50-Sn-113m	FEB91	20.9m	EC (0.089), IT (0.911)	-0.2109
50-Sn-117m	JAN90	13.6d	IT	-0.0006
50-Sn-119m	JAN92	293.0d	IT	-0.1028



Nuclide	Evaluation Date	T _{1/2}	Decay Modes	Q % Deviation
50-Sn-121	NOV07	1.125d	β-	0.0000
50-Sn-121m	NOV07	43.90y	β- (0.224), IT (0.776)	-0.0914
50-Sn-123	APR91	129.2d	β-	-0.0042
50-Sn-123m	APR91	40.1m	β-	-0.0694
50-Sn-125	OCT91	9.640d	β-	-0.0725
50-Sn-125m	NOV09	9.53m	β-	-0.0032
50-Sn-126	NOV09	2.30E+05y	β- (m)(0.331), β- (n)(0.669)	0.0980
50-Sn-129	SEP04	2.230m	β-	-0.0200
50-Sn-129m	SEP04	7.2m	β-(gd) (0.69), β-(m) (0.31)	-0.0531
50-Sn-130	JAN05	3.730m	β-	-0.0085
50-Sn-130m	JAN05	1.7m	β-(gd) (0.84), β-(m) (0.16)	0.0458
51-Sb-119	NOV93	1.596d	EC	0.0186
51-Sb-120	NOV93	15.9m	EC	-0.1123
51-Sb-120m	NOV93	5.760d	EC	-0.0684
51-Sb-122	JUL91	2.696d	β- (0.9763), EC (0.0237)	0.0041
51-Sb-122m	JUL91	4.190m	IT	-0.0135
51-Sb-124	DEC90	60.240d	β-	-0.0495
51-Sb-124m	DEC90	1.550m	β- (0.25), IT (0.75)	-0.3407
51-Sb-124n	DEC90	20.2m	IT	-0.4979
51-Sb-125	JAN92	2.759y	β-(gd) (0.764), β-(m) (0.236)	0.0434
51-Sb-126	JUL01	12.410d	β-	-0.0635
51-Sb-126m	JUL01	19.1m	IT (0.14), β- (0.86)	-0.1708
51-Sb-126n	JUL01	11.0s	IT	-0.5031
51-Sb-127	OCT96	3.840d	β-(gd) (0.832), β-(m) (0.168)	-0.0431
51-Sb-129	MAR92	4.360h	β-(gd) (0.834), β-(m) (0.166)	-0.6673
51-Sb-129m	MAR92	17.7m	β-(gd) (0.02), β-(m) (0.83), IT (0.15)	Incomplete
51-Sb-135	JUL98	1.740s	β- (0.843), β-n (0.157)	-0.0198
51-Sb-141	MAR98	0.3s	β- (0.869), β-n (0.131)	#
52-Te-121	JUL01	19.160d	EC	0.0226
52-Te-121m	JUL01	154.0d	EC (0.113), IT (0.887)	-0.1799
52-Te-125m	JUL91	58.0d	IT	-0.0051
52-Te-127	OCT96	9.350h	β-	-0.0037
52-Te-127m	OCT96	109.0d	IT (0.976), β- (0.024)	-0.0908
52-Te-129	JUN92	1.160h	β-	-0.0619
52-Te-129m	NOV09	33.6d	β- (0.363), IT (0.637)	-0.0088
52-Te-132	OCT96	3.230d	β-	0.1077
53-I -125	JAN92	59.430d	EC	0.0709
53-I -126	OCT90	12.980d	β- (0.437), EC (0.563)	0.0678



Nuclide	Evaluation Date	T _{1/2}	Decay Modes	Q % Deviation
53-I -132	DEC96	2.283h	β-	-0.0832
53-I -132m	NOV96	1.383h	IT (0.86), β- (0.14)	-0.3723
53-I -137	DEC97	24.510s	β- (0.935), β-n (0.065)	0.1276
53-I -138	FEB03	6.460s	β- (0.947), β-n (0.053)	-0.1955
53-I -139	NOV97	2.3s	β- (0.902), β-n (0.098)	-0.0552
54-Xe-125	OCT91	16.9h	EC	-0.0292
54-Xe-125m	OCT91	56.0s	IT	0.0606
54-Xe-127	MAR91	36.440d	EC	-0.1451
54-Xe-127m	MAR91	1.160m	IT	-0.0383
54-Xe-129m	DEC08	8.88d	IT	0.1423
54-Xe-131m	SEP94	11.870d	IT	0.0676
54-Xe-133	SEP93	5.243d	β-	0.0299
54-Xe-133m	SEP93	2.190d	IT	0.0213
54-Xe-134m	NOV08	0.290s	IT	0.0088
55-Cs-123	MAR05	5.910m	EC	-0.0424
55-Cs-123m	MAR05	1.7s	IT	-0.0020
55-Cs-129	SEP94	1.342d	EC	0.0670
55-Cs-131	SEP94	9.690d	EC	0.0477
55-Cs-132	AUG94	6.530d	β- (0.018), EC (0.982)	0.0165
55-Cs-134	MAR92	2.065y	β- (0.9999970), EC (3.0000E-06)	0.0823
55-Cs-134m	MAR92	2.908h	IT	-0.0812
55-Cs-135	JUL91	2.400E+06y	β-	0.0000
55-Cs-135m	JUL91	53.0m	IT	-0.0280
55-Cs-136	OCT91	13.030d	β-	-0.2422
55-Cs-136m	OCT91	19.0s	β- (0.50), IT (0.50)	Incomplete
55-Cs-137	NOV90	30.172y	β-(gd) (0.054), β-(m) (0.946)	0.0000
56-Ba-126	JAN01	1.667h	EC	-0.1958
56-Ba-129	FEB96	2.380h	EC	-0.0730
56-Ba-129m	FEB96	2.140h	EC	0.0550
56-Ba-131	NOV94	11.550d	EC	-0.0195
56-Ba-131m	NOV94	14.6m	IT	0.1392
56-Ba-133	JAN92	10.574y	EC	0.0810
56-Ba-133m	MAR92	1.592d	EC (0.0001010), IT (0.9998990)	-0.0816
56-Ba-137m	NOV90	2.553m	IT	0.0176
57-La-137	JUN01	6.000E+04y	EC	0.0353
57-La-140	OCT96	1.679d	β-	-0.0108
57-La-152	MAR98	0.280s	β- (0.93961), β-n (0.0603930)	#
58-Ce-139	MAY92	137.650d	EC	0.1622
58-Ce-139m	MAY92	56.1s	IT	0.0029



Nuclide	Evaluation Date	T _{1/2}	Decay Modes	Q % Deviation
58-Ce-145	JUL01	2.950m	β-	0.1188
58-Ce-147	NOV96	57.0s	β-	0.0269
58-Ce-149	OCT04	5.3s	β-	0.0777
58-Ce-153	MAR98	1.5s	β- (0.99378), β-n (0.0062190)	#
58-Ce-154	MAR98	2.0s	β- (0.99363), β-n (0.0063730)	#
58-Ce-158	MAR98	1.0s	β- (0.9945), β-n (0.0055)	#
59-Pr-143	SEP96	13.560d	β-	0.0000
59-Pr-144	SEP96	17.280m	β-	0.0382
59-Pr-144m	SEP96	6.9m	IT (0.9993), β- (0.0007)	-0.0860
59-Pr-150	DEC96	6.1s	β-	-0.6261
59-Pr-156	MAR98	0.5s	β- (0.97283), β-n (0.02717)	#
59-Pr-157	MAR98	0.3s	β- (0.936130), β-n (0.063874)	#
60-Nd-140	NOV93	3.370d	EC	0.1286
60-Nd-141	OCT08	2.487h	EC	0.0176
60-Nd-141m	OCT08	1.033m	EC (0.00032), IT (0.99968)	0.0006
60-Nd-147	JUN94	11.02d	β-	0.0450
60-Nd-157	MAR98	2.5s	β-	#
60-Nd-158	MAR98	0.7s	β- (0.99995), β-n (5.3000E-05)	#
60-Nd-159	MAR98	0.5s	β- (0.99764), β-n (0.0023610)	#
60-Nd-160	MAR98	0.3s	β- (0.99053), β-n (0.0094690)	#
61-Pm-143	NOV93	266.0d	EC	0.0493
61-Pm-144	AUG93	363.0d	EC	0.0484
61-Pm-145	JUL91	17.7y	EC (1.00), α (2.8000E-09)	0.1990
61-Pm-146	JUL94	5.531y	β- (0.34), EC (0.66)	-0.3961
61-Pm-147	JUN94	2.622y	β-	0.0000
61-Pm-148	OCT93	5.368d	β-	0.0064
61-Pm-148m	OCT93	41.05d	β- (0.95), IT (0.05)	-0.0147
61-Pm-149	FEB94	2.212d	β-	0.2080
61-Pm-151	AUG94	1.171d	β-	0.4059
61-Pm-152	JAN97	4.120m	β-	-0.3799
61-Pm-152m	JAN97	7.5m	β-	-0.7796
61-Pm-152n	JAN97	14.4m	β-	-0.0401
61-Pm-155	MAR05	41.5s	β-	Incomplete
61-Pm-159	MAR98	3.0s	β- (0.999820), β-n (0.000185)	#
61-Pm-160	MAR98	2.0s	β- (0.997320), β-n (0.002676)	#
62-Sm-145	JUL91	340.0d	EC	0.0659
62-Sm-146	JUL90	1.000E+08y	α	-0.0199
62-Sm-147	SEP96	1.060E+11y	α	-0.0023



Nuclide	Evaluation Date	T _{1/2}	Decay Modes	Q % Deviation
62-Sm-151	FEB94	90.00y	β-	-0.0009
62-Sm-153	AUG94	1.929d	β-	0.1640
63-Eu-149	FEB94	93.1d	EC	0.1254
63-Eu-150	NOV94	36.359y	EC	0.0823
63-Eu-150m	NOV94	12.8h	β- (0.88), EC (0.12)	0.5503
63-Eu-152	JUL92	13.523y	β- (0.28), EC (0.72)	-0.1502
63-Eu-152m	JUL92	9.275h	β- (0.72), EC (0.28)	-0.6753
63-Eu-152n	JUL92	1.6h	IT	0.0207
63-Eu-154	MAY92	8.593y	β- (0.9998), EC (0.0002)	0.0416
63-Eu-154m	MAY92	46.4m	IT	0.0927
63-Eu-155	DEC91	4.846y	β-	0.1705
63-Eu-156	OCT94	15.2d	β-	-0.2787
64-Gd-148	NOV09	75y	α	-0.0034
64-Gd-150	DEC94	1.820E+06y	α	0.0119
64-Gd-151	FEB94	124.0d	EC (1.00), α (1.0000E-08)	-0.1917
64-Gd-153	AUG94	240.5d	EC	-0.0495
64-Gd-163	SEP04	1.133m	β-	0.0550
65-Tb-146	JAN05	8.0s	EC	-0.0027
65-Tb-146m	JAN05	24.0s	EC	-0.1118
65-Tb-156	FEB96	5.170d	EC	-0.3867
65-Tb-156m	FEB96	1.017d	IT	0.5785
65-Tb-156n	FEB96	5.1h	EC (0.0019), IT (0.9981)	-0.0964
65-Tb-157	MAR91	99.00y	EC	1.2277
65-Tb-158	DEC05	180.0y	β- (0.168), EC (0.832)	-0.0411
65-Tb-158m	DEC05	10.8s	IT	0.1545
65-Tb-160	NOV05	72.3d	β-	0.0185
65-Tb-161	OCT96	6.890d	β-	-0.0324
66-Dy-157	OCT91	8.140h	EC	-0.0226
66-Dy-159	APR91	144.4d	EC	0.0906
66-Dy-166	NOV07	3.400d	β-	0.0542
67-Ho-160	FEB03	25.3m	EC	-0.2337
67-Ho-160m	MAR96	5.0h	IT (0.65), EC (0.35)	-0.502
67-Ho-160n	MAR96	2.9s	IT	0.2220
67-Ho-161	OCT96	2.480h	EC	0.0565
67-Ho-161m	OCT96	6.770s	IT	0.1297
67-Ho-162	DEC09	14m	EC	-0.0196
67-Ho-162m	DEC09	1.117h	EC (0.45), IT (0.55)	-0.0152
67-Ho-163	JUN01	4.570E+03y	EC	Incomplete
67-Ho-163m	JUN01	1.1s	IT	0.0373



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67-Ho-164	DEC00	28.6m	β ⁻ (0.517), EC (0.483)	0.0101
67-Ho-164m	DEC00	37.6m	IT	0.0498
67-Ho-170	AUG99	2.780m	β ⁻	-0.4097
67-Ho-170m	AUG99	43.0s	β ⁻	-0.3870
68-Er-167m	JUL06	2.270s	IT	0.0743
68-Er-172	JAN01	2.054d	β ⁻	0.2611
69-Tm-167	DEC08	9.25d	EC(gd) (0.0175), EC(m) (0.9825)	0.1375
69-Tm-168	DEC06	90.0d	β ⁻ (0.0001), EC (0.9999)	0.0759
69-Tm-170	NOV07	128.60d	β ⁻ (0.99862),EC (0.00138)	0.0041
69-Tm-171	JAN06	1.917y	β ⁻	0.0017
69-Tm-172	NOV05	2.650d	β ⁻	0.1605
70-Yb-175	NOV94	4.185d	β ⁻	-0.0012
70-Yb-176m	NOV07	11.40s	IT	-0.0071
71-Lu-171	MAR94	8.250d	EC	0.4900
71-Lu-171m	NOV93	1.3m	IT	-0.0305
71-Lu-172	DEC93	6.7d	EC	-0.4760
71-Lu-172m	NOV93	3.7m	IT	-0.0295
71-Lu-173	JUL94	1.336y	EC	-0.2844
71-Lu-174	NOV93	3.559y	EC	-0.1885
71-Lu-174m	NOV93	142.0d	EC (0.0058), IT (0.9942)	0.2587
71-Lu-177	FEB94	6.7d	β ⁻	0.0612
71-Lu-177m	MAY94	160.3d	β ⁻ (0.774), IT (0.226)	0.2669
72-Hf-173	JUL94	23.9h	EC	0.0977
72-Hf-174	JUL91	2.000E+15y	α	0.0155
72-Hf-175	FEB92	70.0d	EC	0.0337
72-Hf-177m	FEB94	1.080s	IT	0.5106
72-Hf-177n	FEB94	51.4m	IT	-0.2990
72-Hf-178m	AUG98	4.0s	IT	0.0013
72-Hf-178n	AUG98	31.00y	IT	0.1450
72-Hf-179m	OCT05	18.670s	IT	0.0568
72-Hf-179n	OCT05	25.1d	IT	0.0382
72-Hf-180m	AUG98	5.5h	β ⁻ (0.0031), IT (0.9969)	-0.2523
72-Hf-181	JAN92	42.380d	β ⁻	0.0975
73-Ta-177	SEP94	2.350d	EC	-0.0203
73-Ta-179	MAR91	1.610y	EC	0.8418
73-Ta-180	MAR91	8.080h	β ⁻ (0.181), EC (0.819)	0.0321
73-Ta-180m	MAR91	1.800E+15y	β ⁻ (0.20), EC (0.80)	0.1639
73-Ta-182	DEC91	114.7d	β ⁻	-0.0057
73-Ta-182m	DEC91	0.283s	IT	0.1654



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73-Ta-182n	DEC91	15.840m	IT	0.8531
73-Ta-183	JUN94	5.090d	β-(gd) (0.966), β-(m) (0.034)	0.0328
74-W -176	SEP03	2.5h	EC	0.1347
74-W -178	SEP94	21.6d	EC	1.2871
74-W -181	AUG91	120.980d	EC	0.0684
74-W -183m	JUN94	5.250s	IT	0.0409
74-W -185	JAN91	75.1d	β-	0.0001
74-W -185m	JAN91	1.667m	IT	-0.1514
74-W -187	OCT91	23.850h	β-	0.0631
74-W -188	OCT05	69.780d	β-	0.0013
75-Re-183	JAN09	70.0d	EC	0.1119
75-Re-183m	NOV06	1.030E-03s	IT	0.1037
75-Re-184	NOV07	35.400d	EC	0.0468
75-Re-184m	NOV05	168.0d	EC (0.252), IT (0.748)	0.1530
75-Re-186	JUN06	3.750d	β- (0.9313), EC (0.0687)	0.0046
75-Re-186m	JUN06	1.900E+05y	IT	-0.4061
75-Re-191	MAR96	9.7m	β-	0.0000
75-Re-192	MAR96	6.2s	β-	0.0566
76-Os-180	OCT03	21.5m	EC	0.0346
76-Os-185	SEP98	93.8d	EC	0.0570
76-Os-189m	NOV07	5.810h	IT	-0.2464
76-Os-190m	SEP98	9.9m	IT	0.0011
76-Os-191	NOV05	15.3d	β-	0.0000
76-Os-191m	NOV05	13.1h	IT	-0.0030
76-Os-194	JUL06	6.0y	β-	-0.1669
76-Os-195	APR96	6.5m	β-	-0.0396
76-Os-196	AUG03	34.9m	β-	-0.0177
77-Ir-187	OCT00	10.5h	EC	-0.0621
77-Ir-189	DEC08	13.2d	EC(gd) (0.925), EC(m) (0.075)	0.1686
77-Ir-190	FEB03	12.0d	EC	-0.1063
77-Ir-190m	SEP98	1.120h	IT	-0.0849
77-Ir-190n	SEP98	3.087h	IT (0.086), EC (0.914)	0.0893
77-Ir-191m	NOV05	4.9s	IT	0.0772
77-Ir-191n	OCT00	5.5s	IT	0.0097
77-Ir-192	SEP03	73.822d	β- (0.952), EC (0.048)	0.1323
77-Ir-192m	SEP03	1.440m	β- (0.0001750), IT (0.9998250)	-0.0780
77-Ir-192n	SEP03	241.0y	IT	0.0069
77-Ir-193m	AUG08	10.53d	IT	-0.0699
77-Ir-194m	DEC08	0.03183s	IT	0.3813



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77-Ir-194n	DEC08	171.0d	β ⁻	-0.0393
77-Ir-197	OCT00	5.8m	β ⁻	-0.2184
77-Ir-197m	OCT00	8.9m	β ⁻ (0.9975), IT (0.0025)	0.0004
78-Pt-190	JAN08	6.50E+11y	α	-0.0157
78-Pt-193	FEB96	50.00y	EC	2.0682
78-Pt-193m	FEB96	4.340d	IT	-0.3390
78-Pt-195m	OCT06	4.1d	IT	0.2207
78-Pt-197	NOV00	19.892h	β ⁻	0.1082
78-Pt-197m	NOV00	1.588h	β ⁻ (0.033), IT (0.967)	0.1698
78-Pt-202	AUG03	1.833d	β ⁻	0.0000
79-Au-192m	SEP03	0.029s	IT	0.3330
79-Au-192n	SEP03	0.160s	IT	0.0100
79-Au-195	OCT06	186.0d	EC	0.8595
79-Au-195m	OCT06	30.5s	IT	0.0121
79-Au-197m	NOV00	7.740s	IT	-0.0267
79-Au-198	DEC87	2.694d	β ⁻	0.0018
79-Au-198m	APR92	2.3d	IT	Incomplete
79-Au-199	JUN01	3.139d	β ⁻	-0.0640
80-Hg-190	FEB03	20.0m	EC	0.5330
80-Hg-194	JUL06	444.00y	EC	2.4780
80-Hg-197	NOV00	2.692d	EC	0.1223
80-Hg-197m	NOV00	23.9h	EC (0.086), IT (0.914)	0.0878
80-Hg-199m	AUG98	42.1m	IT	0.0441
80-Hg-203	MAR91	46.595d	β ⁻	0.0271
80-Hg-205	JUL01	5.2m	β ⁻	-0.0431
81-Tl-193	JAN01	21.8m	EC	-0.0502
81-Tl-193m	JAN01	2.110m	EC (0.25), IT (0.75)	-0.0042
81-Tl-201	SEP93	3.041d	EC	Incomplete
81-Tl-202	APR94	12.240d	EC	0.0885
81-Tl-204	NOV91	3.790y	β ⁻ (0.978), EC (0.022)	0.0033
82-Pb-201	FEB03	9.4h	EC	0.3405
82-Pb-201m	OCT98	1.017m	IT	0.1220
82-Pb-202	DEC93	5.300E+04y	EC	1.6745
82-Pb-202m	DEC93	3.570h	EC (0.091), IT (0.909)	-0.3569
82-Pb-203	MAR94	2.162d	EC	0.0605
82-Pb-203m	MAR94	6.290s	IT	-0.0116
82-Pb-203n	MAR94	0.480s	IT	0.0625
82-Pb-204	NOV91	1.400E+17y	α	-0.0097
82-Pb-204m	NOV91	1.125h	IT	0.0780



Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
82-Pb-205	DEC93	1.530E+07y	EC	1.9227
82-Pb-205m	JAN10	5.10E-03s	IT	-0.0528
82-Pb-207m	NOV08	0.806s	IT	0.0054
83-Bi-201m	NOV09	55.8m	EC (0.932), IT (0.068), α (3.0000E-05)	0.0087
83-Bi-205	JAN10	15.31d	EC(gd) (0.86), EC(m) (0.14)	-0.1112
83-Bi-207	AUG91	31.760y	EC	0.1833
83-Bi-208	FEB96	3.680E+05y	EC	0.0635
84-Po-208	FEB96	2.930y	EC (1.8100E-05), α (0.9999820)	-0.0380
86-Rn-223	DEC92	24.2m	β^-	-0.3329
90-Th-228	SEP02	1.913y	α	-0.0175
90-Th-231	MAR95	1.063d	β^-	-0.7156
93-Np-239	MAY91	2.355d	β^-	-0.1364
95-Am-241	FEB01	432.808y	α (1.00), SF (3.7700E-12)	0.2443
95-Am-243	FEB03	7.365E+03y	α (1.00), SF (3.7000E-11)	-0.0218

Decay data measurements were unavailable, and therefore theoretical data were adopted from a combination of US ENDF/B-VI (22), Takahashi *et al.* (23) and Audi *et al.* (24).

Incomplete files are described in Section 4.2 of the main text.



Table 2. Summary of Spectral Data

Continuum spectra are indicated by the letter 'c' following the number of discrete spectral lines. Thus, '15c' indicates that there are 15 discrete lines followed by a continuum spectrum, and '0c' indicates that only a continuum spectrum is present.

Nuclide	T _{1/2} (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β ⁻	EC/β ⁺	α	n	SF ⁺	p	e ⁻	X-ray
1-H - 3	3.89105E+08	5.71	0.00	0.00	-	1	-	-	-	-	-	-	-
2-He- 6	8.08100E-01	1561.31	5.64	0.00	-	1	-	-	-	-	-	-	-
2-He- 8	1.22000E-01	4448.62	884.97	141.37	1	2	-	-	1	-	-	-	-
3-Li- 8	8.38000E-01	6204.62	32.98	3125.25	-	1	-	1	-	-	-	-	-
3-Li- 9	1.78300E-01	5696.25	29.90	0.00	-	5	-	-	-	-	-	-	-
4-Be- 7	4.59994E+06	0.00	49.30	0.00	1	-	2	-	-	-	-	-	-
4-Be- 8	7.00000E-17	0.00	0.00	91.90	-	-	-	1	-	-	-	-	-
4-Be- 10	5.04922E+13	252.21	0.00	0.00	-	1	-	-	-	-	-	-	-
4-Be- 11	1.38100E+01	4647.31	1418.78	36.27	8	6	-	1	-	-	-	-	-
5-B - 12	2.02000E-02	6308.41	90.56	6.64	1	4	-	2	-	-	-	-	-
5-B - 13	1.73300E-02	6278.30	313.53	9.76	1	5	-	-	4	-	-	-	-
6-C - 14	1.80825E+11	49.48	0.00	0.00	-	1	-	-	-	-	-	-	-
6-C - 15	2.44900E+00	2856.16	3621.81	0.00	5	6	-	-	-	-	-	-	-
7-N - 13	5.97900E+02	490.11	1020.70	0.00	-	-	1	-	-	-	-	1	2
7-N - 16	7.13000E+00	2679.45	4621.50	0.03	10	7	-	3	-	-	-	-	-
7-N - 17	4.17000E+00	1697.81	44.51	901.13	2	9	-	2	6	-	-	-	-
8-O - 19	2.69100E+01	1709.60	1004.57	0.00	8	3	-	-	-	-	-	-	-
9-F - 18	6.58200E+03	241.49	987.27	0.00	-	-	1	-	-	-	-	1	2
9-F - 20	1.10300E+01	2467.27	1644.68	0.00	2	2	-	-	-	-	-	-	-
9-F - 21	4.15800E+00	2341.83	556.87	0.00	15	7	-	-	-	-	-	4	1
10-Ne- 23	3.72000E+01	1890.05	172.79	0.00	5	4	-	-	-	-	-	-	-



Nuclide	T _{1/2} (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β ⁻	EC/β ⁺	α	n	SF ⁺	p	e ⁻	X-ray
11-Na- 22	8.21444E+07	195.76	2198.92	0.00	1	-	2	-	-	-	-	4	2
11-Na- 24	5.38756E+04	553.60	4122.24	0.00	6	3	-	-	-	-	-	5	2
11-Na- 24m	2.02000E-02	13.77	470.00	0.00	1	1	-	-	-	-	-	-	-
11-Na- 25	5.96000E+01	1496.49	436.90	0.00	10	5	-	-	-	-	-	-	-
11-Na- 26	1.08000E+00	3329.45	2180.29	0.00	19	9	-	-	-	-	-	-	-
12-Mg- 27	5.67480E+02	699.62	894.99	0.00	3	2	-	-	-	-	-	-	-
12-Mg- 28	7.52400E+04	197.86	1379.96	0.00	8	3	-	-	-	-	-	5	3
13-Al- 26	2.27215E+13	446.15	2678.09	0.00	3	-	2	-	-	-	-	2	3
13-Al- 26m	6.34500E+00	1433.75	1026.13	0.00	-	-	1	-	-	-	-	2	3
13-Al- 28	1.34460E+02	1237.60	1782.85	0.00	1	1	-	-	-	-	-	-	-
13-Al- 29	3.93600E+02	972.76	1380.92	0.00	7	4	-	-	-	-	-	-	-
13-Al- 30	3.65000E+00	2290.18	3512.41	0.00	17	7	-	-	-	-	-	-	-
14-Si- 31	9.43200E+03	593.74	2.17	0.00	1	2	-	-	-	-	-	-	-
14-Si- 32	1.04140E+10	64.68	0.00	0.00	-	1	-	-	-	-	-	-	-
15-P - 32	1.23293E+06	692.92	1.71	0.00	-	1	-	-	-	-	-	-	-
15-P - 33	2.19456E+06	76.57	0.00	0.00	-	1	-	-	-	-	-	-	-
15-P - 34	1.24000E+01	2284.55	347.48	0.00	6	5	-	-	-	-	-	-	-
16-S - 35	7.56000E+06	48.83	0.00	0.00	-	1	-	-	-	-	-	-	-
16-S - 37	2.99400E+02	793.24	2936.91	0.00	4	4	-	-	-	-	-	-	-
17-Cl- 34	1.52600E+00	2043.76	1029.20	0.00	-	-	1	-	-	-	-	2	4
17-Cl- 34m	1.92600E+03	441.40	1979.11	0.00	9	-	5	-	-	-	-	8	7
17-Cl- 36	9.68818E+12	246.09	0.03	0.00	-	1	1	-	-	-	-	2	4
17-Cl- 38	2.23200E+03	1522.99	1493.73	0.00	3	3	-	-	-	-	-	-	-
17-Cl- 38m	7.15000E-01	0.43	671.30	0.00	1	-	-	-	-	-	-	5	3
17-Cl- 39	3.33600E+03	822.65	1454.37	0.00	19	7	-	-	-	-	-	12	3



Nuclide	T _{1/2} (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β ⁻	EC/β ⁺	α	n	SF ⁺	p	e ⁻	X-ray
18-Ar- 37	3.02746E+06	2.36	0.32	0.00	-	-	1	-	-	-	-	3	3
18-Ar- 39	8.48899E+09	218.65	0.00	0.00	-	1	-	-	-	-	-	-	-
18-Ar- 41	6.57600E+03	463.60	1284.47	0.00	2	3	-	-	-	-	-	6	3
18-Ar- 42	1.04140E+09	232.82	0.00	0.00	-	1	-	-	-	-	-	-	-
19-K - 38	4.56600E+02	1201.32	3190.50	0.00	3	-	2	-	-	-	-	3	4
19-K - 38m	9.24000E-01	2312.41	1030.62	0.00	-	-	1	-	-	-	-	3	4
19-K - 40	4.03937E+16	521.75	157.20	0.00	1	1	2	-	-	-	-	3	4
19-K - 42	4.45320E+04	1417.12	296.38	0.00	8	5	-	-	-	-	-	-	-
19-K - 43	7.99200E+04	309.56	966.16	0.00	10	5	-	-	-	-	-	12	3
19-K - 44	1.32780E+03	1436.10	2391.27	0.00	122	33	-	-	-	-	-	72	3
20-Ca- 41	3.25043E+12	2.84	0.44	0.00	-	-	1	-	-	-	-	3	3
20-Ca- 45	1.40573E+07	77.22	0.00	0.00	1	2	-	-	-	-	-	6	3
20-Ca- 47	3.92083E+05	344.61	1060.41	0.00	7	4	-	-	-	-	-	6	3
20-Ca- 49	5.23200E+02	869.51	3167.14	0.00	11	6	-	-	-	-	-	-	-
21-Sc- 44	1.41372E+04	595.65	2136.46	0.00	5	-	3	-	-	-	-	6	4
21-Sc- 44m	2.10960E+05	32.82	275.27	0.00	4	-	1	-	-	-	-	12	6
21-Sc- 45m	3.25000E-01	11.71	0.70	0.00	1	-	-	-	-	-	-	6	3
21-Sc- 46	7.23946E+06	112.24	2009.54	0.00	3	2	-	-	-	-	-	9	3
21-Sc- 46m	1.87000E+01	58.90	82.96	0.00	1	-	-	-	-	-	-	6	3
21-Sc- 47	2.89094E+05	162.53	108.53	0.00	1	2	-	-	-	-	-	6	3
21-Sc- 48	1.57212E+05	219.59	3349.60	0.00	5	2	-	-	-	-	-	-	-
21-Sc- 49	3.43200E+03	819.88	3.34	0.00	2	3	-	-	-	-	-	-	-
21-Sc- 50	1.02500E+02	1624.13	3198.10	0.00	10	8	-	-	-	-	-	-	-
21-Sc- 50m	3.50000E-01	40.69	264.40	0.00	2	1	-	-	-	-	-	6	3
22-Ti- 45	1.10880E+04	373.34	871.84	0.00	15	-	6	-	-	-	-	6	4



Nuclide	T _{1/2} (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β ⁻	EC/β ⁺	α	n	SF ⁺	p	e ⁻	X-ray
22-Ti- 51	3.48000E+02	868.93	364.55	0.00	3	2	-	-	-	-	-	6	3
23-V - 48	1.38015E+06	149.28	2915.94	0.00	9	-	6	-	-	-	-	3	4
23-V - 49	2.85120E+07	3.58	0.95	0.00	-	-	1	-	-	-	-	3	3
23-V - 52	2.24700E+02	1064.34	1448.36	0.00	14	8	-	-	-	-	-	15	3
23-V - 53	9.72000E+01	1005.11	1041.59	0.00	7	3	-	-	-	-	-	-	-
23-V - 54	4.98000E+01	1357.52	4097.54	0.00	24	8	-	-	-	-	-	-	-
24-Cr- 49	2.51400E+03	596.49	1047.24	0.00	12	-	8	-	-	-	-	12	4
24-Cr- 51	2.39380E+06	3.85	32.75	0.00	1	-	2	-	-	-	-	6	3
24-Cr- 55	2.12400E+02	1096.51	4.24	0.00	7	5	-	-	-	-	-	6	3
25-Mn- 53	1.16132E+14	4.00	1.42	0.00	-	-	1	-	-	-	-	3	3
25-Mn- 54	2.69827E+07	4.21	836.04	0.00	1	-	1	-	-	-	-	9	6
25-Mn- 56	9.28440E+03	823.81	1700.66	0.00	10	7	-	-	-	-	-	-	-
25-Mn- 58	6.52000E+01	1711.42	2382.19	0.00	39	14	-	-	-	-	-	27	3
25-Mn- 58m	2.70000E+00	2828.39	120.07	0.00	9	4	-	-	-	-	-	9	3
26-Fe- 53	5.10600E+02	1106.98	1184.25	0.00	10	-	8	-	-	-	-	6	4
26-Fe- 53m	1.54800E+02	0.00	3034.68	0.00	6	-	-	-	-	-	-	-	-
26-Fe- 55	8.63136E+07	4.22	1.67	0.00	-	-	1	-	-	-	-	3	3
26-Fe- 59	3.84497E+06	117.89	1189.21	0.00	8	5	-	-	-	-	-	18	3
26-Fe- 60	4.73364E+13	87.67	0.00	0.00	-	1	-	-	-	-	-	-	-
26-Fe- 63	6.10000E+00	2604.28	317.73	0.00	19	14	-	-	-	-	-	21	3
27-Co- 55	6.31080E+04	436.58	2007.03	0.00	23	-	10	-	-	-	-	24	4
27-Co- 56	6.67526E+06	121.02	3589.76	0.00	45	-	13	-	-	-	-	30	4
27-Co- 57	2.34827E+07	20.01	123.99	0.00	10	-	2	-	-	-	-	33	3
27-Co- 58	6.12230E+06	34.31	976.20	0.00	3	-	3	-	-	-	-	12	4
27-Co- 58m	3.21840E+04	23.15	1.82	0.00	1	-	-	-	-	-	-	6	3



Nuclide	T _{1/2} (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β ⁻	EC/β ⁺	α	n	SF ⁺	p	e ⁻	X-ray
27-Co- 60	1.66363E+08	96.71	2503.95	0.00	6	3	-	-	-	-	-	15	3
27-Co- 60m	6.28200E+02	56.50	6.79	0.00	4	2	-	-	-	-	-	15	6
28-Ni- 57	1.28520E+05	162.12	1960.02	0.00	24	-	9	-	-	-	-	18	4
28-Ni- 59	2.39838E+12	4.62	2.54	0.00	-	-	1	-	-	-	-	3	4
28-Ni- 63	3.12420E+09	17.14	0.00	0.00	-	1	-	-	-	-	-	-	-
28-Ni- 65	9.07200E+03	629.70	549.93	0.00	10	5	-	-	-	-	-	18	3
28-Ni- 66	1.95840E+05	65.24	0.00	0.00	-	1	-	-	-	-	-	-	-
28-Ni- 67	2.10000E+01	1523.24	50.25	0.00	7	6	-	-	-	-	-	-	-
29-Cu- 62	5.85000E+02	1282.90	1011.69	0.00	16	-	10	-	-	-	-	3	4
29-Cu- 64	4.57272E+04	125.75	190.56	0.00	1	1	2	-	-	-	-	3	4
29-Cu- 66	3.06000E+02	1070.64	81.86	0.00	3	4	-	-	-	-	-	-	-
29-Cu- 67	2.22840E+05	155.67	115.41	0.00	6	4	-	-	-	-	-	21	3
30-Zn- 63	2.30400E+03	916.73	1104.23	0.00	64	-	20	-	-	-	-	33	4
30-Zn- 65	2.11041E+07	6.98	582.52	0.00	3	-	2	-	-	-	-	6	4
30-Zn- 69	3.38400E+03	322.90	0.01	0.00	2	3	-	-	-	-	-	9	3
30-Zn- 69m	4.96080E+04	22.38	416.43	0.00	2	1	-	-	-	-	-	12	6
31-Ga- 67	2.81768E+05	35.98	159.15	0.00	10	-	5	-	-	-	-	33	3
31-Ga- 70	1.26840E+03	640.49	9.18	0.00	3	3	1	-	-	-	-	12	8
31-Ga- 77	1.30000E+01	2111.68	457.02	0.00	14	9	-	-	-	-	-	21	5
32-Ge- 71	9.87552E+05	5.14	4.2	0.00	-	-	1	-	-	-	-	3	3
32-Ge- 71m	2.04000E-02	33.27	165.17	0.00	2	-	-	-	-	-	-	9	5
32-Ge- 73m	5.00000E-01	55.61	11.35	0.00	2	-	-	-	-	-	-	9	5
32-Ge- 75	4.96680E+03	419.78	34.73	0.00	11	5	-	-	-	-	-	18	5
32-Ge- 75m	4.80000E+01	81.87	58.06	0.00	14	1	-	-	-	-	-	48	10
32-Ge- 80	2.70000E+01	949.23	342.75	0.00	17	9	-	-	-	-	-	33	5
33-As- 73	6.93792E+06	5.23	4.76	0.00	-	-	1	-	-	-	-	3	5



Nuclide	T _{1/2} (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β ⁻	EC/β ⁺	α	n	SF ⁺	p	e ⁻	X-ray
33-As- 74	1.53619E+06	268.31	759.66	0.00	14	3	6	-	-	-	-	15	11
33-As- 76	9.43920E+04	1063.82	419.75	0.00	61	22	-	-	-	-	-	69	5
33-As- 82	2.00000E+01	3156.07	343.10	0.00	17	13	-	-	-	-	-	9	5
33-As- 82m	1.36000E+01	2037.24	2969.60	0.00	13	6	-	-	-	-	-	15	5
33-As- 85	2.04000E+00	3380.98	358.54	151.84	10	14	-	-	11	-	-	24	5
34-Se- 75	1.03369E+07	14.65	390.20	0.00	20	-	9	-	-	-	-	36	5
34-Se- 77m	1.75500E+01	73.28	88.81	0.00	1	-	-	-	-	-	-	6	5
34-Se- 79	1.18970E+13	52.55	0.00	0.00	-	1	-	-	-	-	-	-	-
34-Se- 79m	2.34000E+02	81.87	13.96	0.00	1	1	-	-	-	-	-	6	5
34-Se- 81	1.10340E+03	609.06	8.55	0.00	11	7	-	-	-	-	-	30	5
34-Se- 81m	3.43680E+03	85.40	18.03	0.00	8	2	-	-	-	-	-	30	10
35-Br- 72	7.86000E+01	2716.91	2921.83	0.00	35	-	13	-	-	-	-	57	6
35-Br- 72m	1.06000E+01	50.88	50.00	0.00	1	-	-	-	-	-	-	6	5
35-Br- 77	2.05326E+05	7.97	318.88	0.00	60	-	14	-	-	-	-	161	6
35-Br- 79m	4.88000E+00	50.00	157.16	0.00	1	-	-	-	-	-	-	6	5
35-Br- 80	1.05600E+03	724.04	77.00	0.00	6	4	3	-	-	-	-	24	12
35-Br- 80m	1.58760E+04	61.76	24.26	0.00	2	-	-	-	-	-	-	9	5
35-Br- 82	1.27152E+05	142.69	2638.03	0.00	34	6	-	-	-	-	-	60	6
35-Br- 82m	3.65400E+02	70.09	8.18	0.00	26	11	-	-	-	-	-	33	11
35-Br- 87	5.57000E+01	1576.66	3089.26	3.78	374	181	-	-	24	-	-	51	6
35-Br- 88	1.65000E+01	2393.53	3112.18	8.07	167	66	-	-	2	-	-	75	6
35-Br- 89	4.37000E+00	2572.12	1711.12	6.48	116	60	-	-	5	-	-	27	6
35-Br- 90	1.90000E+00	3290.29	1537.77	21.91	75	47	-	-	6	-	-	12	6
35-Br- 91	5.38000E-01	3908.96	451.19	10.00	4	6	-	-	1	-	-	15	6
36-Kr- 79	1.26144E+05	24.63	257.77	0.00	41	-	11	-	-	-	-	57	6



Nuclide	T _{1/2} (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β ⁻	EC/β ⁺	α	n	SF ⁺	p	e ⁻	X-ray
36-Kr- 79m	5.00000E+01	90.06	39.80	0.00	1	-	-	-	-	-	-	6	6
36-Kr- 81	6.62710E+12	5.39	7.37	0.00	1	-	2	-	-	-	-	6	5
36-Kr- 81m	1.32000E+01	58.77	131.72	0.00	1	-	1	-	-	-	-	9	11
36-Kr- 83m	6.58800E+03	39.12	2.70	0.00	2	-	-	-	-	-	-	8	6
36-Kr- 85	3.38602E+08	250.65	2.23	0.00	3	2	-	-	-	-	-	12	6
36-Kr- 85m	1.61280E+04	255.51	157.18	0.00	7	3	-	-	-	-	-	27	12
37-Rb- 83	7.44768E+06	8.64	496.07	0.00	11	-	6	-	-	-	-	35	6
37-Rb- 84	2.89440E+06	144.04	887.23	0.00	3	1	3	-	-	-	-	3	7
37-Rb- 84m	1.22400E+03	80.18	382.88	0.00	3	-	-	-	-	-	-	12	6
37-Rb- 86	1.60963E+06	665.79	96.75	0.00	1	2	1	-	-	-	-	3	6
37-Rb- 86m	6.10000E+01	9.96	546.02	0.00	1	-	-	-	-	-	-	6	6
37-Rb- 89	9.24000E+02	929.24	2234.21	0.00	62	22	-	-	-	-	-	114	6
37-Rb- 93	5.80000E+00	2117.68	2602.36	4.15	272	92	-	-	27	-	-	48	6
37-Rb- 94	2.70200E+00	3101.54	2747.43	10.05	161	87	-	-	8	-	-	72	6
37-Rb- 95	3.81000E-01	2828.94	2642.12	7.85	252	88	-	-	15	-	-	60	6
38-Sr- 83	1.16676E+05	148.99	776.22	0.00	120	-	23	-	-	-	-	122	7
38-Sr- 83m	4.95000E+00	31.17	228.09	0.00	1	-	-	-	-	-	-	6	6
38-Sr- 85	5.60295E+06	9.16	518.50	0.00	7	-	3	-	-	-	-	15	6
38-Sr- 85m	4.05660E+03	13.25	215.91	0.00	11	-	4	-	-	-	-	26	12
38-Sr- 87m	1.01376E+04	66.56	320.89	0.00	1	-	1	-	-	-	-	9	12
38-Sr- 89	4.36493E+06	582.30	1.29	0.00	-	2	-	-	-	-	-	-	-
38-Sr- 90	9.11002E+08	195.71	0.00	0.00	-	1	-	-	-	-	-	-	-
38-Sr- 92	9.75600E+03	179.90	1380.97	0.00	9	3	-	-	-	-	-	15	6
38-Sr- 94	7.53000E+01	833.17	1427.32	0.00	16	8	-	-	-	-	-	45	6
39-Y - 87	2.87280E+05	7.2	461.66	0.00	1	-	2	-	-	-	-	6	7



Nuclide	T _{1/2} (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β ⁻	EC/β ⁺	α	n	SF ⁺	p	e ⁻	X-ray
39-Y – 87m	4.81320E+04	78.65	308.17	0.00	1	-	1	-	-	-	-	9	13
39-Y - 88	9.21283E+06	6.77	2696.62	0.00	7	-	4	-	-	-	-	9	7
39-Y - 89m	1.60500E+01	7.71	901.36	0.00	1	-	-	-	-	-	-	6	6
39-Y - 90	2.30400E+05	930.62	2.87	0.00	3	3	-	-	-	-	-	3	-
39-Y – 90m	1.14840E+04	46.44	635.23	0.00	3	1	-	-	-	-	-	12	6
39-Y - 91	5.07168E+06	602.41	5.00	0.00	1	2	-	-	-	-	-	-	-
39-Y - 91m	2.98320E+03	27.99	527.61	0.00	1	-	-	-	-	-	-	6	6
39-Y - 96	5.37000E+00	3179.25	95.61	0.00	64	43	-	-	-	-	-	48	6
39-Y - 96m	9.62000E+00	1851.14	4486.45	0.00	59	15	-	-	-	-	-	117	6
39-Y - 97	3.75000E+00	2135.04	1845.99	0.12	25	11	-	-	1	-	-	30	6
39-Y - 97m	1.17000E+00	2317.49	2110.63	0.14	63	24	-	-	1	-	-	54	12
39-Y - 97n	1.42000E-01	120.75	2807.45	0.00	47	1	-	-	-	-	-	84	12
39-Y - 98	5.90000E-01	2779.90	2613.36	1.04	32	12	-	-	0c	-	-	54	6
39-Y - 98m	2.00000E+00	2788.18	3294.44	15.76	28	9	-	-	0c	-	-	54	6
39-Y - 99	1.47700E+00	2948.70	916.74	7.36	117	39	-	-	0c	-	-	213	6
39-Y -104	1.30000E-01	3494.00	3750.00	49.48	0c	0c	-	-	0c	-	-	-	-
39-Y -105	1.50000E-01	3325.00	2372.00	123.48	0c	0c	-	-	0c	-	-	-	-
40-Zr- 88	7.20576E+06	16.09	391.81	0.00	1	-	1	-	-	-	-	6	6
40-Zr- 89	2.82240E+05	92.78	253.88	0.00	4	-	5	-	-	-	-	3	7
40-Zr- 89m	2.50800E+02	32.74	638.03	0.00	2	-	2	-	-	-	-	9	13
40-Zr- 90m	8.08200E-01	16.2	2303.78	0.00	5	-	-	-	-	-	-	12	6
40-Zr- 93	4.82821E+13	19.18	0.00	0.00	-	2	-	-	-	-	-	-	-
40-Zr- 95	5.53219E+06	118.03	730.54	0.00	2	4	-	-	-	-	-	-	-
40-Zr- 99	2.20000E+00	1538.96	841.41	0.00	14	6	-	-	-	-	-	42	6
40-Zr-105	6.00000E-01	2662.00	1764.00	4.47	0c	0c	-	-	0c	-	-	-	-
40-Zr-106	9.00000E-01	2138.00	1091.00	5.80	0c	0c	-	-	0c	-	-	-	-



Nuclide	T _{1/2} (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β ⁻	EC/β ⁺	α	n	SF ⁺	p	e ⁻	X-ray
40-Zr-107	2.40000E-01	2982.00	2201.00	17.51	0c	0c	-	-	0c	-	-	-	-
41-Nb- 90	5.25240E+04	391.77	1960.33	0.00	33	-	9	-	-	-	-	45	7
41-Nb- 90m	1.88100E+01	42.3	82.38	0.00	2	-	-	-	-	-	-	7	6
41-Nb- 90n	6.22000E-03	38.7	218.55	0.00	1	-	-	-	-	-	-	6	6
41-Nb- 91	2.14592E+10	5.88	12.57	0.00	-	-	1	-	-	-	-	3	7
41-Nb- 91m	5.26176E+06	93.46	38.03	0.00	2	-	1	-	-	-	-	9	12
41-Nb- 92	1.10452E+15	7.93	1503.31	0.00	2	-	1	-	-	-	-	9	6
41-Nb- 92m	8.76960E+05	6.45	970.38	0.00	6	-	5	-	-	-	-	15	7
41-Nb- 93m	5.08698E+08	28.85	2.05	0.00	1	-	-	-	-	-	-	6	6
41-Nb- 94	6.30720E+11	168.27	1571.53	0.00	2	1	-	-	-	-	-	9	6
41-Nb- 94m	3.75600E+02	35.09	12.27	0.00	4	3	-	-	-	-	-	15	6
41-Nb- 95	3.02184E+06	44.60	764.35	0.00	3	3	-	-	-	-	-	12	6
41-Nb- 95m	3.11760E+05	173.65	71.68	0.00	5	4	-	-	-	-	-	12	12
41-Nb- 96	8.40600E+04	250.16	2445.75	0.00	39	8	-	-	-	-	-	93	6
41-Nb-100	1.40000E+00	2443.19	744.36	0.00	40	19	-	-	-	-	-	66	6
41-Nb-100m	2.90000E+00	2047.30	2064.43	0.00	22	7	-	-	-	-	-	69	6
41-Nb-109	1.90000E-01	3158.00	2263.00	68.40	0c	0c	-	-	0c	-	-	-	-
42-Mo- 93	9.50400E+10	5.65	10.94	0.00	-	-	2	-	-	-	-	3	6
42-Mo- 93m	2.46600E+04	107.21	2317.51	0.00	13	-	2	-	-	-	-	15	12
42-Mo- 99	2.37420E+05	392.36	146.76	0.00	35	12	-	-	-	-	-	42	6
42-Mo-103	6.79000E+01	1316.28	636.20	0.00	43	17	-	-	-	-	-	90	6
42-Mo-109	5.00000E-01	2675.00	1876.00	0.91	0c	0c	-	-	0c	-	-	-	-
42-Mo-111	5.00000E-01	3098.00	2413.00	3.57	0c	0c	-	-	0c	-	-	-	-
42-Mo-112	1.00000E+00	2552.00	1354.00	7.96	0c	0c	-	-	0c	-	-	-	-
43-Tc- 97	8.20498E+13	5.65	11.68	0.00	-	-	1	-	-	-	-	3	6
43-Tc- 97m	7.79328E+06	87.04	9.50	0.00	1	-	-	-	-	-	-	6	6



Nuclide	T _{1/2} (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β ⁻	EC/β ⁺	α	n	SF ⁺	p	e ⁻	X-ray
43-Tc- 98	1.35695E+14	122.72	1394.91	0.00	2	1	-	-	-	-	-	9	6
43-Tc- 99m	2.16360E+04	16.13	126.48	0.00	6	3	-	-	-	-	-	22	12
43-Tc-113	1.30000E-01	2732.00	1822.00	33.53	0c	0c	-	-	0c	-	-	-	-
43-Tc-114	2.00000E-01	3578.00	3257.00	32.88	0c	0c	-	-	0c	-	-	-	-
43-Tc-115	2.70000E-01	2995.00	2162.00	79.74	0c	0c	-	-	0c	-	-	-	-
43-Tc-116	1.20000E-01	3693.00	3495.00	71.73	0c	0c	-	-	0c	-	-	-	-
43-Tc-99	6.66812E+12	100.98	0.00	0.00	1	2	-	-	-	-	-	6	6
44-Ru-103	3.39206E+06	66.45	497.68	0.00	18	6	-	-	-	-	-	57	6
44-Ru-115	7.00000E-01	2538.00	1806.00	0.61	0c	0c	-	-	0c	-	-	-	-
44-Ru-116	1.70000E+00	1843.00	986.00	3.61	0c	0c	-	-	0c	-	-	-	-
44-Ru-117	3.40000E-01	2697.00	2026.00	8.31	0c	0c	-	-	0c	-	-	-	-
44-Ru-118	7.00000E-01	2094.00	1118.00	17.80	0c	0c	-	-	0c	-	-	-	-
44-Ru-119	1.90000E-01	2920.00	2311.00	20.66	0c	0c	-	-	0c	-	-	-	-
45-Rh-101	1.00982E+08	28.04	312.04	0.00	8	-	3	-	-	-	-	27	6
45-Rh-101m	3.75840E+05	20.17	305.55	0.00	10	-	2	-	-	-	-	36	12
45-Rh-102	9.15840E+07	12.16	2122.05	0.00	16	-	2	-	-	-	-	33	6
45-Rh-102m	1.79712E+07	173.60	493.17	0.00	30	2	7	-	-	-	-	57	19
45-Rh-103m	3.36690E+03	38.21	1.70	0.00	1	-	-	-	-	-	-	6	6
45-Rh-104	4.23000E+01	980.49	15.02	0.00	17	7	3	-	-	-	-	30	13
45-Rh-104m	2.60400E+02	86.20	45.52	0.00	22	7	-	-	-	-	-	27	12
45-Rh-105	1.27368E+05	153.21	78.04	0.00	5	4	-	-	-	-	-	18	6
45-Rh-105m	4.00000E+01	95.24	34.60	0.00	1	-	-	-	-	-	-	6	6
45-Rh-106	3.01000E+01	1401.28	218.09	0.00	87	36	-	-	-	-	-	48	6
45-Rh-106m	7.92000E+03	321.63	2759.22	0.00	40	5	-	-	-	-	-	84	6
45-Rh-110	2.85000E+01	1182.14	2553.61	0.00	25	5	-	-	-	-	-	45	6



Nuclide	T _{1/2} (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β ⁻	EC/β ⁺	α	n	SF ⁺	p	e ⁻	X-ray
45-Rh-110m	3.20000E+00	2266.23	335.96	0.00	8	6	-	-	-	-	-	27	6
45-Rh-111	1.20000E+01	1389.42	357.05	0.00	43	13	-	-	-	-	-	96	6
45-Rh-118	3.20000E-01	3094.00	2494.00	12.16	0c	0c	-	-	0c	-	-	-	-
45-Rh-120	1.70000E-01	3261.00	2837.00	29.19	0c	0c	-	-	0c	-	-	-	-
45-Rh-121	2.50000E-01	2671.00	1852.00	74.06	0c	0c	-	-	0c	-	-	-	-
46-Pd-103	1.46707E+06	5.88	14.68	0.00	8	-	4	-	-	-	-	27	6
46-Pd-107	2.05124E+14	9.40	0.00	0.00	-	1	-	-	-	-	-	-	-
46-Pd-107m	2.13000E+01	62.99	151.84	0.00	1	-	-	-	-	-	-	6	6
46-Pd-109	4.84560E+04	359.82	1.05	0.00	31	12	-	-	-	-	-	84	6
46-Pd-109m	2.82600E+02	77.49	111.43	0.00	1	-	-	-	-	-	-	6	6
46-Pd-112	7.30800E+04	89.90	5.25	0.00	1	1	-	-	-	-	-	4	2
46-Pd-113	9.10000E+01	1330.18	127.55	0.00	33	14	-	-	-	-	-	90	6
46-Pd-113m	3.00000E-01	59.42	21.40	0.00	1	-	-	-	-	-	-	6	6
46-Pd-121	6.00000E-01	2335.00	1638.00	0.75	0c	0c	-	-	0c	-	-	-	-
47-Ag-105	3.56832E+06	19.93	530.41	0.00	62	-	9	-	-	-	-	120	6
47-Ag-105m	4.33800E+02	25.34	1.22	0.00	20	-	9	-	-	-	-	34	8
47-Ag-106	1.44000E+03	503.52	705.98	0.00	36	1	17	-	-	-	-	30	7
47-Ag-106m	7.30944E+05	12.27	2754.44	0.00	57	-	5	-	-	-	-	87	6
47-Ag-107m	4.41000E+01	80.67	12.51	0.00	1	-	-	-	-	-	-	6	6
47-Ag-108	1.44000E+02	605.53	22.83	0.00	13	2	6	-	-	-	-	24	13
47-Ag-108m	1.31911E+10	16.04	1630.06	0.00	5	-	1	-	-	-	-	21	12
47-Ag-109m	3.97000E+01	76.74	11.30	0.00	1	-	-	-	-	-	-	6	6
47-Ag-110	2.47000E+01	1174.85	34.77	0.00	15	11	2	-	-	-	-	24	12
47-Ag-110m	2.15819E+07	69.02	2760.64	0.00	61	9	-	-	-	-	-	46	12
47-Ag-111	6.43680E+05	353.29	26.34	0.00	14	7	-	-	-	-	-	45	6



Nuclide	T _{1/2} (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β ⁻	EC/β ⁺	α	n	SF ⁺	p	e ⁻	X-ray
47-Ag-111m	6.48000E+01	56.01	6.88	0.00	11	4	-	-	-	-	-	39	12
47-Ag-114	4.70000E+00	2096.51	271.79	0.00	43	26	-	-	-	-	-	36	6
47-Ag-114m	1.50000E-03	101.88	97.12	0.00	4	-	-	-	-	-	-	15	6
47-Ag-115	1.23000E+03	779.22	1132.27	0.00	145	44	-	-	-	-	-	93	6
47-Ag-115m	1.86000E+01	844.05	454.99	0.00	25	10	-	-	-	-	-	66	12
48-Cd-107	2.34720E+04	6.27	21.24	0.00	35	-	12	-	-	-	-	81	7
48-Cd-109	3.99686E+07	5.71	15.15	0.00	-	-	1	-	-	-	-	3	6
48-Cd-111m	2.92440E+03	109.59	286.67	0.00	2	-	-	-	-	-	-	9	6
48-Cd-113	2.46144E+23	92.59	0.00	0.00	-	1	-	-	-	-	-	-	-
48-Cd-113m	4.60731E+08	184.49	0.07	0.00	1	1	-	-	-	-	-	6	6
48-Cd-115	1.92456E+05	317.32	192.90	0.00	16	7	-	-	-	-	-	39	6
48-Cd-115m	3.84048E+06	602.48	33.63	0.00	25	8	-	-	-	-	-	60	6
49-In-111	2.42326E+05	33.49	406.47	0.00	2	-	2	-	-	-	-	9	6
49-In-111m	4.74000E+02	67.84	469.64	0.00	1	-	-	-	-	-	-	6	6
49-In-112	8.82000E+02	245.21	290.19	0.00	16	1	9	-	-	-	-	30	7
49-In-112m	1.24200E+03	122.20	34.56	0.00	1	-	-	-	-	-	-	6	6
49-In-113m	5.96880E+03	131.33	260.35	0.00	1	-	-	-	-	-	-	6	6
49-In-114	7.19000E+01	769.23	4.37	0.00	3	2	2	-	-	-	-	3	7
49-In-114m	4.32000E+06	140.90	88.99	0.00	3	-	1	-	-	-	-	9	12
49-In-114n	4.30000E-02	33.96	277.66	0.00	1	-	-	-	-	-	-	6	6
49-In-115	1.39169E+22	207.88	0.00	0.00	-	1	-	-	-	-	-	-	-
49-In-115m	1.61496E+04	170.99	162.50	0.00	2	2	-	-	-	-	-	12	12
49-In-116	1.42000E+01	1356.65	5.27	0.00	11	8	-	-	-	-	-	21	6
49-In-116m	3.27600E+03	312.60	2490.78	0.00	40	7	-	-	-	-	-	114	6
49-In-116n	2.17000E+00	94.12	68.17	0.00	1	-	-	-	-	-	-	6	6



Nuclide	T _{1/2} (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β ⁻	EC/β ⁺	α	n	SF ⁺	p	e ⁻	X-ray
50-Sn-110	1.47600E+04	14.17	290.43	0.00	1	-	1	-	-	-	-	6	6
50-Sn-113	9.94378E+06	6.27	23.25	0.00	3	-	3	-	-	-	-	6	6
50-Sn-113m	1.25400E+03	58.58	14.48	0.00	1	-	1	-	-	-	-	9	12
50-Sn-117m	1.17504E+06	158.24	156.34	0.00	3	-	-	-	-	-	-	12	6
50-Sn-119m	2.53152E+07	78.26	11.36	0.00	2	-	-	-	-	-	-	8	6
50-Sn-121	9.71640E+04	115.89	0.00	0.00	-	1	-	-	-	-	-	-	-
50-Sn-121m	1.38535E+09	35.49	5.11	0.00	2	1	-	-	-	-	-	10	8
50-Sn-123	1.11629E+07	519.90	8.00	0.00	9	6	-	-	-	-	-	6	6
50-Sn-123m	2.40600E+03	475.46	141.20	0.00	5	3	-	-	-	-	-	6	6
50-Sn-125	8.32896E+05	805.01	316.10	0.00	49	15	-	-	-	-	-	60	6
50-Sn-125m	5.71800E+02	800.53	348.27	0.00	26	11	-	-	-	-	-	33	6
50-Sn-126	7.25809E+12	109.32	56.4	0.00	6	1	-	-	-	-	-	19	6
50-Sn-129	1.33800E+02	1097.58	1350.01	0.00	70	31	-	-	-	-	-	99	6
50-Sn-129m	4.32000E+02	705.53	1707.46	0.00	81	32	-	-	-	-	-	137	6
50-Sn-130	2.23800E+02	462.10	937.55	0.00	33	9	-	-	-	-	-	42	6
50-Sn-130m	1.02000E+02	1388.46	813.03	0.00	93	48	-	-	-	-	-	51	6
51-Sb-119	1.37880E+05	25.97	23.42	0.00	1	-	1	-	-	-	-	5	6
51-Sb-120	9.54000E+02	306.76	460.03	0.00	3	-	4	-	-	-	-	12	7
51-Sb-120m	4.97664E+05	45.05	2462.26	0.00	5	-	1	-	-	-	-	15	6
51-Sb-122	2.32920E+05	564.67	437.88	0.00	8	6	2	-	-	-	-	3	7
51-Sb-122m	2.51400E+02	93.06	70.53	0.00	3	-	-	-	-	-	-	11	6
51-Sb-124	5.20474E+06	381.74	1863.29	0.00	66	21	-	-	-	-	-	45	6
51-Sb-124m	9.30000E+01	114.07	437.54	0.00	5	3	-	-	-	-	-	16	8
51-Sb-124n	1.21200E+03	25.77	0.34	0.00	1	-	-	-	-	-	-	4	2
51-Sb-125	8.70653E+07	101.08	430.25	0.00	24	8	-	-	-	-	-	74	6



Nuclide	T _{1/2} (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β ⁻	EC/β ⁺	α	n	SF ⁺	p	e ⁻	X-ray
51-Sb-126	1.07222E+06	332.68	2752.52	0.00	27	14	-	-	-	-	-	84	6
51-Sb-126m	1.14600E+03	624.77	1575.98	0.00	9	4	-	-	-	-	-	31	8
51-Sb-126n	1.10000E+01	22.44	0.38	0.00	1	-	-	-	-	-	-	4	2
51-Sb-127	3.31776E+05	314.67	658.38	0.00	36	15	-	-	-	-	-	96	6
51-Sb-129	1.56960E+04	354.83	1380.09	0.00	70	30	-	-	-	-	-	48	6
51-Sb-129m	1.06200E+03	998.86	1477.98	0.00	37	8	-	-	-	-	-	42	12
51-Sb-135	1.74000E+00	2966.53	688.10	177.09	41	26	-	-	8	-	-	51	6
51-Sb-141	3.00000E-01	3511.07	3275.00	85.00	-	-	-	-	-	-	-	-	-
52-Te-121	1.65542E+06	9.84	577.47	0.00	5	-	2	-	-	-	-	18	6
52-Te-121m	1.33056E+07	80.09	216.95	0.00	12	-	6	-	-	-	-	42	13
52-Te-125m	5.01120E+06	108.78	36.00	0.00	3	-	-	-	-	-	-	12	6
52-Te-127	3.36600E+04	224.40	4.85	0.00	9	5	-	-	-	-	-	30	6
52-Te-127m	9.41760E+06	82.14	11.58	0.00	6	4	-	-	-	-	-	24	12
52-Te-129	4.17600E+03	543.03	60.45	0.00	58	11	-	-	-	-	-	71	6
52-Te-129m	2.90304E+06	266.52	38.83	0.00	40	9	-	-	-	-	-	104	12
52-Te-132	2.79072E+05	103.13	233.69	0.00	4	1	-	-	-	-	-	15	6
53-I -125	5.13475E+06	19.22	42.44	0.00	1	-	1	-	-	-	-	6	6
53-I -126	1.12147E+06	143.82	435.63	0.00	10	3	6	-	-	-	-	21	13
53-I -132	8.21880E+03	489.82	2255.72	0.00	165	34	-	-	-	-	-	282	6
53-I -132m	4.98000E+03	162.74	344.82	0.00	9	4	-	-	-	-	-	29	12
53-I -137	2.45100E+01	1861.83	1219.64	39.38	272	178	-	-	38	-	-	102	6
53-I -138	6.46000E+00	2720.49	1324.93	5.29	100	54	-	-	9	-	-	39	6
53-I -139	2.30000E+00	2532.93	672.34	11.12	111	44	-	-	6	-	-	115	6
54-Xe-125	6.08400E+04	34.51	270.53	0.00	35	-	11	-	-	-	-	36	7
54-Xe-125m	5.60000E+01	136.39	116.06	0.00	2	-	-	-	-	-	-	9	6



Nuclide	T _{1/2} (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β ⁻	EC/β ⁺	α	n	SF ⁺	p	e ⁻	X-ray
54-Xe-127	3.14842E+06	32.50	280.66	0.00	6	-	3	-	-	-	-	21	6
54-Xe-127m	6.96000E+01	128.74	168.48	0.00	2	-	-	-	-	-	-	9	6
54-Xe-129m	7.67232E+05	183.89	51.92	0.00	2	-	-	-	-	-	-	9	6
54-Xe-131m	1.02557E+06	142.62	21.20	0.00	1	-	-	-	-	-	-	6	6
54-Xe-133	4.52995E+05	135.67	46.19	0.00	6	3	-	-	-	-	-	21	6
54-Xe-133m	1.89216E+05	192.38	40.79	0.00	1	-	-	-	-	-	-	6	6
54-Xe-134m	2.90000E-01	69.26	1896.07	0.00	3	-	-	-	-	-	-	12	6
55-Cs-123	3.54600E+02	942.45	1067.53	0.00	64	-	25	-	-	-	-	111	7
55-Cs-123m	1.70000E+00	112.15	44.13	0.00	4	-	-	-	-	-	-	14	6
55-Cs-129	1.15920E+05	17.42	283.21	0.00	30	-	8	-	-	-	-	87	6
55-Cs-131	8.37216E+05	6.37	23.12	0.00	-	-	1	-	-	-	-	3	6
55-Cs-132	5.64192E+05	14.11	715.25	0.00	13	2	4	-	-	-	-	45	13
55-Cs-134	6.51698E+07	163.39	1554.09	0.00	12	3	1	-	-	-	-	42	12
55-Cs-134m	1.04688E+04	111.78	27.08	0.00	3	-	-	-	-	-	-	11	6
55-Cs-135	7.57382E+13	66.86	0.00	0.00	-	1	-	-	-	-	-	-	-
55-Cs-135m	3.18000E+03	36.92	1596.54	0.00	2	-	-	-	-	-	-	9	6
55-Cs-136	1.12579E+06	141.89	2145.59	0.00	23	7	-	-	-	-	-	60	6
55-Cs-136m	1.90000E+01	616.67	616.67	0.00	-	-	-	-	-	-	-	-	-
55-Cs-137	9.52128E+08	186.54	0.04	0.00	-	2	-	-	-	-	-	-	-
56-Ba-126	6.00000E+03	18.13	565.11	0.00	90	-	26	-	-	-	-	114	7
56-Ba-129	8.56800E+03	127.27	466.47	0.00	94	-	8	-	-	-	-	209	7
56-Ba-129m	7.70400E+03	69.10	1207.46	0.00	95	-	12	-	-	-	-	206	7
56-Ba-131	9.97920E+05	46.25	459.52	0.00	62	-	12	-	-	-	-	177	7
56-Ba-131m	8.76000E+02	110.09	77.15	0.00	2	-	-	-	-	-	-	9	6
56-Ba-133	3.33677E+08	53.64	402.64	0.00	9	-	2	-	-	-	-	30	6



Nuclide	T _{1/2} (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β ⁻	EC/β ⁺	α	n	SF ⁺	p	e ⁻	X-ray
56-Ba-133m	1.37520E+05	221.61	66.91	0.00	4	-	1	-	-	-	-	17	12
56-Ba-137m	1.53180E+02	62.93	598.61	0.00	1	-	-	-	-	-	-	6	6
57-La-137	1.89346E+12	6.55	25.59	0.00	-	-	1	-	-	-	-	3	6
57-La-140	1.45026E+05	535.11	2312.59	0.00	39	18	-	-	-	-	-	74	6
57-La-152	2.80000E-01	2355.00	2885.00	23.97	0c	0c	-	-	0c	-	-	-	-
58-Ce-139	1.18930E+07	34.16	161.39	0.00	1	-	1	-	-	-	-	6	6
58-Ce-139m	5.61000E+01	55.09	699.12	0.00	1	-	-	-	-	-	-	6	6
58-Ce-145	1.77000E+02	762.59	601.03	0.00	88	22	-	-	-	-	-	153	6
58-Ce-147	5.70000E+01	1282.00	174.16	0.00	50	20	-	-	-	-	-	147	6
58-Ce-149	5.30000E+00	1818.17	84.56	0.00	21	12	-	-	-	-	-	57	6
58-Ce-153	1.50000E+00	1680.00	1125.00	1.57	0c	0c	-	-	0c	-	-	-	-
58-Ce-154	2.00000E+00	1694.00	958.70	1.62	0c	0c	-	-	0c	-	-	-	-
58-Ce-158	1.00000E+00	2441.75	2277.00	1.70	-	-	-	-	-	-	-	-	-
59-Pr-143	1.17158E+06	314.60	0.00	0.00	1	2	-	-	-	-	-	3	-
59-Pr-144	1.03680E+03	1200.64	33.76	0.00	21	10	-	-	-	-	-	27	6
59-Pr-144m	4.14000E+02	47.17	13.66	0.00	8	3	-	-	-	-	-	21	12
59-Pr-150	6.10000E+00	2230.23	554.20	0.00	41	23	-	-	-	-	-	75	6
59-Pr-156	5.00000E-01	2149.00	2688.00	8.93	0c	0c	-	-	0c	-	-	-	-
59-Pr-157	3.00000E-01	2387.00	1881.00	23.72	0c	0c	-	-	0c	-	-	-	-
60-Nd-140	2.91168E+05	6.73	27.73	0.00	-	-	1	-	-	-	-	3	6
60-Nd-141	8.95200E+03	16.29	77.79	0.00	14	-	9	-	-	-	-	15	7
60-Nd-141m	6.20000E+01	61.01	695.87	0.00	10	-	3	-	-	-	-	21	13
60-Nd-147	9.52128E+05	270.60	138.13	0.00	14	6	-	-	-	-	-	39	6
60-Nd-157	2.50000E+00	1668.00	1140.00	0.00	0c	0c	-	-	-	-	-	-	-
60-Nd-158	7.00000E-01	1589.00	923.90	0.01	0c	0c	-	-	0c	-	-	-	-



Nuclide	T _{1/2} (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β ⁻	EC/β ⁺	α	n	SF ⁺	p	e ⁻	X-ray
60-Nd-159	5.00000E-01	2063.00	1666.00	0.51	0c	0c	-	-	0c	-	-	-	-
60-Nd-160	3.00000E-01	2100.00	1206.00	2.49	0c	0c	-	-	0c	-	-	-	-
61-Pm-143	2.29824E+07	8.11	315.82	0.00	1	-	2	-	-	-	-	6	6
61-Pm-144	3.13632E+07	16.77	1555.59	0.00	12	-	4	-	-	-	-	30	6
61-Pm-145	5.58570E+08	12.20	31.53	0.00	2	-	3	1	-	-	-	9	6
61-Pm-146	1.74528E+08	94.41	754.29	0.00	6	2	3	-	-	-	-	24	12
61-Pm-147	8.27440E+07	61.76	0.00	0.00	3	3	-	-	-	-	-	12	6
61-Pm-148	4.63795E+05	726.30	576.49	0.00	20	10	-	-	-	-	-	30	6
61-Pm-148m	3.54672E+06	171.05	1983.64	0.00	23	4	-	-	-	-	-	72	12
61-Pm-149	1.91088E+05	366.77	12.70	0.00	44	15	-	-	-	-	-	119	6
61-Pm-151	1.01160E+05	303.20	324.16	0.00	262	33	-	-	-	-	-	727	6
61-Pm-152	2.47200E+02	1391.25	147.10	0.00	92	24	-	-	-	-	-	162	6
61-Pm-152m	4.50000E+02	900.26	1501.81	0.00	83	19	-	-	-	-	-	144	6
61-Pm-152n	8.64000E+02	728.41	2160.79	0.00	56	1	-	-	-	-	-	153	6
61-Pm-155	4.15000E+01	1061.08	561.66	0.00	5	37	-	-	-	-	-	18	6
61-Pm-159	3.00000E+00	1782.00	1160.00	0.02	0c	0c	-	-	0c	-	-	-	-
61-Pm-160	2.00000E+00	1969.00	2500.00	0.55	0c	0c	-	-	0c	-	-	-	-
62-Sm-145	2.93760E+07	29.50	62.99	0.00	3	-	3	-	-	-	-	6	6
62-Sm-146	3.15576E+15	0.00	0.00	2570.51	-	-	-	1	-	-	-	-	-
62-Sm-147	3.34511E+18	0.00	0.00	2310.65	-	-	-	1	-	-	-	-	-
62-Sm-151	2.84018E+09	19.87	0.01	0.00	1	2	-	-	-	-	-	4	2
62-Sm-153	1.66680E+05	268.30	62.82	0.00	58	15	-	-	-	-	-	76	6
63-Eu-149	8.04384E+06	24.14	66.02	0.00	27	-	10	-	-	-	-	77	6
63-Eu-150	1.14739E+09	27.21	1528.02	0.00	122	-	23	-	-	-	-	354	7
63-Eu-150m	4.60800E+04	307.29	50.22	0.00	20	1	9	-	-	-	-	57	7



Nuclide	T _{1/2} (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β ⁻	EC/β ⁺	α	n	SF ⁺	p	e ⁻	X-ray
63-Eu-152	4.26730E+08	129.10	1164.20	0.00	130	14	17	-	-	-	-	252	13
63-Eu-152m	3.33900E+04	501.95	311.09	0.00	59	7	8	-	-	-	-	96	13
63-Eu-152n	5.76000E+03	72.26	75.51	0.00	5	-	-	-	-	-	-	15	6
63-Eu-154	2.71166E+08	274.46	1245.26	0.00	139	25	2	-	-	-	-	201	12
63-Eu-154m	2.78400E+03	82.50	74.36	0.00	16	-	-	-	-	-	-	36	6
63-Eu-155	1.52928E+08	66.56	64.16	0.00	12	6	-	-	-	-	-	33	6
63-Eu-156	1.31328E+06	447.83	1283.21	0.00	96	21	-	-	-	-	-	189	6
64-Gd-148	2.36677E+09	0.00	0.00	3271.32	-	-	-	1	-	-	-	-	-
64-Gd-150	5.74348E+13	0.00	0.00	2796.67	-	-	-	1	-	-	-	-	-
64-Gd-151	1.07136E+07	38.83	70.40	0.00	27	-	12	1	-	-	-	83	6
64-Gd-153	2.07792E+07	43.73	106.65	0.00	16	-	6	-	-	-	-	49	6
64-Gd-163	6.80000E+01	1064.29	490.40	0.00	19	7	-	-	-	-	-	41	6
65-Tb-146	8.00000E+00	2994.34	1365.81	0.00	3	-	3	-	-	-	-	9	7
65-Tb-146m	2.40000E+01	1454.43	4097.18	0.00	16	-	10	-	-	-	-	21	7
65-Tb-156	4.46688E+05	84.60	1935.37	0.00	111	-	20	-	-	-	-	201	6
65-Tb-156m	8.78400E+04	22.06	37.59	0.00	2	-	-	-	-	-	-	6	2
65-Tb-156n	1.83600E+04	84.06	4.74	0.00	1	-	1	-	-	-	-	9	13
65-Tb-157	3.12420E+09	5.70	10.39	0.00	1	-	2	-	-	-	-	6	6
65-Tb-158	5.68025E+09	111.73	813.70	0.00	14	2	7	-	-	-	-	48	13
65-Tb-158m	1.08000E+01	85.93	24.20	0.00	1	-	-	-	-	-	-	6	6
65-Tb-160	6.24672E+06	257.28	1129.73	0.00	41	13	-	-	-	-	-	108	6
65-Tb-161	5.95296E+05	200.74	33.76	0.00	37	9	-	-	-	-	-	109	6
66-Dy-157	2.93040E+04	13.29	350.36	0.00	26	-	11	-	-	-	-	66	6
66-Dy-159	1.24762E+07	12.82	45.51	0.00	9	-	5	-	-	-	-	30	6
66-Dy-166	2.93760E+05	157.86	41.87	0.00	7	4	-	-	-	-	-	22	6



Nuclide	T _{1/2} (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β ⁻	EC/β ⁺	α	n	SF ⁺	p	e ⁻	X-ray
67-Ho-160	1.51800E+03	70.34	1713.47	0.00	82	-	23	-	-	-	-	144	7
67-Ho-160m	1.80000E+04	81.67	649.78	0.00	166	-	46	-	-	-	-	90	13
67-Ho-160n	2.90000E+00	93.88	105.68	0.00	5	-	-	-	-	-	-	15	6
67-Ho-161	8.92800E+03	33.44	58.17	0.00	51	-	12	-	-	-	-	151	6
67-Ho-161m	6.77000E+00	107.19	103.68	0.00	1	-	-	-	-	-	-	6	6
67-Ho-162	8.40000E+02	59.85	165.54	0.00	27	-	7	-	-	-	-	66	7
67-Ho-162m	4.02000E+03	82.22	650.91	0.00	48	-	4	-	-	-	-	148	13
67-Ho-163	1.44218E+11	2.65	0.00	0.00	-	-	1	-	-	-	-	-	-
67-Ho-163m	1.10000E+00	61.24	236.53	0.00	1	-	-	-	-	-	-	6	6
67-Ho-164	1.71600E+03	184.26	28.16	0.00	4	2	3	-	-	-	-	18	12
67-Ho-164m	2.25600E+03	91.90	48.03	0.00	4	-	-	-	-	-	-	13	6
67-Ho-170	1.66800E+02	836.08	1834.58	0.00	43	11	-	-	-	-	-	89	6
67-Ho-170m	4.30000E+01	1365.31	679.36	0.00	31	22	-	-	-	-	-	24	6
68-Er-167m	2.27000E+00	110.06	97.59	0.00	1	-	-	-	-	-	-	6	6
68-Er-172	1.77480E+05	128.72	515.68	0.00	44	8	-	-	-	-	-	131	6
69-Tm-167	7.99200E+05	21.21	51.56	0.00	9	-	4	-	-	-	-	28	6
69-Tm-168	7.77600E+06	83.08	1210.45	0.00	72	1	17	-	-	-	-	174	13
69-Tm-170	1.11110E+07	327.54	4.15	0.00	2	2	2	-	-	-	-	12	12
69-Tm-171	6.04800E+07	25.56	0.68	0.00	1	2	-	-	-	-	-	6	6
69-Tm-172	2.28960E+05	527.71	480.50	0.00	50	16	-	-	-	-	-	69	6
70-Yb-175	3.61584E+05	121.64	79.94	0.00	6	3	-	-	-	-	-	21	6
70-Yb-176m	1.14000E+01	144.56	905.32	0.00	5	-	-	-	-	-	-	18	6
71-Lu-171	7.12800E+05	88.33	641.30	0.00	90	-	23	-	-	-	-	207	7
71-Lu-171m	7.80000E+01	69.44	1.79	0.00	1	-	-	-	-	-	-	6	6
71-Lu-172	5.78880E+05	111.38	1955.21	0.00	197	-	29	-	-	-	-	534	7



Nuclide	T _{1/2} (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β ⁻	EC/β ⁺	α	n	SF ⁺	p	e ⁻	X-ray
71-Lu-172m	2.22000E+02	40.20	1.67	0.00	1	-	-	-	-	-	-	4	2
71-Lu-173	4.21632E+07	46.18	170.16	0.00	19	-	6	-	-	-	-	59	6
71-Lu-174	1.12320E+08	44.82	116.67	0.00	5	-	3	-	-	-	-	18	7
71-Lu-174m	1.22688E+07	116.85	61.67	0.00	12	-	1	-	-	-	-	40	12
71-Lu-177	5.78880E+05	147.42	36.86	0.00	6	4	-	-	-	-	-	21	6
71-Lu-177m	1.38499E+07	82.08	167.77	0.00	10	1	-	-	-	-	-	33	6
72-Hf-173	8.60400E+04	52.05	396.61	0.00	79	-	20	-	-	-	-	167	7
72-Hf-174	6.31152E+22	0.00	0.00	2503.61	-	-	-	1	-	-	-	-	-
72-Hf-175	6.04800E+06	45.51	362.99	0.00	8	-	4	-	-	-	-	27	6
72-Hf-177m	1.08000E+00	240.71	1068.02	0.00	39	-	-	-	-	-	-	118	6
72-Hf-177n	3.08400E+03	251.54	1177.27	0.00	10	-	-	-	-	-	-	27	6
72-Hf-178m	4.00000E+00	141.51	1005.89	0.00	5	-	-	-	-	-	-	18	6
72-Hf-178n	9.78286E+08	73.62	1223.12	0.00	11	-	-	-	-	-	-	35	6
72-Hf-179m	1.86700E+01	134.08	240.74	0.00	3	-	-	-	-	-	-	12	6
72-Hf-179n	2.16864E+06	186.34	919.03	0.00	13	-	-	-	-	-	-	41	6
72-Hf-180m	1.98000E+04	148.58	992.43	0.00	7	2	-	-	-	-	-	26	12
72-Hf-181	3.66163E+06	204.39	530.53	0.00	10	2	-	-	-	-	-	29	6
73-Ta-177	2.03040E+05	22.72	67.75	0.00	47	-	12	-	-	-	-	138	7
73-Ta-179	5.08032E+07	7.40	29.25	0.00	-	-	1	-	-	-	-	3	6
73-Ta-180	2.90880E+04	64.06	45.93	0.00	2	2	2	-	-	-	-	12	12
73-Ta-180m	5.68037E+22	125.85	562.52	0.00	6	1	1	-	-	-	-	24	12
73-Ta-182	9.91008E+06	216.34	1283.32	0.00	43	10	-	-	-	-	-	128	6
73-Ta-182m	2.83000E-01	14.32	1.92	0.00	1	-	-	-	-	-	-	4	2
73-Ta-182n	9.50400E+02	244.38	254.64	0.00	5	-	-	-	-	-	-	18	6
73-Ta-183	4.39776E+05	349.36	286.64	0.00	31	4	-	-	-	-	-	93	6



Nuclide	T _{1/2} (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β ⁻	EC/β ⁺	α	n	SF ⁺	p	e ⁻	X-ray
74-W -176	9.00000E+03	57.30	171.53	0.00	6	-	3	-	-	-	-	18	6
74-W -178	1.86624E+06	6.99	19.16	0.00	-	-	1	-	-	-	-	3	6
74-W -181	1.04527E+07	12.68	41.21	0.00	3	-	4	-	-	-	-	10	6
74-W -183m	5.25000E+00	183.99	125.39	0.00	6	-	-	-	-	-	-	19	6
74-W -185	6.48864E+06	126.80	0.05	0.00	1	2	-	-	-	-	-	6	6
74-W -185m	1.00000E+02	171.99	25.74	0.00	14	-	-	-	-	-	-	38	6
74-W -187	8.58600E+04	301.26	442.10	0.00	48	17	-	-	-	-	-	118	6
74-W -188	6.02899E+06	99.59	1.91	0.00	6	4	-	-	-	-	-	20	6
75-Re-183	6.04800E+06	108.91	161.37	0.00	28	-	9	-	-	-	-	84	6
75-Re-183m	1.03000E-03	316.99	1588.64	0.00	16	-	-	-	-	-	-	51	6
75-Re-184	3.05856E+06	54.72	905.64	0.00	30	-	9	-	-	-	-	90	7
75-Re-184m	1.45152E+07	140.48	390.15	0.00	36	-	1	-	-	-	-	112	12
75-Re-186	3.24000E+05	337.33	20.89	0.00	9	4	2	-	-	-	-	30	12
75-Re-186m	5.99582E+12	129.8	19.81	0.00	4	-	-	-	-	-	-	12	6
75-Re-191	5.82000E+02	726.98	2.23	0.00	-	1	-	-	-	-	-	-	-
75-Re-192	6.20000E+00	1637.85	159.06	0.00	5	4	-	-	-	-	-	18	6
76-Os-180	1.29000E+03	23.82	136.78	0.00	21	-	10	-	-	-	-	60	7
76-Os-185	8.10432E+06	18.33	719.03	0.00	16	-	6	-	-	-	-	50	6
76-Os-189m	2.09160E+04	28.71	2.18	0.00	1	-	-	-	-	-	-	4	2
76-Os-190m	5.94000E+02	116.85	1588.53	0.00	5	-	-	-	-	-	-	17	6
76-Os-191	1.32192E+06	37.52	0.00	0.00	-	1	-	-	-	-	-	-	-
76-Os-191m	4.71600E+04	66.58	7.81	0.00	1	-	-	-	-	-	-	6	6
76-Os-194	1.89342E+08	44.29	4.09	0.00	2	3	-	-	-	-	-	8	6
76-Os-195	3.90000E+02	715.26	142.23	0.00	17	6	-	-	-	-	-	44	6
76-Os-196	2.09400E+03	372.56	77.03	0.00	10	8	-	-	-	-	-	30	6



Nuclide	T _{1/2} (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β ⁻	EC/β ⁺	α	n	SF ⁺	p	e ⁻	X-ray
77-Ir-187	3.78000E+04	63.79	301.51	0.00	96	-	24	-	-	-	-	273	7
77-Ir-189	1.14048E+06	44.77	79.47	0.00	25	-	7	-	-	-	-	71	6
77-Ir-190	1.03680E+06	72.11	1478.08	0.00	63	-	10	-	-	-	-	132	7
77-Ir-190m	4.03200E+03	23.84	2.28	0.00	1	-	-	-	-	-	-	4	2
77-Ir-190n	1.11132E+04	28.88	58.87	0.00	6	-	1	-	-	-	-	21	12
77-Ir-191m	4.90000E+00	95.72	75.39	0.00	4	-	-	-	-	-	-	13	6
77-Ir-191n	5.50000E+00	45.76	1868.05	0.00	4	-	-	-	-	-	-	15	6
77-Ir-192	6.37822E+06	217.29	816.48	0.00	27	6	3	-	-	-	-	87	12
77-Ir-192m	8.64000E+01	54.43	2.44	0.00	4	3	-	-	-	-	-	16	8
77-Ir-192n	7.60522E+09	165.04	3.09	0.00	2	-	-	-	-	-	-	7	6
77-Ir-193m	9.09792E+05	77.70	2.59	0.00	1	-	-	-	-	-	-	6	6
77-Ir-194m	3.18300E-02	96.54	49.97	0.00	10	-	-	-	-	-	-	26	6
77-Ir-194n	1.47744E+07	103.37	2352.62	0.00	11	2	-	-	-	-	-	36	6
77-Ir-197	3.48000E+02	733.37	223.79	0.00	40	23	-	-	-	-	-	91	6
77-Ir-197m	5.34000E+02	680.01	2.04	0.00	1	1	-	-	-	-	-	6	6
78-Pt-190	2.05120E+19	0.00	0.00	3251.51	-	-	-	1	-	-	-	-	-
78-Pt-193	1.57788E+09	7.86	33.78	0.00	-	-	1	-	-	-	-	3	6
78-Pt-193m	3.74976E+05	137.96	12.33	0.00	3	-	-	-	-	-	-	7	6
78-Pt-195m	3.54240E+05	182.26	76.47	0.00	9	-	-	-	-	-	-	27	6
78-Pt-197	7.16094E+04	254.43	24.38	0.00	3	3	-	-	-	-	-	11	6
78-Pt-197m	5.71800E+03	316.94	76.08	0.00	2	1	-	-	-	-	-	8	6
78-Pt-202	1.58400E+05	658.92	1.93	0.00	-	1	-	-	-	-	-	-	-
79-Au-192m	2.90000E-02	126.10	8.85	0.00	4	-	-	-	-	-	-	12	6
79-Au-192n	1.60000E-01	161.47	134.69	0.00	6	-	-	-	-	-	-	19	6
79-Au-195	1.60785E+07	48.79	86.33	0.00	5	-	5	-	-	-	-	17	6



Nuclide	T _{1/2} (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β ⁻	EC/β ⁺	α	n	SF ⁺	p	e ⁻	X-ray
79-Au-195m	3.05000E+01	115.53	203.01	0.00	5	-	-	-	-	-	-	16	6
79-Au-197m	7.74000E+00	183.82	225.44	0.00	5	-	-	-	-	-	-	17	6
79-Au-198	2.32788E+05	327.34	402.89	0.00	3	3	-	-	-	-	-	12	6
79-Au-198m	1.98720E+05	262.08	527.82	0.00	6	-	-	-	-	-	-	18	6
79-Au-199	2.71210E+05	145.08	96.07	0.00	3	3	-	-	-	-	-	11	6
80-Hg-190	1.20000E+03	68.07	204.38	0.00	25	-	14	-	-	-	-	76	7
80-Hg-194	1.40113E+10	7.34	14.68	0.00	-	-	1	-	-	-	-	3	6
80-Hg-197	2.32560E+05	69.15	73.51	0.00	3	-	3	-	-	-	-	11	6
80-Hg-197m	8.60400E+04	200.56	77.98	0.00	2	-	1	-	-	-	-	12	12
80-Hg-199m	2.52600E+03	347.70	184.57	0.00	4	-	-	-	-	-	-	15	6
80-Hg-203	4.02581E+06	99.11	237.74	0.00	1	1	-	-	-	-	-	6	6
80-Hg-205	3.12000E+02	536.24	6.89	0.00	13	7	-	-	-	-	-	24	6
81-Tl-193	1.30800E+03	94.34	555.90	0.00	50	-	26	-	-	-	-	87	7
81-Tl-193m	1.26600E+02	109.18	363.45	0.00	3	-	1	-	-	-	-	13	13
81-Tl-201	2.62742E+05	44.08	95.41	0.00	9	-	3	-	-	-	-	22	6
81-Tl-202	1.05754E+06	22.51	466.54	0.00	3	-	3	-	-	-	-	12	7
81-Tl-204	1.19603E+08	236.21	1.06	0.00	-	1	1	-	-	-	-	3	6
82-Pb-201	3.38400E+04	58.28	768.05	0.00	74	-	25	-	-	-	-	143	7
82-Pb-201m	6.10000E+01	262.19	366.14	0.00	1	-	-	-	-	-	-	6	7
82-Pb-202	1.67255E+12	9.28	69.97	0.00	-	-	1	-	-	-	-	3	6
82-Pb-202m	1.28520E+04	138.45	1975.52	0.00	22	-	3	-	-	-	-	72	13
82-Pb-203	1.86804E+05	52.33	315.18	0.00	3	-	2	-	-	-	-	12	6
82-Pb-203m	6.29000E+00	171.21	654.09	0.00	3	-	-	-	-	-	-	10	7
82-Pb-203n	4.80000E-01	216.40	1906.57	0.00	14	-	-	-	-	-	-	44	7
82-Pb-204	4.41806E+24	0.00	0.00	1971.69	-	-	-	1	-	-	-	-	-



Nuclide	T _{1/2} (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β ⁻	EC/β ⁺	α	n	SF [*]	p	e ⁻	X-ray
82-Pb-204m	4.05000E+03	103.27	2080.67	0.00	6	-	-	-	-	-	-	21	7
82-Pb-205	4.82831E+14	8.95	59.29	0.00	-	-	1	-	-	-	-	3	6
82-Pb-205m	5.10000E-03	39.92	974.47	0.00	13	-	-	-	-	-	-	39	7
82-Pb-207m	8.06000E-01	122.92	1510.36	0.00	2	-	-	-	-	-	-	9	7
83-Bi-201m	3.34800E+03	284.31	265.44	0.16	1	-	1	1	-	-	-	9	15
83-Bi-205	1.32278E+06	26.29	1554.68	0.00	147	-	26	-	-	-	-	409	8
83-Bi-207	1.00224E+09	118.46	1539.51	0.00	6	-	4	-	-	-	-	21	8
83-Bi-208	1.16132E+13	8.52	2657.34	0.00	1	-	1	-	-	-	-	3	7
84-Po-208	9.24638E+07	0.00	0.02	5215.29	8	-	1	2	-	-	-	28	14
86-Rn-223	1.45200E+03	624.91	330.14	0.00	294	60	-	-	-	-	-	270	7
90-Th-228	6.03590E+07	20.48	3.08	5497.53	14	-	-	9	-	-	-	43	7
90-Th-231	9.18720E+04	164.94	25.82	0.00	47	13	-	-	-	-	-	122	7
93-Np-239	2.03472E+05	262.84	182.19	0.00	33	8	-	-	-	-	-	89	7
95-Am-241	1.36581E+10	39.08	27.51	5557.44	185c	-	-	53	0c	0	-	372	7
95-Am-243	2.32416E+11	23.93	56.97	5358.99	18c	-	-	12	0c	0	-	46	7

* A zero in this column indicates the presence of spontaneous fission fragment data - no spectral data are specified (only mean energies) for the SF fragments in ENDF-6 format.



Table 3. Nuclides Evaluated in 2009/10

Nuclide	Half-life	Consistency (% Deviation)
35-Br- 77	2.3765 d	0.0255
48-Cd-111m	48.74 min	-0.0121
50-Sn-125m	9.53 min	-0.0032
50-Sn-126	2.30E+05 y	0.0980
52-Te-129m	33.6 d	-0.0088
64-Gd-148	75 y	-0.0034
67-Ho-162	14 min	-0.0196
67-Ho-162m	1.117 h	-0.0152
[82-Pb-205m]	5.10E-03 s	-0.0528
83-Bi-201m	55.8 min	0.0087
83-Bi-205	15.31 d	-0.1112

Radionuclide in parentheses has not been specifically requested (82-Pb-205m), but has been included because this short-lived metastable state is strongly associated with parent 83-Bi-205.



Appendix I

Comments from New Evaluations



Appendix I: Comments from New Evaluations

Reproduced below are the comments associated with each of the nuclides evaluated in 2009/10. These comments cite a significant number of specific references by first-named author. However, these references are not listed in this report as they are too numerous for such an exercise, and the reader is referred to the Comments Section of the relevant ENDF-6 decay-data file of the radionuclide for their full details.

35-Br- 77

The half-life of 57.035(6) hours is the least-squares weighted mean value of the measurements of Girgis et al (1959), Sarantites and Erdal (1969), and Waters and Woods (1975; two sets of precise data).

A reasonably comprehensive decay scheme has been derived from measurements of the relative gamma-ray emission probabilities by Girgis et al (1959), Monaro (1963), Ardisson and Ythier (1967), Sarantites and Erdal (1969), Dzhelepov et al (1971), and Braga and Sarantites (1974). All of these data were measured relative to the emission probability of the 239.00-keV gamma ray (100%). Tokunaga et al (1985) also provided some guidance on nuclear level energies and specific gamma-ray transitions. The EC transition probabilities were determined from balancing the population/depopulation of each nuclear level of Se-77, based on the recommended gamma-ray emission probabilities and the theoretical internal conversion coefficients of Kibedi et al (2008). The existence of the 13.38-keV gamma transition was suggested by Tokunaga et al (1985) in order to balance the population-depopulation of the 175.31-keV nuclear level of Se-77 for which direct EC decay was assumed to be zero on the basis of spin-parity considerations. Direct EC decay to the 161.92-keV nuclear level of Se-77m was also assumed to be zero on the basis of spin-parity considerations. Various mixing ratios and multipolarities were extracted from the studies of Braga and Sarantites (1974), Dzhelepov et al (1975), Tokunaga et al (1985), and Mohsen and Pleiter (1988). However, multipolarities for a significant number of (M1 + E2) gamma transitions were arbitrarily assigned to be (50%M1 + 50%E2) with a relatively high uncertainty (13.38, 81.19, 141.56, 187.33, 189.66, 243.42, 331.22, 565.73, 585.43, 610.38, 766.19 and 791.17 keV), while other transitions were assumed to be 100%M1 (180.75, 303.79, 518.18, 520.64 and 578.86 keV).

A normalisation factor of 0.2315(34) was calculated for the relative emission probabilities of the gamma rays and a relative intensity of 6.35(20) for the annihilation radiation as measured by Sarantites and Erdal (1969):

$$2 \times (EC + \beta^+) / (1 + (EC/\beta^+)) \text{ for the ground state} = 6.35(20)NF,$$

in which a theoretical (EC/ β^+) ratio of 59.6 was taken from Gove and Martin (1971), and NF is the normalisation factor.

Thus, (EC + β^+) directly to the ground state = (6.35(20)NF x 60.6) / 2 = 192.405(6060)NF.

Gamma and EC decay to the Se-77 ground state are quantified by 230.67(168)NF + (EC + β^+), while gamma decay to the first excited state (Se-77m) is 8.92(23)NF (with no associated EC decay). These three components of decay sum to 100 (as defined from the proposed decay scheme). Therefore:

$$230.67(168)NF + 192.405(6060)NF + 8.92(23)NF = 100$$

$$NF = 100 / 431.995(6293) = 0.2315(34)$$

Branching fractions were calculated from the relative emission probabilities of the gamma rays populating the ground and metastable states of Se-77, the normalisation factor of 0.2315(34), the relevant internal conversion coefficients, and the EC population of the ground state as determined from the tabulations of Gove and Martin (1971). The decay data for Se-77m are not included within the Br-77 file (half-life of 17.4 secs, with a single gamma-ray emission of 161.92 keV).



While the overall features of the proposed decay scheme are judged to be reasonably well defined, there are some unsatisfactory aspects within the detail. These problems are mainly identified with the derivation of the normalisation factor for the gamma-ray emission probabilities and the quantification of the EC/β^+ decay directly to the ground state of Se-77. Further measurements are merited, particularly accurate determinations of the absolute gamma-ray emission probabilities and the annihilation radiation.

48-Cd-111m

The half-life of 48.74(20) mins is the least-squares weighted mean of the measurements of Wiedenbeck (1945), Hole (1948), Helmholtz et al (1949), and Bornemisza-Pausperl et al (1968), as also defined by Heath and Helmer (1998). Further measurements are merited to fortify such a limited set of pre-1970 data.

A simple decay scheme has been derived from the gamma-ray and conversion-electron studies of Hole (1948), McGinnis (1951), Lu (1960), Shevelev et al (1975), and Heath and Helmer (1998). Theoretical conversion coefficients for the 150.825-keV (E3) and 245.395-keV (E2) gamma cascade were derived from Kibedi et al (2008); absolute gamma-ray emission probabilities were calculated on the basis of transition probabilities of 100%. Further measurements of the absolute gamma-ray emission probabilities are merited to confirm the detail within the proposed decay scheme.

50-Sn-125m

The adopted half-life of 9.53(5) mins is the least-squares weighted mean of the measurements of Lee and Pool (1949), Nelson et al (1950), and Erdal and Wahl (1968). Significant emphasis has inevitably been placed on the measurement of Erdal and Wahl (9.52(5) mins), and therefore further studies are merited to substantiate the adoption of the recommended half-life and uncertainty.

A comprehensive decay scheme has been derived from measurements of the relative gamma-ray emission probabilities by Baedeker and Walters (1968), Berzins and Auble (1968), Kawase et al (1971), and Krane and Sylvester (2006) - all measurements are relative to a 331.94-keV gamma-ray emission probability of 100%. A multipolarity of (94.6%M1 + 5.4%E2) was adopted for the 331.94-keV gamma-ray transition from the analysis of Krane (1977), and similar mixing ratios were assumed for the 278.59- and 311.0-keV gamma-ray transitions. Multipolarities of (50%M1 + 50%E2) were assigned to the 429.9-, 779.0- and 840.8-keV gamma-ray transitions to generate theoretical internal coefficients with assumed uncertainties of approximately 10%. The 386.5-, 589.61- and 642.96-keV gamma rays are defined as E2 transitions. Beta-particle emission probabilities were determined from the population/depopulation of the nuclear levels of Sb-125, based on the recommended relative gamma-ray emission probabilities, a calculated normalisation factor of 0.9724(5), and the theoretical internal conversion coefficients of Kibedi et al (2008). Direct beta decay to the ground state of Sb-125 was assumed to be zero on the basis of spin-parity considerations.

50-Sn-126

The adopted half-life of 2.30(14)E+05 years is the least-squares weighted mean value of the measurements of Haas et al (1996) and Zhang et al (1996). Further studies are required to fortify these measurements, and so improve the quantification of this half-life and associated uncertainty.

Beta-decay has been defined as a single, 100% emission from Sn-126 directly to the 127.9-keV nuclear level of Sb-126, followed by a six-gamma cascade that populates two metastable states of Sb-126 (Sb-126m (half-life of 19.1 min) and Sb-126n (half-life of 11 sec)). The relative emission probabilities of the gamma rays were adopted from the measurements of Smith et al (1976), although a small adjustment has been made to the relative emission probability of the 42.6-keV



gamma ray to ensure a balance of the gamma transitions that populate/depopulate the 83.0-keV nuclear level of Sb-126 (relative emission probability reduced from 1.35(14) to 1.25(13)). Gamma population/depopulation of each nuclear level of Sb-126 was based on the derivation of their transition probabilities from the relative gamma-ray emission probabilities and the theoretical internal conversion coefficients of Kibedi et al (2008). Multipolarities of the (M1 + E2) gamma transitions were defined to be 100%M1 for the 42.64-keV gamma ray, and (99.75%M1 + 0.25%E2) for the 23.28-keV gamma ray. A normalisation factor for the gamma-ray emissions of 0.37(2) was calculated from the relative transition probabilities of the 23.28- and 87.57-keV gamma transitions that represent the full depopulation of the 127.9-keV nuclear level of Sb-126.

Sn-126 decays to Sb-126m (which undergoes 86% beta decay and 14% IT decay, with a half-life of 19.1 min) and Sb-126n (which undergoes 100% IT decay to Sb-126m by means of a 22.70-keV gamma ray, with a half-life of 11 sec) - the recommended decay data for both daughter states can be found in the relevant data files for Sb-126m and Sb-126n. There are a number of minor uncertainties associated with the consistency of the gamma-ray transition probabilities - measurements of the absolute gamma-ray emission probabilities would be of benefit in clarifying and fully defining the proposed decay scheme.

52-Te-129m

The adopted half-life of 33.6(3) days is the least-squares weighted mean of the measurements of Pappas (1953), Hahn (1963), Andersson et al (1965), Bormann et al (1970), Baba et al (1971), and Emery et al (1972), with the uncertainty expanded from ± 0.14 to 0.3 so that the range includes the most precise value of 33.3(1) days of Pappas (1953).

A comprehensive decay scheme has been derived from measurements of the relative gamma-ray emission probabilities by Devare and Devare (1964), Dickinson et al (1969), De Raedt et al (1974), and Mann et al (1976) - all measurements involved initial mixed sources of Te-129 and Te-129m in equilibrium, and Te-129m after substantial decay of Te-129 (half-life of 1.16 hours). However, recommended gamma-ray emission probabilities were primarily adopted from the extensive studies of Mann et al (1976), with the addition in quadrature of systematic uncertainties of 3% in combination with the statistical uncertainties specified by the authors. The IT-decay mode consists of a single gamma transition of 105.50(5) keV directly to the ground state of Te-129, for which an IT branching fraction of 0.637(50) was calculated from the studies of Devare and Devare (1964) and Mann et al (1976). Mixing ratios and multipolarities were taken from the extensive studies of Silverans et al (1973), Kalinauskas et al (1973), De Raedt et al (1974), Soni et al (1977) and Krane (1977). Various assignments included E1 transition type for the 671.86- and 705.54-keV gamma rays; E2 transition type for the 242.22-, 278.38-, 490.38-, 695.89-, 701.77-, 771.83-, 925.2- and 1003.61-keV gamma rays; M2 transition type for the 556.61-keV gamma ray; M4 transition type for the 105.50-keV gamma ray (IT-decay mode); and (80%M1 + 20%E2) multipolarity for the 250.58- and 487.35-keV gamma rays, (82.5%M1 + 17.5%E2) multipolarity for the 817.02-keV gamma ray, (89.6%M1 + 10.4%E2) multipolarity for the 729.57-keV gamma ray, (93.2%M1 + 6.8%E2) multipolarity for the 740.96-keV gamma ray, (95.4%M1 + 4.6%E2) multipolarity for the 208.97-keV gamma ray, (99.4%M1 + 0.6%E2) multipolarity for the 281.41- and 459.55-keV gamma rays, (99.80%M1 + 0.20%E2) multipolarity for the 27.80-keV gamma ray, and (99.96%M1 + 0.04%E2) multipolarity for the 1022.41-keV gamma ray. The more poorly defined (M1 + E2) gamma transitions of 76.06-, 115.25-, 281.45-, 320.64-, 357.47-, 552.42-, 562.86-, 716.3-, 768.76-, 794.64- and 844.82-keV were arbitrarily assigned multipolarities of (50%M1 + 50%E2) to determine theoretical internal conversion coefficients with assumed uncertainties of approximately 10%.

Direct beta-particle decay to the ground state of I-129 was assumed to be 32.2(50)% from relevant data tabulated by Dickinson et al (1969), and a normalisation factor of 0.049(7) was calculated from this value for the relative gamma-ray emission probabilities. All other beta-particle emission probabilities were determined from the population/depopulation of the nuclear levels of I-129 based on the recommended relative gamma-ray emission probabilities, the normalisation factor of 0.049(7), and theoretical internal conversion coefficients derived by means of the procedure of Kibedi et al (2008). Beta decay to the 27.80, 278.38 and 487.35-keV nuclear levels of I-129 were assumed to be zero on the basis of spin-parity considerations; these assumptions impact directly



on the relative emission probabilities of the 208.97-, 250.58- and 278.38-keV gamma rays that populate/depopulate these levels - adjustments had to be made to their relative emission probabilities to achieve the necessary balances. A relative emission probability of 0.59(5) was calculated in a similar manner for the 27.80-keV, (99.80%M1 + 0.20%E2) gamma ray depopulating the 27.80-keV nuclear level of I-129. Defined with respect to the gamma rays from the beta-decay mode, a relative emission probability of 3.02(24) was also determined for the IT-decay gamma ray of 105.50-keV from an absolute transition probability of 63.7(50)%, a total theoretical internal coefficient of 429(7) for this M4 transition, and the normalisation factor of 0.049(7).

Further measurements are merited, particularly accurate determinations of the absolute and relative gamma-ray emission probabilities identified with the reasonably complex beta-decay mode.

64-Gd-148

The recommended half-life of 75(3) years has been adopted from a measured value of 74.6(30) years by Prestwood et al (1981). However, other half-life measurements by Siivola (1962) and Friedman et al (1966) of 84(9) and 97.5(65) years, respectively, are not in alignment with this particular recommendation. A least-squares weighted analysis of these disparate data produces a weighted mean half-life value of 84(4) years. Further measurements are required to extend and improve such a limited and disparate set of data.

Direct decay data measurements are extremely sparse, and there is no evidence of the existence of any gamma transitions, nor further detail concerning the assumed 100% alpha decay directly to the ground state of Sm-144. The alpha-particle energy and associated uncertainty were calculated from the adopted $Q(\alpha)$ value and uncertainty.

67-Ho-162

The half-life of 14(2) mins is the least-squares weighted mean value of the measurements of Jorgensen et al (11.8(10) mins (1961)), Stenstrom and Jung (15.0(10) mins (1965)), Akhmed et al (12(2) mins (1970)), and Baskova et al (15(1) mins (1973)). These data are disparate, and the recommended uncertainty has been significantly increased from ± 0.6 to 2 to encompass the range of observed values. Further measurements are required to fortify such a limited data set, and better quantify and resolve this ill-defined parameter.

Gamma-ray studies have normally involved mixed Ho-162/Ho-162m sources. The resulting gamma-ray spectra for both states are reasonably complex, and are difficult to analyse with respect to the relative contributions of Ho-162 and Ho-162m. A partial decay scheme was determined from measurements of the relative gamma-ray emission probabilities by Wood and Brenner (1971), Baskova et al (1973), Edvardson et al (1975), and Zamfir et al (1999). These data have been significantly fortified by the inclusion of gamma transitions derived from the Dy-162(n,n' γ), Dy-161(n, γ) and Gd-160(α ,2n) reactions, as proposed by Govor et al (2002) and Aprahamian et al (2006). Minor adjustments were also made to the relative emission probabilities of the 512.1- and 1782.7-keV gamma rays (8.3(40) changed to 8(4), and 0.41(6) modified to 0.52(6), respectively). All of these data were defined relative to the emission probability of the 1319.6-keV gamma ray (100%). Various mixing ratios and multipolarities were extracted from the studies of Govor et al (2002), and Aprahamian et al (2006). However, the multipolarities of specific (M1 + E2) gamma transitions were arbitrarily assigned (50%M1 + 50%E2) with a relatively high uncertainty (565.31, 819.7 and 894.5 keV).

Relative EC transition probabilities were determined from assessments and quantification of the population/depopulation of each nuclear level of Dy-162, based on the recommended relative gamma-ray emission probabilities and the theoretical internal conversion coefficients of Kibedi et al (2008). Direct EC decay to the 1060.99-, 962.94- and 265.66-keV nuclear levels of Dy-162 were assumed to be zero on the basis of spin-parity considerations, while a value of zero was also determined for EC decay to the 888.16-keV nuclear level of Dy-162 arising from consideration of the gamma-ray population/depopulation of this particular level. EC decay of Ho-162 has been



identified predominantly with two EC/ β^+ transitions to the 80.66-keV (2^+) nuclear level and ground state (0^+) of Dy-162. Jorgensen et al (1961) determined a feeding ratio for these two EC transitions:

$$EC(1^+ \rightarrow 2^+) / EC(1^+ \rightarrow 0^+) \approx 385/300 = 1.28.$$

This uncertain ratio was adopted along with a relative emission probability of 210(10) for the 80.66-keV gamma ray (Baskova et al (1973)) and lesser relative gamma-ray emission probabilities to calculate a relative EC transition probability to the 80.66-keV nuclear level, and hence derive the relative EC transition probability to the ground state of Dy-162. The proposed decay scheme and these parameters in particular were used to calculate a normalisation factor of 0.0390(2) for the relative emission probabilities of the gamma rays. Positron emission probabilities to the 80.66-keV and ground states of Dy-162 were determined from the theoretical (EC/ β^+) tabulations of Gove and Martin (1971).

An E0 gamma transition of 1400.3 keV was defined with an estimated relative transition probability of 0.055(4), based on the conversion-electron studies of Edvardson et al (1975):

$$P_{\text{cek}}(1400.3 \text{ keV}) / P_{\text{cek}}(1319.6 \text{ keV}) = 0.31(2), \text{ and}$$

$$P_{\text{ce}} = (\alpha / (1 + \alpha(\text{total}))) P_{\text{TP}}$$

Combining these two equations in a general manner:

$$\begin{aligned} \text{relative } P_{\text{ce}}(1400.3 \text{ keV}) &= (\alpha(\text{total}) / (1 + \alpha(\text{total}))) \times 0.31(2) \times P_{\text{TP}}(1319.6 \text{ keV}) \\ &= (0.001767 / 1.001767) \times 0.31(2) \times 100.177(3) = 0.055(4). \end{aligned}$$

As an E0 gamma transition ($0^+ \rightarrow 0^+$):

$$P_{\gamma}(1400.3 \text{ keV}) = 0.0, \text{ and}$$

$$\text{relative } P_{\text{ce}}(1400.3 \text{ keV}) = \text{relative } P_{\text{TP}}(1400.3 \text{ keV}) = 0.055(4).$$

E0 transitions cannot be correctly accommodated within the ENDF-B format. However, the absolute transition probability represents a minor contribution to the proposed decay scheme (absolute transition probability of 0.0021(2)%). Ultra-high internal conversion coefficients have been arbitrarily adopted to calculate conversion-electron data for this transition, and the 1400.3-keV gamma ray was subsequently removed from the data file.

There are a significant number of uncertainties associated with the proposed decay scheme, and specific assumptions have been made concerning the relative merits of the main sources of gamma-ray data. Furthermore, gamma transitions unobserved in EC-decay measurements have been introduced from the Dy-162(n,n' γ), Dy-161(n, γ) and Gd-160(α ,2n) reaction studies of Govor et al (2002) and Aprahamian et al (2006). More importantly, the normalisation factor for the relative gamma-ray emission probabilities and the recommended EC transition probabilities are based entirely on a qualitative interpretation of scintillation spectra by Jorgensen et al (1961). Further measurements of the absolute and relative gamma-ray emission probabilities are required to derive the decay scheme with much greater confidence, particularly the determination of the EC transition probabilities directly to the 80.66-keV and ground states of Dy-162.

67-Ho-162m

The half-life of 67.0(7) mins is the least-squares weighted mean value of the measurements of May and Yaffe (1964), Gromov and Mukhtasimov (1965), Honig (1969), Akhmed et al (1970), Wood and Brenner (1971), and Baskova et al (1973).

Gamma-ray studies have normally involved mixed Ho-162/Ho-162m sources. The resulting gamma-ray spectra are reasonably complex, and are difficult to analyse with respect to the relative contributions of Ho-162 and Ho-162m. A partial decay scheme was derived from measurements of the relative gamma-ray emission probabilities by Akhmed et al (1970), Wood and Brenner (1971), and Zamfir et al (1999). These data arise as a consequence of the EC-decay mode, and have been fortified by the inclusion of gamma transitions derived from the Dy-162(n,n' γ), Dy-161(n, γ) and Gd-160(α ,2n) reactions, as proposed by Govor et al (2002) and Aprahamian et al (2006). Both



major and minor adjustments were also made to the relative emission probabilities of specific gamma rays: 251.2 keV (0.11(3) changed to 0.2(1)); 278.6 keV (0.4(2) changed to 0.8(4)); 697.3 keV (0.23(4) changed to 0.20(4)); 807.5 keV (0.4(1) changed to 0.18(9)); 882.3 keV (1.32(3) changed to 1.19(15)); 888.16 keV (0.34(17) changed to 0.17(8)); 917.1 keV (2.13(4) changed to 1.98(15)); 937.15 keV (43.6(9) changed to 37.3(12)); 1124.8 keV (4.44(11) changed to 4.54(11)); and 1220.0 keV (78.4(35) changed to 75.7(40)). All gamma-ray emissions were defined relative to the emission probability of the 185.00-keV gamma ray (100%). Various mixing ratios and multipolarities were extracted from the studies of Govor et al (2002), and Aprahamian et al (2006).

The EC transition probabilities were determined from balancing the population/depopulation of each nuclear level of Dy-162, based on the recommended gamma-ray emission probabilities and the theoretical internal conversion coefficients of Kibedi et al (2008). Direct EC decay to the 1390.5-, 1324.5-, 1297.0-, 1210.1-, 1182.76-, 1060.99-, 962.94-, 888.16-, 265.66-, 80.66-keV nuclear levels and the ground state of Dy-162 were assumed to be zero on the basis of either spin-parity considerations or observed population/depopulation balances. A normalisation factor of 0.334(52) was calculated for the relative emission probabilities of the gamma rays associated with the EC-decay mode, based on the sum of the relative gamma-ray emission probabilities populating the ground state of Dy-162 and an assumed BF_{EC} of 0.45(7) – see below. The positron emission probability to the 548.52-keV nuclear level of Dy-162 was determined from the theoretical (EC/ β^+) tabulations of Gove and Martin (1971).

Gamma-ray emission probabilities from the IT-decay mode were determined from the conversion-electron studies of Islamov et al (1999), based initially on specifying an IT branching fraction of 1.00 (100%).

38.34-keV gamma ray:

$$P_{\gamma} = P_{ce}(L1) / \alpha(L1) = 61.5(70) / 4.86(7) = 12.7(15);$$

$$P_{\gamma} = P_{ce}(L2) / \alpha(L2) = 5.7(12) / 0.446(7) = 12.8(27);$$

$$P_{\gamma} = P_{ce}(L3) / \alpha(L3) = 0.91(15) / 0.0726(11) = 12.5(21);$$

least-squares weighted mean of 12.7(11)%; adopted P_{γ} of 12.62(130)%.

57.73-keV gamma ray:

$$P_{\gamma} = P_{ce}(L1) / \alpha(L1) = 10.7(13) / 1.459(21) = 7.3(9);$$

$$P_{\gamma} = P_{ce}(L2) / \alpha(L2) = 0.92(13) / 0.1311(19) = 7.0(10);$$

$$P_{\gamma} = P_{ce}(L3) / \alpha(L3) = 0.14(3) / 0.0209(3) = 6.7(14);$$

least-squares weighted mean of 7.1(6)%; adopted P_{γ} of 7.29(80)%.

96.07-keV gamma ray:

$$P_{\gamma} = P_{ce}(K) / \alpha(K) = 0.15(3) / 1.210(17) = 0.124(25);$$

$$P_{\gamma} = P_{ce}(L2) / \alpha(L2) = 0.10(2) / 0.741(11) = 0.135(27);$$

$$P_{\gamma} = P_{ce}(L3) / \alpha(L3) = 0.10(2) / 0.739(11) = 0.135(27);$$

least-squares weighted mean of 0.131(15)% adopted.

Equivalent data for the 9.80-keV gamma ray were determined directly from the proposed IT decay scheme (i.e. transition probability of 100% for the 9.80-keV gamma ray from the 105.87(6)-keV metastable state) and an approximated total internal conversion coefficient for this low-energy E3 transition of $4.8(2)E07$ (Kibedi et al (2008)). All P_{γ} data for the IT-decay mode were subsequently adjusted to make them commensurate with the relative gamma-ray emission probabilities of the EC-decay mode (re-defined as relative to P_{γ} of the 185.0-keV gamma ray (100%)), with a normalisation factor of 0.334(52). The method adopted to derive the IT decay data is somewhat convoluted, and doubts remain concerning the overall accuracy and efficacy of the procedure. Further measurements of the conversion-electron and gamma-ray emission probabilities are required to support and increase confidence in the data adopted to characterise this particular decay mode.



EC and IT branching fractions have been determined from ratios of the measured conversion-electron emission probabilities listed by Harmatz et al (1961) and Jorgensen et al (1961).

Based on 57.73-keV (IT decay mode) and 185.0-keV (EC decay mode) transition data:

$$P_{ce}(L)57.7 \text{ keV} / P_{ce}(K)185.0 \text{ keV} = 1.27(2)$$

$$\frac{\frac{TP(57.7 \text{ keV}) \times \alpha(L)}{(1 + \alpha(\text{total}))}}{\frac{TP(185.0 \text{ keV}) \times \alpha(K)}{(1 + \alpha(\text{total}))}} = 1.27(2)$$

$$\frac{TP(57.7 \text{ keV}) \times 1.611(23)}{13.64(18)} \bigg/ \frac{TP(185.0 \text{ keV}) \times 0.200(3)}{1.307(5)} = 1.27(2)$$

$$\frac{TP(57.7 \text{ keV})}{TP(185.0 \text{ keV})} = \frac{1.27(2) \times 13.64(18) \times 0.200(3)}{1.611(23) \times 1.307(5)} = 1.65(5)$$

With TP(57.7 keV) calculated to be 99.44(6)% of the IT decay (BF_{IT}), and TP(185.0 keV) estimated to be 96.9(5)% of the decay within the EC mode (and $BF_{EC} = 1 - BF_{IT}$):

$$\frac{TP(57.7 \text{ keV})}{TP(185.0 \text{ keV})} = \frac{0.9944(6) \times BF_{IT}}{0.969(5) \times (1 - BF_{IT})} = 1.65(5)$$

$$BF_{IT} = 0.62(2),$$

$$\text{and hence } BF_{EC} = 0.38(2).$$

However, equivalent calculations with L, M and N conversion-electron data for the 57.7-keV (IT-decay mode) gamma transition and the 80.7- and 185.0-keV (both EC-decay mode) gamma transitions are not in good agreement with the above values. Thus,

$$P_{ce}(L)57.7 \text{ keV} / P_{ce}(L)80.7 \text{ keV} = 0.21(1)$$

$$\frac{\frac{TP(57.7 \text{ keV}) \times \alpha(L)}{(1 + \alpha(\text{total}))}}{\frac{TP(80.7 \text{ keV}) \times \alpha(L)}{(1 + \alpha(\text{total}))}} = 0.21(1)$$

$$\frac{TP(57.7 \text{ keV}) \times 1.611(23)}{13.64(18)} \bigg/ \frac{TP(80.7 \text{ keV}) \times 3.32(5)}{7.14(9)} = 0.21(1)$$

$$\frac{TP(57.7 \text{ keV})}{TP(80.7 \text{ keV})} = \frac{0.21(1) \times 13.64(18) \times 3.32(5)}{1.611(23) \times 7.14(9)} = 0.83(5)$$

With TP(57.7 keV) calculated to be 99.44(6)% of the IT decay (BF_{IT}), and TP(80.7 keV) estimated to be 99.87(57)% of the decay within the EC mode (and $BF_{EC} = 1 - BF_{IT}$):

$$\frac{TP(57.7 \text{ keV})}{TP(80.7 \text{ keV})} = \frac{0.9944(6) \times BF_{IT}}{0.9987(57) \times (1 - BF_{IT})} = 0.83(5)$$

$$BF_{IT} = 0.45(3),$$

$$\text{and hence } BF_{EC} = 0.55(3).$$

Similar consideration of $P_{ce}(M+N)57.7 \text{ keV} / P_{ce}(M+N)80.7 \text{ keV}$ of 0.21(3) results in calculated BF_{IT} of 0.47(4) and BF_{EC} of 0.53(4); while $P_{ce}(L)57.7 \text{ keV} / P_{ce}(L)185.0 \text{ keV}$ of 2.7(2) produces BF_{IT} of 0.58(5) and BF_{EC} of 0.42(5). Under such unsatisfactory circumstances, these four sets of branching fraction data have been brought together to derive least-squares weighted mean values:



$$BF_{IT} = 0.55 \pm 0.07, \text{ and } BF_{EC} = 0.45 \pm 0.07$$

Weighted averages were adopted, and the uncertainties expanded slightly from ± 0.06 so that both ranges included their most precise values.

There are a significant number of uncertainties associated with the decay scheme, and specific assumptions have been made concerning the relative merits of the main sources of gamma-ray data. Furthermore, gamma transitions unobserved in the EC-decay measurements have been introduced from the Dy-162(n,n' γ), Dy-161(n, γ) and Gd-160(α ,2n) reaction studies of Govor et al (2002) and Aprahamian et al (2006). While the overall features of the proposed decay scheme are judged to be qualitatively acceptable, there are significant uncertainties in the quantification of the IT and EC branching fractions that need to be satisfactorily resolved. These specific parameters impact on the derivation of the normalisation factor for the gamma-ray emission probabilities and the determination of the gamma transition data for the IT decay mode. Further measurements are merited, particularly accurate determinations of the absolute and relative gamma-ray emission probabilities and the absolute conversion-electron emission probabilities.

82-Pb-205m

The half-life of 5.10(44) millisecs is the least-squares weighted mean value of the measurements of Vegors and Heath (1960), Bergstrom et al (1960), Maier et al (1971), and Salaita and Eapen (1973), with the uncertainty increased to include the most precise value. Further measurements are merited to resolve the existing discrepancy between the measurements in 1960 and those that followed.

The proposed decay scheme has been derived from the studies of Vegors and Heath (1960), Stockendal (1960), Johnston et al (1971), and Kosanke (1971), fortified by the more extensive gamma-ray measurements of parent Bi-205 by Rupp and Vegors (1971) and Hamilton et al (1972). Various mixing ratios and multipolarities were also extracted from the studies of Schmorak et al (1956/57), Hamilton et al (1972), and Simeckova et al (1990). Absolute gamma-ray emission probabilities were calculated from the proposed decay scheme, relative transition probabilities derived from EC-decay studies of parent Bi-205(+ Pb-205m), and the theoretical internal conversion coefficients of Kibedi et al (2008). These gamma-ray measurements are primarily identified with Rupp and Vegors (1971) and Hamilton et al (1972), and all parent decay data can be found in the equivalent file for Bi-205. Further studies are merited, particularly measurements that assist in defining the absolute emission probabilities of the most prominent gamma rays.

83-Bi-201m

The half-life of 55.8(14) mins is the least-squares weighted mean of the measurements of Neumann and Perlman (1950), Siivola et al (1964), and Mahunka et al (1967). Further measurements are merited to fortify and improve such a limited, disparate set of pre-1970 data.

Direct decay data measurements are extremely sparse, and there is little to no evidence of the existence of any gamma transitions, nor detail concerning the EC- and alpha-decay modes. All EC decay was assumed to occur directly to the ground state of Pb-201 (first forbidden unique), with no equivalent population of higher-energy levels on the basis of spin and parity considerations. However, Braga et al (1980) have suggested the observation of both 846.4- and 847.7-keV gamma rays as a doublet. The latter implies the additional EC population of the 936.1-keV nuclear level of Pb-201 (3rd forbidden non-unique) and subsequent depopulation via the 88.5-keV nuclear level of Pb-201 through the emission of 847.7- and 88.5-keV gamma rays - this possibility remains extremely doubtful, and has not been incorporated into the recommended decay scheme. A further contradiction is that Neumann and Perlman (1950) found no evidence for any positron emissions, and assumed only electron capture within the EC-decay mode. Nevertheless, positron and EC components for the 4688-keV transition were estimated from the tabulations of Gove and Martin (1970).



An IT branching fraction of 0.068 has been reported in gamma-ray and conversion-electron measurements by Braga et al (1980), and was adopted in this evaluation with an uncertainty of ± 0.007 (10%). A single IT gamma transition was introduced (846.35 keV, M4) with theoretical conversion coefficients derived from Kibedi et al (2008), albeit with a poorly defined absolute emission probability – Korman et al (1976) did not observe this transition which effectively brings into question the existence of an IT-decay mode. Despite these unsatisfactory circumstances, the adopted IT branching fraction was used to derive an EC branching fraction of 0.932(7).

The alpha branching fraction of 0.00003 was calculated from the studies of Neumann and Perlman (1950) in which an EC/ α ratio of 30000 was determined with no uncertainty – an uncertainty of ± 0.00001 was arbitrarily assigned. Such a small value and associated uncertainty are judged to be highly questionable, and these parameters need to be quantified with much greater confidence.

A number of major assumptions are associated with the proposed decay scheme, and significant uncertainties are identified with the three proposed decay modes. Further measurements are required to assess the detail within the decay scheme, particularly with respect to the dominance of the EC branching fraction in association with the minor IT-decay mode.

83-Bi-205

The half-life of 15.31(4) days is the least-squares weighted mean value of the measurements of Fritsch and Hollander (1958), and Brunner et al (1961). Further measurements are merited to fortify such a limited set of pre-1970 data.

A complex and comprehensive decay scheme has been derived from measurements of the relative gamma-ray emission probabilities by Schmorak et al (1956/57), Stockendal and Hultberg (1959), Rupp and Vegors (1971), and Hamilton et al (1972). While the extensive data sets of Rupp and Vegors, and Hamilton et al were measured relative to the emission probability of the 703.4-keV gamma ray (placed twice within the decay scheme), the evaluated emission probabilities were re-defined relative to the emission probability of the slightly more prominent 1764.37-keV gamma ray (100%). Vegors and Heath (1960), Stockendal (1960) Johnston et al (1971), and Giesler et al (1971) also provided guidance on the decay characteristics of specific gamma-ray transitions and the energy, spin and parity of nuclear levels. Various mixing ratios and multipolarities were extracted from the studies of Schmorak et al (1956/57), Hamilton et al (1972), Ahluwalia and Chasan (1973), and Simeckova et al (1990). However, multipolarities for a significant number of (M1 + E2) gamma transitions were arbitrarily assigned to be (50%M1 + 50%E2) with a relatively high uncertainty (122.3, 354.59, 361.24, 361.82, 445.25, 503.30, 561.30, 661.24, 668.3, 670.1, 683.6, 701.27, 703.5, 729.45, 757.1, 777.5, 788.17, 795.71, 806.49, 828.21, 848.25, 852.89, 871.91, 922.26, 971.56, 978.37, 1060.94, 1075.7, 1256.7, 1264.73, 1277.1, 1760.0, 1818.03 and 1966.00 keV), while other transitions were defined as 100%M1 (185.24, 220.99, 235.79, 284.20, 576.19, 720.63, 910.89 and 1072.37 keV). Assumed uncertainties of approximately 10% were assigned to the theoretical internal conversion coefficients for these transitions. A limited number of lower-energy (M1 + E2) gamma transitions were also defined arbitrarily as 99%M1 + 1%E2: 90.7, 115.18, 129.64 and 165.07 keV. Modest adjustments were made to the relative emission probabilities of specific gamma rays: 349.59 keV (1.73(3) changed to 1.31(15)); 549.82 keV (9.13(10) changed to 8.86(40)); 573.86 keV (1.92(4) changed to 1.74(20)); 701.27 keV (0.48(20) changed to 0.24(10)); 759.10 keV (3.25(14) changed to 3.53(25)); 1014.37 keV (2.83(6) changed to 2.52(25)); and 1351.49 keV (3.27(10) changed to 3.10(20)). Previously unplaced gamma transitions were introduced into the proposed decay scheme - although sixteen of these gamma rays were successfully allocated, one observed transition remained unplaced (1265.9 keV).

A reasonable segment of the gamma decay occurs via internal pair production for gamma-transition energies above 1022 keV (judged as significant above 1107 keV). This behaviour is not accommodated satisfactorily within the ENDF-B format, and therefore the relevant gamma-ray energies and their internal pair-production coefficients are listed below:



Energy (keV)	Internal pair-production coefficient	Energy (keV)	Internal pair-production coefficient
1107.74(8)	0.000001	1551.27(6)	0.000080(1)
1190.03(8)	0.000006(1)	1593.03(7)	0.000095(1)
1199.61(7)	0.000004	1614.32(3)	0.00014(1)
1208.55(7)	0.000018	1619.25(7)	0.000253(4)
1216.25(8)	0.000021	1676.1(1)	0.000084(1)
1256.7(2)	0.000014(1)	1760.0(2)	0.00021(2)
1262.40(4)	0.000010	1764.37(4)	0.00027(3)
1264.66(7)	0.000038(1)	1775.80(4)	0.00028(3)
1264.73(3)	0.000015(2)	1818.03(15)	0.00024(2)
1277.1(5)	0.000017(2)	1861.69(5)	0.000430(6)
1351.49(6)	0.000025	1903.45(6)	0.000460(6)
1499.14(4)	0.000063(1)	1966.00(7)	0.00033(3)
1501.54(7)	0.000064(1)	2565.2(3)	0.000454(7)
1512.97(7)	0.000068(1)	2606.88(4)	0.000477(6)

EC transition probabilities were determined from population/depopulation balancing of each nuclear level of Pb-205, based on the recommended gamma-ray emission probabilities and theoretical internal conversion coefficients of Kibedi et al (2008). EC decay to the 1817.99-, 1264.73-, 761.43-, 576.19-, 262.83- and 2.33-keV nuclear levels and ground state of Pb-205 were assumed to be zero on the basis of spin-parity considerations. Furthermore, EC decay to the 1499.14- and 1043.74-keV nuclear levels of Pb-205 were calculated to be zero from the observed population/depopulation balances. The positron emission probability to the 1013.85-, 987.63- and 703.43-keV nuclear levels of Pb-205 were determined from the theoretical (EC/ β^+) tabulations of Gove and Martin (1971).

The normalisation factor for the relative emission probabilities of the gamma rays was calculated by two routes:

- total direct gamma-ray decay to the ground state of Pb-205 to equal 100%, based on no EC decay directly to the 2.329-keV nuclear level and ground state;
- sum of the relative EC transition probabilities to equal 100%, as calculated from the relative emission probabilities of the gamma rays and the theoretical internal conversion coefficients derived from Kibedi et al (2008).

Both procedures were adopted separately to derive a normalisation factor of 0.324(2) for the relative emission probabilities of the gamma rays and calculated EC transitions.

The Pb-205 nuclear level at 1013.86 keV is populated in the EC decay of Bi-205, and has an evaluated half-life of 5.10 millisecs (i.e. defined as a metastable state). Hence, the decay of Bi-205 has been quantified in terms of two EC decay modes to the ground and metastable states of Pb-205. Both the Bi-205(EC)Pb-205m and Bi-205(EC)Pb-205 branching fractions were calculated from the relative emission probabilities of the relevant gamma rays, their theoretical internal conversion coefficients, and the normalisation factor of 0.324(2):

- determination of branching fraction to metastable state from summed direct EC and gamma population to 1013.85-keV nuclear level

$$\begin{aligned}
 \text{BF(Pb-205m)} &= \text{sum gamma transition probabilities} + \text{direct EC transition} \\
 &= 30.71(30)F + 12.3(38)F = 43.0(38)F \\
 &= 43.0(38) \times 0.324(2) = 13.9(12)\% \quad [= 0.139(12)]
 \end{aligned}$$



(b) determination of branching fraction to ground state from summed gamma emissions crossing the 1013.85-keV nuclear level, and EC decay to nuclear levels below the metastable state (with EC energies of 1720 and 2005 keV)

$$\begin{aligned} \text{BF(Pb-205)} &= \text{sum gamma transition probabilities} + \text{EC(1720 + 2005 keV) transitions} \\ &= 207.9(7)\text{F} + 57.4(20)\text{F} = 265.3(21)\text{F} \\ &= 265.3(21)\text{F} \times 0.324(2) = 86.0(7)\% \quad [= 0.860(7)] \end{aligned}$$

Thus, adoption of the least uncertain EC branching fraction gives BF(to Pb-205) of 0.860(7), and BF(to Pb-205m) of 0.140(7).

Appropriate adjustments have been made to the relative emission probabilities of the gamma transitions identified directly with the IT decay of Pb-205m that are also populated by other routes associated with the EC decay of Bi-205. Impacts on the recommended gamma-ray emission probabilities in Bi-205 decay are as follows:

negligible - 2.329, 260.50, 262.83, 313.36 and 573.86 keV;

minor – 127.24 and 576.19 keV

significant – 284.203, 703.43 and 987.63 keV

complete removal from the Bi-205 data file – 26.22-, 310.42- and 1013.85-keV gamma transitions that depopulate the 1013.85-keV metastable state.

The decay data for this metastable state are not contained within this file, but can be found in the equivalent file for Pb-205m (half-life of 5.10 milliseconds, and emission of thirteen gamma rays).

While the overall features of the proposed decay scheme are judged to be well defined, there are some unsatisfactory aspects within the detail. These problems are mainly identified with the derivation of the normalisation factor for the gamma-ray emission probabilities. Further studies are merited, particularly accurate measurements of the absolute gamma-ray emission probabilities.



Distribution

Dr J-C Sublet	Culham Centre for Fusion Energy, Culham, Abingdon, Oxon OX14 3DB
Dr A L Nichols	38 Mattock Way, Abingdon, Oxon OX14 2PQ,
Dr R A Forrest	Department of Nuclear Sciences and Applications, International Atomic Energy Agency, Wagramer Strasse 5, PO Box 100, A-1400 Vienna, AUSTRIA
Dr M A Kellett	Department of Nuclear Sciences and Applications, International Atomic Energy Agency, Wagramer Strasse 5, PO Box 100, A-1400 Vienna, AUSTRIA
Dr R W Mills	Desk 210/Level 3, B170, BNFL Sellafield, Seascale, Cumbria, CA201PG
Dr O Bersillon	CEA/DIF, BP no. 12, F-91680CEA Centre DAM Ile-de-France, Service de Physique Nucleaire, Bruyères-le-Châtel, 91297 ARPAJON Cedex, FRANCE
Dr C Nordborg	NEA Data Bank, OECD Nuclear Energy Agency, Le Seine Saint-Germain, 12 boulevard des Iles, F-92130 Issy-les-Moulineaux, France
Dr Y Rugama	NEA Data Bank, OECD Nuclear Energy Agency, Le Seine Saint-Germain, 12 boulevard des Iles, F-92130 Issy-les-Moulineaux, France
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