



Activation Product Decay Data: UKPADD6.9

Report to UK Atomic Energy Authority

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Executive Summary

The latest version of the UK Activation Product Decay Data Library (UKPADD6.9) is described in this report, as assembled for general use in March 2009.

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 in ENDF-6 format, including lists of the references used to produce the proposed decay schemes and comments that identify any observed inadequacies.

All evaluations for UKPADD6.9 were carried out by Dr A L Nichols¹.

Data for 20 nuclides have been newly evaluated or re-evaluated for UKPADD6.9 during the course of 2008/09. These evaluations were sponsored by the UK Atomic Energy Authority in support of the European Fusion Programme.

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

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1 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 in support of the European Fusion Programme. Specific nuclides requiring improved decay data have been identified by R A Forrest (UKAEA) and A L Nichols (5). Over the period from 1999 to early 2008, a further 154 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). All evaluations were 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 (UKPADD6.9), released in March 2009, is described in this paper. This latest library contains evaluations for 582 radionuclides.

Data for 20 nuclides have been newly evaluated or re-evaluated in preparation for the release of UKPADD6.9. These evaluations were carried out by Dr A L Nichols and sponsored by the UK Atomic Energy Authority in support of the European Fusion Programme. The evaluation procedure and contents of UKPADD6.9 are summarized in the following sections.

2 Decay Data

UKPADD6.9 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 have been defined, and uncertainties are assigned to all evaluated data. Other data in UKPADD6.9 (mean energies, discrete electrons and mean X-rays) were derived from the above data by using the processing code COGEND (14). 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 (15). 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 (16, 17).

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 UKPADD6.9 are listed as described in Reference 15, 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:

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

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 UKPADD6.9 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 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 (18), CHECKR (18) and FIZCON (19) 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, UKPADD6.9

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 (UKAEA Fusion, Culham Laboratory), on the basis of their relative activities and gamma-dose rates as a function of time (20). Over 750 radionuclides were assessed, and a set of 338 nuclides were recommended for new measurements and re-evaluation with various degrees of priority.

Twenty nuclides were evaluated or re-evaluated during 2008/09 (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 the radionuclide for full details.

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 UKPADD6.9 were checked using CHECKR7.02 (18) and FIZCON (19).

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 (15), 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, 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 UKPADD6.9 evaluated decay data library has been assembled in the internationally-accepted ENDF-6 format adopted for nuclear applications, as described in Reference 15. Comprehensive decay scheme data are presented for 582 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 (UKPADD6.9), 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 UKPADD6.9 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 (21), and they were considered as possible candidates for incorporation into UKPADD, with supportive data from Takahashi *et al.* (22) and Audi *et al.* (23). 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 Tl-201 decay scheme.

There are 582 full evaluations in UKPADD6.9, of which 35 files are assembled from theoretical data and 9 are defined as being incomplete data sets. The remaining 538 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 20 nuclides have been newly evaluated or re-evaluated and exhibit good to excellent consistency. A significant number of radionuclides remain to be evaluated in greater detail as documented by Forrest (20), and one intention should be to continue this work in order to bring this evaluation programme to a satisfactory conclusion.

All of the evaluated decay data have been assembled with other files from previous versions of UKPADD to create the UKPADD6.9 library in ENDF-6 format (582 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 individual ENDF-6 files.

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. UKPADD6.9 is available via the NEA Data Bank, and all the decay data comprising UKPADD6.9 have been submitted for possible inclusion in the JEFF-3 Decay Data Library.

6 References

- 1 A L Nichols
Radioactive Decay Data for Reactor Calculations: Activation Products and Related Isotopes.
UKAEA Harwell Report AERE-R 8903
1977
- 2 A L Nichols
Activation Product Decay Data: UKPADD2 Data Files.
AEA-RS-5449
March 1993
- 3 JEF-2.2 Radioactive Decay Data.
JEF Report 13
http://db.nea.fr/html/dbdata/nds_jefreports/jefreport-13.pdf
August 1994
- 4 A L Nichols, C J Dean, A P Neill, R J Perry
UKPADD6: Evaluated Decay Data Library.
AEAT-5281
March 1999
- 5 A L Nichols
Assessment and Evaluation of Decay Data for EAF – 1999/2000.
UKNSF(99)P130
1999



- 6 A L Nichols
Assessment and Evaluation of Decay Data for EAF – 2000/2001.
UKNSF(2001)P144
2001
- 7 A L Nichols
Assessment and Evaluation of Decay Data for EAF – 2001/02.
UKNSF(2001)P151
2001
- 8 A L Nichols, R J Perry
Assessment and Evaluation of Decay Data for EAF – 2002/04.
UKNSF(2003)P175
2003
- 9 A L Nichols, R J Perry
Assessment and Evaluation of Decay Data for EAF – 2004/05.
UKNSF(2005)P188, JEF/DOC-1072
2005
- 10 A L Nichols, R J Perry
Assessment and Evaluation of Decay Data for EAF – 2005/06.
UKNSF(2006)P200, JEF/DOC-1128
2006
- 11 A L Nichols, R J Perry
Assessment and Evaluation of Decay Data for EAF – 2006/07.
UKNSF(2007)P214, JEF/DOC-1167
March 2007
- 12 A L Nichols, R J Perry
Activation Product Decay Data: UKPADD6.7.
SA/NST/18923/W001 Issue 1
March 2007
- 13 A L Nichols, R J Perry
Activation Product Decay Data: UKPADD6.8.
SERCO/TAS/000343/W003 Issue 1
March 2008
- 14 R J Perry, C J Dean (originally A Tobias)
COGEN: A Code to Generate Nuclear Decay Scheme Data in ENDF-6 Format.
UKNSF(04)P190, JEF/DOC-1083
2004
- 15 M Herman (Editor)
ENDF-6 Formats Manual
ENDF-102 Data Formats and Procedures for the Evaluated Nuclear Data File,
ENDF/B-VI and ENDF/B-VII.
Document ENDF-102, Report BNL-NCS-44945-05-Rev.
Revised June 2005

- 16 C M Lederer, V S Shirley (Editors)
K X-rays: Energies, Relative Intensities and Fluorescence Yields.
Table of Isotopes, 7th Edition, APPENDIX III, Table 10,
John Wiley and Sons Inc, New York
1978
- 17 S I Salem, S L Panossian, R A Krause
Experimental K and L Relative X-ray Emission Rates.
At. Data Nucl. Data Tables, 14(2), 91
1974
- 18 C L Dunford
ENDF Utility Codes Release 7.01/02.
May 2005
- 19 R J Perry, M J Grimstone, C J Dean
Specification and Maintenance Document for Decay Data Checking in FIZCON.
JEF/DOC-959, UKNSF(2003)P160
March 2003
- 20 R A Forrest
Data Requirements for Neutron Activation, Part II: Decay Data.
Fusion Eng. Design, 81, 2157-2174
2006
- 21 C L Dunford
Evaluated Nuclear Data File ENDF/B-VI.
pp 788-792 in Proc. Int. Conf. Nucl. Data for Science and Technology
Editor: Qaim, S.M., Springer-Verlag, Berlin, Germany
1992
- 22 K Takahashi, M Yamada, T Kondoh
Beta-decay Half-lives Calculated on the Gross Theory.
At. Data Nucl. Data Tables, 12(1), 101-142
1973
- 23 G Audi, O Bersillon, J Blachot, A H Wapstra
The NUBASE Evaluation of Nuclear and Decay Properties.
Nucl. Phys., A624, 1-124
1997



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
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



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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
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



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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
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- 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



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36-Kr- 85m	APR94	4.480h	β- (0.789), IT (0.211)	0.0483
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
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 (0.981), EC (0.019)	-0.0108
41-Nb- 90m	NOV07	18.810s	IT	0.0185
41-Nb- 90n	NOV07	6.220E-03s	IT	0.0158



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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)	#
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)	#



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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
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	JAN91	48.540m	IT	-0.0834
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



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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
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	OCT91	9.520m	β-	0.1417
50-Sn-126	JUL01	2.420E+05y	β-(m) (0.332), β-(n) (0.668)	0.0675
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	JUN92	33.8d	β- (0.31), IT (0.69)	-0.2257
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
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



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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
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



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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
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-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-163	JUN01	4.570E+03y	EC	Incomplete
67-Ho-163m	JUN01	1.1s	IT	0.0373
67-Ho-164	DEC00	28.6m	β ⁻ (0.517), EC (0.483)	0.0101



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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
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



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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
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

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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
82-Pb-205	DEC93	1.530E+07y	EC	1.9227
83-Bi-207	AUG91	31.760y	EC	0.1833
82-Pb-207m	NOV08	0.806s	IT	0.0054
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 (21), Takahashi *et al.* (22) and Audi *et al.* (23).

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



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- 73	6.93792E+06	5.23	4.76	0.00	-	-	1	-	-	-	-	3	5
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- 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	-	-	-	-



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-106	9.00000E-01	2138.00	1091.00	5.80	0c	0c	-	-	0c	-	-	-	-
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	-	-	-	-



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- 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
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



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-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
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



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-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
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	2.91240E+03	104.88	291.67	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



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
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
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	5.71200E+02	796.81	347.03	0.00	23	8	-	-	-	-	-	21	6
50-Sn-126	7.63694E+12	108.99	56.24	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



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-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
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	2.92032E+06	240.18	38.94	0.00	40	9	-	-	-	-	-	65	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



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-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
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



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-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
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



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-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	-	-	-	-
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



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-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
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-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



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
66-Dy-166	2.93760E+05	157.86	41.87	0.00	7	4	-	-	-	-	-	22	6
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-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
71-Lu-172m	2.22000E+02	40.20	1.67	0.00	1	-	-	-	-	-	-	4	2



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-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
74-W -176	9.00000E+03	57.30	171.53	0.00	6	-	3	-	-	-	-	18	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 -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
77-Ir-187	3.78000E+04	63.79	301.51	0.00	96	-	24	-	-	-	-	273	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
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
79-Au-195m	3.05000E+01	115.53	203.01	0.00	5	-	-	-	-	-	-	16	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-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	-	-	-	-	-
82-Pb-204m	4.05000E+03	103.27	2080.67	0.00	6	-	-	-	-	-	-	21	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
82-Pb-205	4.82831E+14	8.95	59.29	0.00	-	-	1	-	-	-	-	3	6
83-Bi-207	1.00224E+09	118.46	1539.51	0.00	6	-	4	-	-	-	-	21	8
82-Pb-207m	8.06000E-01	122.92	1510.36	0.00	2	-	-	-	-	-	-	9	7
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.

**Table3. Nuclides Evaluated in 2008/09**

Nuclide	Half-life	Consistency (% Deviation)
31-Ga- 67	78.269(11) h	-0.0255
36-Kr- 83m	1.83(2) h	-0.6199
40-Zr- 93	1.53(10) x 10 ⁶ y	0.0000
[41-Nb- 93m]	16.12(15) y	-0.2611
43-Tc- 98	4.3(2) x 10 ⁶ y	0.0097
45-Rh-101	3.2(3) y	-0.0017
45-Rh-101m	4.35(1) d	-0.0119
[48-Cd-115]	53.46(4) h	0.0269
48-Cd-115m	44.45(30) d	-0.0407
54-Xe-129m	8.88(2) d	0.1423
54-Xe-134m	0.290(17) s	0.0088
60-Nd-141	149.2(17) min	0.0176
60-Nd-141m	62.0(10) s	0.0006
69-Tm-167	9.25(2) d	0.1375
75-Re-183	70(2) d	0.1119
77-Ir-189	13.2(1) d	0.1686
77-Ir-193m	10.53(4) d	-0.0699
[77-Ir-194m]	0.03183(24) s	0.3813
77-Ir-194n	171(11) d	-0.0393
82-Pb-207m	0.806(8) s	0.0054

Radionuclides in parentheses have not been specifically requested, but have been included because they are related ground/metastable states or short-lived daughter nuclides.



Appendix I

Comments from New Evaluations



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Appendix 1: Comments from New Evaluations

Reproduced below are the comments associated with each of the nuclides evaluated in 2008/09. 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.

31-Ga- 67

The half-life of 78.269(11) hours is the weighted mean value of the measurements of McCown et al (1948), Tobailem (1955), Rudstam (1964), Crisler et al (1972; total of eight measurements – but two rejected as outliers), Lewis et al (1972), Lagoutine et al (1978), Meyer (1978), Debertain et al (1979), Houtermans et al (1980), Unterweger (2002), da Silva et al (2004), and Schrader (2004).

A reasonably comprehensive decay scheme has been derived from measurements of the absolute gamma-ray emission probabilities by Freedman et al (1966), Meyer et al (1978), Debertain et al (1979), Hirshfeld et al (1991), and Yalcin and Kurucu (2005). The EC transition probabilities were determined from balancing the population/depopulation of each nuclear level of Zn-67, based on the recommended gamma-ray emission probabilities and the theoretical internal conversion coefficients of Kibedi et al (2008). The multipolarity of the 91.267-keV gamma transition was determined to be 99.64%M1 + 0.36%E2 from the studies of Throop et al (1975); the multipolarities of the 184.579-, 208.952-, 300.219-, 393.531-, and 703.122-keV gamma transitions were determined to be 89.1%M1 + 10.9%E2, 99.88%M1 + 0.12%E2, 96.86%M1 + 3.14%E2, 99.815%M1 + 0.185%E2 and 99.2%M1 + 0.8%E2, respectively, from the studies of Bargholtz et al (1973); and the multipolarities of the 494.170- and 887.701-keV gamma transitions were determined to be 98.08%M1 + 1.92%E2 and 52%M1 + 48%E2, respectively, from the studies of Lornie et al (1978).

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 calculation of the EC transition probability directly to the ground state of Zn-67. A value of 0.015(5) has been derived, whereas Simpson and Ntsoane (2000) determined a value of 0.0401(27), and an equivalent decay scheme evaluation by Chechev and Kuzmenko (2004) furnished a value of 0.036(20). Further measurements are merited, particularly accurate determinations of the absolute gamma-ray emission probabilities.

36-Kr- 83m

The recommended half-life of 1.83(2) hours has been adopted from the studies of Ruby et al (1971). Further measurements are required to confirm the validity of this decay parameter and associated uncertainty.

An extremely accurate determination of the mixing ratio (δ) of 0.0129(3) for the 9.4-keV gamma ray has been carried out by Kovalik and Gorozhankin (1993). This value dominates a weighted mean analysis of the available data, and was adopted to derive the simple IT-decay scheme (two gamma cascade). Absolute gamma-ray emission probabilities and their uncertainties were determined on the basis of 100% transition probabilities and the theoretical internal conversion coefficients of Kibedi et al (2008).



40-Zr- 93

The adopted half-life of $1.53(10)E+06$ years is the value defined by Flynn (Argonne National Laboratory) in a private communication to Kocher (Oak Ridge National Laboratory) which constitutes a brief letter dated 1 May 1972. No information is given as to the method used to obtain such a value. Further measurements are most certainly required to improve the quantification of this decay parameter and associated uncertainty.

The absolute emission probabilities and uncertainties of the beta-particle transitions are also based on the brief private communication of Flynn (Argonne National Laboratory) to Kocher (Oak Ridge National Laboratory). The 60.4-keV beta-particle emission probability to the 30.82-keV nuclear level of Nb-93m was specified as being equal to or greater than 95%, while the 91.2-keV beta-particle emission probability to the ground state of Nb-93 was defined as being equal to or less than 5%. Knight et al (1959) adopted a beta-transition type of first forbidden unique ($J = 2$, yes) for the main emission of Zr-93 in their spectral studies of Y-93, which also conforms with the simple decay scheme proposed by Flynn (1972). Minor adjustments have been made to these beta-particle emission probabilities that still agree within the suggestions of Flynn (60.4 keV beta-particle emission probability of 97(2)%; 91.2-keV beta-particle emission probability of 3(2)%). Well-documented decay scheme measurements are required to provide much stronger support in the evolution and recommendation of an entirely satisfactory decay scheme for Zr-93.

41-Nb- 93m

The recommended half-life of 16.12(15) years is the weighted mean of the measurements of Lloret (1981) and Vaninbroukx (1983) that supersede earlier studies, with the uncertainty increased from ± 0.12 to 0.15 years in line with the lowest measured uncertainty. Further measurements are required to confirm the validity of this decay parameter and associated uncertainty.

The absolute emission probability and uncertainty of the 30.82-keV gamma ray were determined on the basis of 100% transition probability and the theoretical internal conversion coefficients derived from Kibedi et al (2008).

43-Tc- 98

The half-life of $4.3(2)E+6$ years is the weighted mean of the measurements of Goeking (1966) and Kobayashi et al (1999). A half-life of $4.2(3)E+6$ years arises from a measurement by Goeking (1966) quoted at the 95% confidence level, and also listed in a brief internal memo by O'Kelley to Horen (ORNL, 1973). Estimated half-lives of $6.5E+6$ and $9E+6$ years have also been obtained from activity measurements by Kobayashi et al (1993), while a value of $6.6(10)E+6$ years was determined by means of ICP-MS by Kobayashi et al (1999). Further measurements are required to improve this unsatisfactory situation.

An emission probability ratio for two gamma rays has been measured by Collins (1973) (also reported in an internal memo by O'Kelley (ORNL, 1973)), and this same number is listed in a compilation by Dzhelepov and Shestopalova (1979):

$$P(745.38 \text{ keV}) / P(652.44\text{-keV}) = 1.02(7)$$



Kobayashi et al (1993 and 1999) found no evidence of EC decay to Mo-98 ($EC/\beta^- < 0.037$), while Collins was unable to detect a possible 1397.8-keV gamma-ray emission directly from the 1397.8-keV nuclear level to the ground state of Ru-98. Hence, a single 100% beta decay to the 1397.9-keV nuclear level of Ru-98 is proposed of transition type second forbidden non-unique, followed by a simple two-gamma cascade to the ground state (both E2 transitions, with energies of 652.44 and 745.38 keV). Although the spin of the ground state of Tc-98 is not known with any degree of confidence, a value of 6 mitigates against the existence of additional beta transitions to other nuclear levels of Ru-98 on the basis of spin-parity considerations. Transition probabilities for both of the E2 gamma rays are 100%. Theoretical internal conversion coefficients from Kibedi et al (2008) were adopted to calculate their recommended emission probabilities (rather than adopted the less accurate emission probability ratio of 1.02(7)).

The resulting decay scheme possesses a number of significant uncertainties. Accurate measurements of the absolute gamma-ray emission probabilities would aid considerably in defining the proposed decay scheme with much greater confidence.

45-Rh-101

The half-life of 3.2(3) years is the least-squares weighted mean of the measurements of Evans and Naumann (1965), and Hisatake et al (1965). Further measurements are required to determine this decay parameter and associated uncertainty with much greater confidence.

A significant number of low-intensity gamma rays ranging in energy from 97 to 462.5 keV were observed by Sieniawski et al (1971), and assigned to the decay scheme of Rh-101. However, Vanin et al (1985) were able to set aside these additional gamma transitions, identifying some with the decay of Rh-102 and Rh-102m and justifiably discarding others. Under these circumstances, the proposed decay scheme was derived from measurements of the relative gamma-ray emission probabilities by Evans and Naumann (1965) and Vanin et al (1985), while the equivalent studies of Sieniawski et al (1971) were discarded. The (97.2%M1 + 2.8%E2) and (98.6%M1 + 1.4%E2) multipolarities for the 127.229- and 198.00-keV gamma rays, respectively, were adopted from Wood et al (1966); the 294.99-, 311.37- and 422.2-keV gamma rays were defined as essentially 100%M1; (80%M1 + 20%E2) and (90%M1 + 10%E2) multipolarities were calculated for the 110.8- and 184.14-keV gamma rays, respectively, to achieve the expected population-depopulation balance for the 311.37-keV nuclear level of Ru-101. This quantification of the population-depopulation balance for the 311.37-keV nuclear level of Ru-101 indicates no EC decay directly to this level, while adoption of a normalisation factor of 0.794(8) for the relative gamma-ray emission probabilities based on the absolute gamma-ray emission probabilities of Laurec et al (1996) suggests no EC decay directly to the ground state of Ru-101. The other EC transition probabilities were calculated from the relative gamma-ray emission probabilities, the normalisation factor of 0.794(8) and the theoretical conversion coefficients derived from Kibedi et al (2008).

There are a 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. Therefore, further measurements of the absolute gamma-ray emission probabilities are required to help in the development of specific features of the proposed decay scheme, particularly the determination of the EC transition probability directly to the ground state of Ru-101 (assigned a value of zero).

45-Rh-101m

The half-life of 4.35(1) days is the least-squares weighted mean of the measurements of Evans et al (1965), Aras et al (1966), Liskien (1968), Vanin et al (1985), and Heath and Helmer (1998).

A reasonably simple decay scheme has been derived from the gamma-ray studies of Sieniawski et al (1971), Vanin et al (1985), and Heath and Helmer (1998). A significant number of low-intensity gamma rays with energies greater than 330 keV were observed by Sieniawski et al, although Vanin et al were able to discard these particular transitions as belonging to the decay of Rh-100, Rh-101, Rh-102 and Rh-102m, and activated Sb and Ir contamination. The majority of the recommended relative gamma-ray emission probabilities are the weighted mean values of the data of Sieniawski et al, Vanin et al, and Heath and Helmer, with a minor adjustment made to the 179.63-keV gamma ray to achieve the expected population-depopulation balance of the 127.23-keV nuclear level of Ru-101. The (97.2%M1 + 2.8%E2) multipolarity for the 127.229-keV gamma ray was adopted from Wood et al (1966); (99%M1 + 1%E2) and (51%M1 + 49%E2) multipolarities for the 306.858- and 545.115-keV gamma rays, respectively, were adopted from Kaindl et al (1973); the 233.75-, 238.26- and 311.37-keV gamma rays were defined as essentially 100%M1; and the (90%M1 + 10%E2) multipolarity for the 184.14-keV gamma ray was derived from calculations of the population-depopulation balance for the 311.37-keV nuclear level of Ru-101. EC decay to the 311.137-, 127.23-keV nuclear levels and ground state of Ru-101 were assumed to be zero on the basis of spin and parity considerations. Under these circumstances and with a well-defined IT gamma transition (M4, 157.32 keV), a reasonably consistent decay scheme was derived with a normalisation factor of 0.859(6) for the relative gamma-ray emission probabilities. All EC transition probabilities were calculated from the relative gamma-ray emission probabilities, their normalisation factor and the theoretical conversion coefficients derived from Kibedi et al (2008). These data were then used to determine the EC and IT branching fractions.

There are a 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. Further measurements of the absolute and relative gamma-ray emission probabilities are required to confirm and improve some of the detail within the proposed decay scheme.

48-Cd-115

The half-life of 53.46(4) hours is the weighted mean value of the measurements of Wyatt et al (1961), Beda et al (1964), Roche (1968) and Baba et al (1971), with the uncertainty increased from ± 0.03 to 0.04 hours in line with the lowest measured uncertainty.

A reasonably comprehensive decay scheme has been derived from measurements of the absolute gamma-ray emission probabilities by Heyde et al (1978); equivalent studies by Bäcklin et al (1967) and Bosch et al (1974) are less comprehensive and report only limited sets of relative emission probability data. The beta-particle emission probabilities were determined from balancing the population/depopulation of each nuclear level of In-115, based on the recommended gamma-ray emission probabilities and the theoretical internal conversion coefficients of Kibedi et al (2008). Beta transitions to the 941.42-keV nuclear level and ground state of In-115 were assumed to be zero on the basis of spin-parity considerations. Other assumptions involve the multiplicities of the various M1 + E2 gamma transitions that are arbitrarily defined to be 100%M1 for the 251.07-, 260.90-, 328.35- and 363.90-keV gamma rays, and determined to be 97%M1 + 3%E2 for the low-energy 35.55-keV gamma ray from the internal conversion coefficient studies of Bäcklin et al ($\delta = -0.176(30)$). Depopulation of the 941.4-keV nuclear level is assumed to occur via two gamma transitions (941.42 and 344.28



keV), based on the Coulombic excitation studies of In-115 by Tuttle et al (1976). Although only the 941.4-keV gamma ray has been observed by Heyde et al, the 344.28-keV gamma transition has been included in the proposed decay scheme and the emission probability calculated from the gamma population/depopulation balance of the 941.42-keV nuclear level. However, all of these assumptions have only small to modest impacts on the reasonably well-defined decay scheme.

The extensive reliance on the gamma-ray measurements of Heyde et al (1978) is judged to be unsatisfactory, and further measurements are merited in support of these studies.

48-Cd-115m

The half-life of 44.45(30) days is the weighted mean value of the measurements of Wahl (1959), Moret (1969), and Baba et al (1971), with the uncertainty increased from ± 0.22 to 0.30 days in line with the lowest measured uncertainty.

A reasonably comprehensive decay scheme has been derived from measurements of the relative gamma-ray emission probabilities by Graeffe et al (1966), Sergeev et al (1973), Bosch et al (1975), and Heyde et al (1978). Beta transitions to the 1078.16-, 941.42-, 828.59-, 597.14- and 336.244-keV nuclear levels of In-115 were assumed to be zero on the basis of spin-parity considerations. Multipolarity assignments for the 158.01-, 260.90-, 316.21-, 484.47-, 933.78- and 1132.58-keV gamma transitions were derived from the studies of Sergeev et al (1973), Koshut and Arya (1973), Sturm et al (1973), Rosenblum and Steyert (1975), Bosch et al (1975) and Hansen (1981). Population/depopulation balances of the various nuclear levels of In-115 were achieved through minor adjustments to the relative emission probabilities of the 105.19-, 136.7-, 353.5-, 481.0 and 941.42-keV gamma rays, while the 1078.2-keV gamma ray assigned previously to the depopulating of the 1078.2-keV nuclear level was discarded; furthermore, the 544.7-keV gamma ray was placed twice in the proposed decay scheme.

The normalisation factor for the gamma-ray emission probabilities is a key parameter in the determination of a complete and consistent decay scheme, and a value of 0.0195(5) has been adopted from the only known measurement of Moret (1969); this value was quantified by Moret as an absolute emission probability of 1.95(5) per 100 disintegrations for the 933.8-keV gamma ray. All of the beta-particle emission probabilities and the branching fractions to the ground and metastable states of In-115 were calculated from the relative gamma-ray emission probabilities and this normalisation factor. The resulting decay scheme contains a number of significant assumptions and uncertainties, of which this normalisation factor is significant. Extensive absolute gamma-ray emission probability measurements are merited that would assist greatly in the resolution of the current difficulties and uncertainties.

54-Xe-129m

The recommended half-life of 8.88(2) days is the least-squares weighted mean of the measurements of Miller and Schima (1973), Hoffman et al (1975), and Tam et al (1990), with the uncertainty increased from ± 0.015 to 0.02 days in line with the lowest measured uncertainty.

The absolute emission probabilities and uncertainties of the 39.578- and 196.56-keV two gamma cascade were determined on the basis of 100% transition probabilities and the theoretical internal conversion coefficients derived from Kibedi et al (2008). A multipolarity of



(99.93%M1 + 0.07%E2) was adopted for the 39.578-keV gamma ray from the studies of Geiger et al (1965) and Marest et al (1974), and M4 for the 196.56-keV gamma ray.

54-Xe-134m

The recommended half-life of 0.290(17) secs represents the only known measurement by Winn (1968). Further measurements are required to determine this decay parameter and associated uncertainty with much greater confidence.

The absolute emission probabilities and uncertainties of the 234.3-, 847.04- and 884.13-keV components of the three gamma-ray cascade were determined on the basis of 100% transition probabilities and the theoretical internal conversion coefficients derived from Kibedi et al (2008). Measurements of the absolute intensity of the 234.3-keV gamma ray are required to confirm the detail within the proposed decay scheme.

60-Nd-141

The half-life of 149.2(17) mins is the weighted mean value of the measurements of Wilkinson and Hicks (1949), Rayburn (1961), Biryukov and Shimanskaya (1963), Grissom et al (1966), Lange and Münzel (1968), and Bormann et al (1970).

A reasonably comprehensive decay scheme has been derived from measurements of the relative gamma-ray emission probabilities by Beery et al (1968), Hesse (1969) and Buttsev et al (1974). The EC transition probabilities were determined from balancing the population/depopulation of each nuclear level of Pr-141, based on the recommended gamma-ray emission probabilities and the theoretical internal conversion coefficients of Kibedi et al (2008). Direct EC decay to the 145.44-keV nuclear level of Pr-141 was assumed to be zero on the basis of spin-parity considerations. The multipolarity of the 145.443-keV gamma-ray transition was determined to be 99.54%M1 + 0.46%E2 from the studies of Schooley et al (1962), Haag et al (1963), Gelletly et al (1968) and Hansen (1979). A normalisation factor of 0.0082(3) was calculated for the relative emission probabilities of the gamma rays, based on a relative intensity of 628(24) for the annihilation radiation as measured by Buttsev et al (1974):

$$2 \times (EC + \beta^+) / (1 + (EC/\beta^+)) \text{ for the ground state} = 628(24)NF,$$

in which a theoretical (EC/β^+) ratio of 37.15 was taken from Gove and Martin (1971), and NF is the normalisation factor.

Thus, $(EC + \beta^+)$ directly to the ground state = $(628(24)NF \times 38.15) / 2 = 11979.1(4578)NF$.

Now, $225.45(615)NF + (EC + \beta^+)$ directly to the ground state = 100 (from the proposed decay scheme as derived), and therefore:

$$225.45(615)NF + 11979.1(4578)NF = 100$$

$$NF = 100 / 12204.55(46395) = 0.0082(3)$$

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 Pr-141. Further measurements are merited, particularly accurate determinations of the absolute gamma-ray emission probabilities and the annihilation radiation.

60-Nd141m

The half-life of 62.0(10) secs is the weighted mean value of the measurements of James and Bingham (1960), Kotajima and Morinaga (1960), Grissom et al (1966), Geiger and Graham (1967), Jansen et al (1969), and Chattopadhyay et al (1988), with the uncertainty increased from ± 0.5 to 1.0 secs in line with the lowest measured uncertainty.

The decay scheme is dominated by the 756.5-keV gamma ray of the isomeric transition decay. However, a small EC-decay mode has been proposed as derived from the upper limits placed on the EC-based gamma-ray emission probabilities measured by Chattopadhyay et al (1988) and coupled with studies of the EC/IT branching fraction ratio by Abulaffio et al (1970). Gamma-ray emission probabilities and their uncertainties were subsequently estimated on the basis of the relative intensities obtained by Trostell and Fogelberg from their studies of the Pr-141(n,n' γ) reaction and the theoretical internal conversion coefficients of Kibedi et al (2008). Both the absolute EC transition and gamma-ray emission probabilities were crudely derived from the upper limits of the EC transition probabilities as defined by Chattopadhyay et al, and normalised to an overall EC branching fraction of 0.032(10)% as determined by Abulaffio et al. Direct EC decay to the 145.44-keV nuclear level and ground states of Pr-141 were assumed to be zero on the basis of spin-parity considerations. The multipolarity of the 145.443-keV gamma-ray transition was determined to be 99.54%M1 + 0.46%E2 from the studies of Schooley et al (1962), Haag et al (1963), Gelletly et al (1968) and Hansen (1979).

Both the existence and detailed derivation of the EC-decay mode are judged to be questionable. Further measurements are merited to determine the validity of previous studies, and also confirm or disprove the correctness of the proposed decay scheme.

69-Tm-167

The half-life of 9.25(2) days is the least-squares weighted mean of the measurements of Bjornholm et al (1961), Bonner et al (1962), Nethaway and Missimer (1968), and Karol (1970), with the uncertainty increased from ± 0.014 to 0.02 years in line with the lowest measured uncertainty. Slightly higher values around 9.6 days have been measured, some without quantified uncertainties, by Wilkinson and Hicks (1949), Michel and Templeton (1954), Narasimhaiah and Pool (1960), Butement and Glentworth (1960), and Rayudu and Yaffe (1963), but these particular data were set aside. Further measurements are merited to confirm the validity of the recommended value.

A reasonably simple decay scheme has been developed from the relative gamma-ray emission probability measurements of Funke et al (1968) and the conversion-electron studies of Artamanova et al (1979). This decay scheme was built-up initially by including the 207.801-keV gamma ray of the Er-167m daughter (half-life of 2.270(6) secs). While the relative emission probabilities of the gamma rays are expressed in terms of the 531.54-keV gamma ray (100%), the major transition would appear to be the 57.07-keV emission which did not fall within the measurement range of the gamma-ray detector used by Funke et al. The relative emission probability of this important 57.07-keV gamma ray was determined from the relative emission probability of the 207.801-keV gamma ray and the conversion-electron ratios measured by Artamanova et al:

$$P(\text{ce(L)} 57.07\text{-keV})/P(\text{ce(K)} 207.8\text{-keV}) = 18.7(9)/19.76(24) = 0.946(57).$$

Since $\text{ICC(X)} = P(\text{ce(X)})/P(\text{gamma})$, then



$$ICC((L) 57.07\text{-keV}) \times P(57.07\text{-keV}) / ICC((K) 207.8\text{-keV}) \times P(207.8\text{-keV}) = 0.946(57),$$

in which $ICC((L) 57.07\text{-keV}) = 4.0(4)$, $ICC((K) 207.8\text{-keV}) = 0.476(7)$ (Kibedi et al (2008)), and $P(207.8\text{-keV}) = 2580(350)$ expressed as relative emission probability (Funke et al (1968)).

$$\text{Therefore, } 4.0(4) \times P(57.07\text{-keV}) / 0.476(7) \times 2580(350) = 0.946(57),$$

$P(57.07\text{-keV}) = 290(40)$ defined as a relative emission probability, with an uncertainty assigned only on the basis of the equivalent uncertainty of $P(207.8\text{-keV})$.

Various assumptions were made during the derivation of the decay scheme. EC decay to the 281.57-keV and ground state of Er-167 were assumed to be zero on the basis of spin and parity considerations (although these same criteria do not apply to the 346.55-keV nuclear level due to the observation of the 346.55-keV gamma ray). The 249.97-keV gamma ray that originates from the 531.54-keV nuclear level populates the 281.57-keV nuclear level, from which depopulation was assumed to occur via the unobserved 16.70- and 73.77-keV gamma transitions. Only estimates could be made of the multipolarities of the (99.9%M1 + 0.1%E2)16.70- and (88.5%M1 + 11.5%E2)57.07-keV gamma transitions, and the relative emission probabilities of the 16.70-, 57.07- (see above), 73.77- and 264.87-keV gamma rays were either calculated or crudely approximated. The uncertainties in the branching fractions are based solely on the calculation of the decay to the ground state of Er-167 (0.0175(4)); the equivalent calculation for the branching fraction to Er-167m contains significant uncertainties (0.98(27)), and therefore a value of 0.9825(4) has been adopted.

The measured and calculated relative gamma-ray emission probabilities and the theoretical internal conversion coefficients derived from Kibedi et al were used to calculate the relative EC transition probabilities to the nuclear levels of Er-167 (prior to their conversion to absolute values). Assuming zero EC decay direct to the ground state of Er-167, a normalisation factor of 0.016(3) was determined for both the gamma-ray emission probabilities and EC transition probabilities. Tm-167 decays partially to Er-167m (which undergoes 100% IT decay with a half-life of 2.270(6) secs by means of the 207.801-keV gamma ray) - the recommended decay data for this daughter state can be found in the relevant data file for Er-167m.

There are a number of very significant uncertainties associated with the proposed decay scheme. Furthermore, highly questionable assumptions have been made concerning the gamma-ray and EC transition probabilities. Measurements of the relative and absolute gamma-ray emission probabilities are required, particularly for the 57.07- and 264.87-keV gamma transitions, in order to define the decay scheme with considerably greater confidence.

75-Re-183

The half-life of 70(2) days is the least-squares weighted mean of the measurements of Gallagher et al (1958), Foster et al (1958), and Blichert-Toft (1965), with the uncertainty increased from ± 1.4 to 2 days in line with the lowest measured uncertainty. Further measurements are merited to fortify such a limited pre-1970 data set.

A reasonably complex decay scheme has been derived from the relative gamma-ray emission probability measurements of Brabec and Maly (1972), Brenner et al (1977), and Heath and Helmer (1998). The various multipolarities of the gamma transitions were derived or estimated from the studies of Alexander and Hager (1965), Ageev et al (1971), Krane et al (1973), Batist et al (1973), and Artamonova et al (1980), particularly with respect to the (M1 + E2) transitions, and the resulting theoretical internal conversion coefficients were derived from Kibedi et al (2008). Brenner et al have determined an EC transition probability directly to the ground state of W-183 of 1.7(6)%, and this value was adopted to derive a normalisation factor of 0.244(6) for

use in conjunction with the relative gamma-ray emission probabilities. The EC transition probabilities were calculated from the relative gamma-ray emission probabilities, the normalisation factor of 0.244(6) and the theoretical internal conversion coefficients.

There are a number of uncertainties associated with the proposed decay scheme. The EC transition probability directly to the ground state of W-183 is an extremely important parameter in the derivation of the decay scheme, and studies are required to confirm the adopted value of 1.7(6)% as proposed originally by Brenner et al. Furthermore, assumptions have been made concerning the relative emission probabilities of the 120.371- and 161.347-keV gamma rays and the multiplicities of various gamma transitions. Measurements of the absolute gamma-ray and conversion-electron emission probabilities are merited to help in the development of specific features of the proposed decay scheme.

77-Ir-189

The half-life of 13.2(1) days is the least-squares weighted mean value of the measurements of Kane (1959), Grant and Yaffe (1963), Lewis et al (1964), and Bayhurst et al (1975), with the uncertainty increased from ± 0.07 to 0.1 days in line with the lowest measured uncertainty.

The decay scheme is based solely on the gamma-ray measurements of Malmskog et al (1970), and their quantification of the uncertainties in the relative emission probabilities. Multiplicities of (99.8%M1 + 0.2%E2), 100%M1, (99.5%M1 + 0.5%E2), (67.7%M1 + 32.3%E2) and (91.2%M1 + 8.8%E2) for the 36.179-, 56.53-, 59.07-, 69.535 and 95.248-keV gamma rays, respectively, were adopted from Malmskog et al (1970); multiplicities of (73.5%M1 + 26.5%E2), (50%M1 + 50%E2), (33.8%M1 + 66.2%E2), (33.8%M1 + 66.2%E2) and (37.2%M1 + 62.8%E2) for the 138.32-, 147.85-, 188.58-, 233.57- and 275.92-keV gamma rays, respectively, were adopted from Harmatz et al (1962); the 343.47-, 402.54- and 438.72-keV gamma rays were defined as essentially 100%M1; and the multiplicities of (99%M1 + 1%E2), (50%M1 + 50%E2), (73.5%M1 + 26.5%E2), (45.2%M1 + 54.8%E2) and (41%M1 + 59%E2) for the 25.71-, 164.03-, 180.67-, 185.85- and 206.39-keV gamma rays, respectively, were derived from calculations of the population-depopulation balances for specific nuclear levels of Os-189. Direct EC decay to the 219.39-, 216.66- and 30.812-keV nuclear levels of Os-189/Os-189m were assumed to be zero on the basis of spin-parity considerations.

The relative total K X-ray intensity measurement by Malmskog et al (1970) of 1270(120) was used to calculate the normalization factor after correction for internal conversion and fluorescence yield.

Relative internal conversion contribution to $\sum KX$ is given by $\sum (P_{\gamma}^{rel} \times \alpha_K)_i = 55.3$

Correction for internal conversion and fluorescence yield: $\sum KX = \sum (P_{EC}^{rel} \times P_K \times \omega_K)_i$

in which $\sum KX$ is the total K X-ray less K X-rays arising from the internal conversion process; P_K is the fraction of decay proceeding by K capture, and ω_K is the K-shell fluorescence yield of 0.957(4) from Schönfeld and Janssen (1996) to give:

$$1270 - 55 = 729 + 0.75(P_{EC}^{rel})_{gd}$$

where $(P_{EC}^{rel})_{gd}$ is the relative EC transition probability directly to the Os-189 ground state:

$$(P_{EC}^{rel})_{gd} = 486 / 0.75 = 648$$



Adopting this relative value in the summation of EC transitions to the Os-189 ground state gives an EC and gamma-ray normalisation factor of 0.061 ± 0.006 .

These data provide the means of determining the branching fractions to the meta-stable and ground states of Os-189:

$$\text{BF}(\text{Ir-189 to Os-189m}) = 0.075(8)$$

$$\text{BF}(\text{Ir-189 to Os-189}) = 0.925(8)$$

All EC transition probabilities were calculated from the relative gamma-ray emission probabilities, the normalisation factor of 0.061(6) and the theoretical conversion coefficients derived from Kibedi et al (2008).

The derivation of the normalisation factor for the relative gamma-ray emission probabilities is based on the K X-ray measurements of Malmskog et al, and is judged to be questionable. Measurements of the absolute and relative gamma-ray emission probabilities are required to derive the decay scheme with much greater confidence.

77-Ir-193m

The recommended half-life of 10.53(4) days constitutes the only known measurement in which the uncertainty is quantified (Lindner et al (1987)). Further measurements are required to confirm the validity of this decay parameter and associated uncertainty.

An extremely accurate determination of the ICC(K) for the 80.24-keV gamma ray has been carried out by Nica et al (2004)/Hardy et al (2006) to assess the most appropriate modelling procedure to be adopted for ICC calculations in general. These studies support the frozen orbital approximation with K-shell hole that has been subsequently adopted by Kibedi et al (2008) to interpolate all of the ICC data of Band-Raman (2002). Thus, these data were used to determine an absolute emission probability of 0.00474(7)% for the single 80.24-keV gamma ray, which is in very good agreement with a direct measurement of 0.00470(14)% by Lindner et al (1987).

77-Ir-194m

The recommended half-life of 0.03183(24) secs is the least-squares weighted mean of the measurements of Alexander and Brinckmann (1961), Lundan and Siivola (1968), and Brandstadter et al (1972).

There are significant uncertainties associated with the proposed decay scheme. Neutron capture and (d,p) reaction studies by Balodis, Kondurov and co-workers (1998) proved to be particularly important in deriving the recommended decay data from the relative transition probabilities of the gamma transitions depopulating each individual nuclear level of Ir-194. A multipolarity of 100%M1 was assumed for the 27.947-keV gamma ray, while all other multipolarities were adopted from Balodis et al (1998). The absolute emission probabilities and uncertainties of the gamma rays that constitute the ten gamma cascade were determined on the basis of the total populating transition probability for each nuclear level, the relative transition probabilities of the depopulating gamma rays from each nuclear level as determined by Balodis et al (1998), and the theoretical internal conversion coefficients derived from Kibedi et al (2008). The resulting gamma-ray emission probabilities are highly questionable, and measurements of these intensities are required in order to develop the decay scheme with greater confidence.

77-Ir-194n

The recommended half-life of 171(11) days represents the only known measurement by Sunyar et al (1968). Further measurements are required to determine this decay parameter and associated uncertainty with much greater confidence.

There are significant uncertainties associated with the level energy, spin and parity of Ir-194n. Sunyar et al (1968) proposed a nuclear level energy that was defined as ≤ 250 keV above Ir-194m and/or ≤ 450 keV above the Ir-194 ground state. Effectively, a value ≤ 250 keV above Ir-194m has been adopted – when this parameter is defined as (125 ± 125) keV, a nuclear level energy of (272 ± 125) keV is defined with a Q(beta) of 2233.8(17) keV for Ir-194 to give a Q(beta) of (2506 ± 127) keV for Ir-194n. Both the spin and parity also pose problems – first forbidden beta transitions were assumed, and result in a spin and parity of $(10 -)$. All of these assignments (and the two beta transition energies and their extremely arbitrary uncertainties of approximately 10%) are extremely doubtful indeed.

The absolute emission probabilities and uncertainties of the gamma rays were determined on the basis of their estimated transition probabilities and the theoretical internal conversion coefficients derived from Kibedi et al (2008). These emission probabilities are in reasonably good agreement with the measurements of Sunyar et al (1968), which are reported as relative gamma-ray emission probabilities while observed to be extremely close to being absolute emission probabilities. The absolute emission probability of the ill-defined 324.1-keV gamma ray was derived from the estimated depopulation of the 2423.6-keV nuclear level of Pt-194, and was arbitrarily assigned a multipolarity of $(50\%M1 + 50\%E2)$. Measurements of the absolute intensities of all the gamma rays are required to confirm much of the detail within the proposed decay scheme.

82-Pb-207m

The recommended half-life of 0.806(8) secs is the weighted mean of the measurements of Lascoux and Vendryes (1951), Hopkins (1952), Friedlander et al (1953), Reid and McNeill (1954), Bendel et al (1955), Campbell and Nelson (1956), Glagolev and Yampol'skii (1961), Yule (1967), Salaita and Eapen (1973), and Alstad et al (1986), with the uncertainty increased from ± 0.005 to 0.008 secs in line with the lowest measured uncertainty.

The absolute emission probabilities and uncertainties of the 569.70- and 1063.66-keV two gamma cascade were determined on the basis of 100% transition probabilities and the theoretical internal conversion coefficients derived from Kibedi et al (2008). These data are in good agreement with the internal conversion coefficient studies of van Nooijen and van Krugten (1967), Hedin and Bäcklin (1969), and Freund (1973).



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