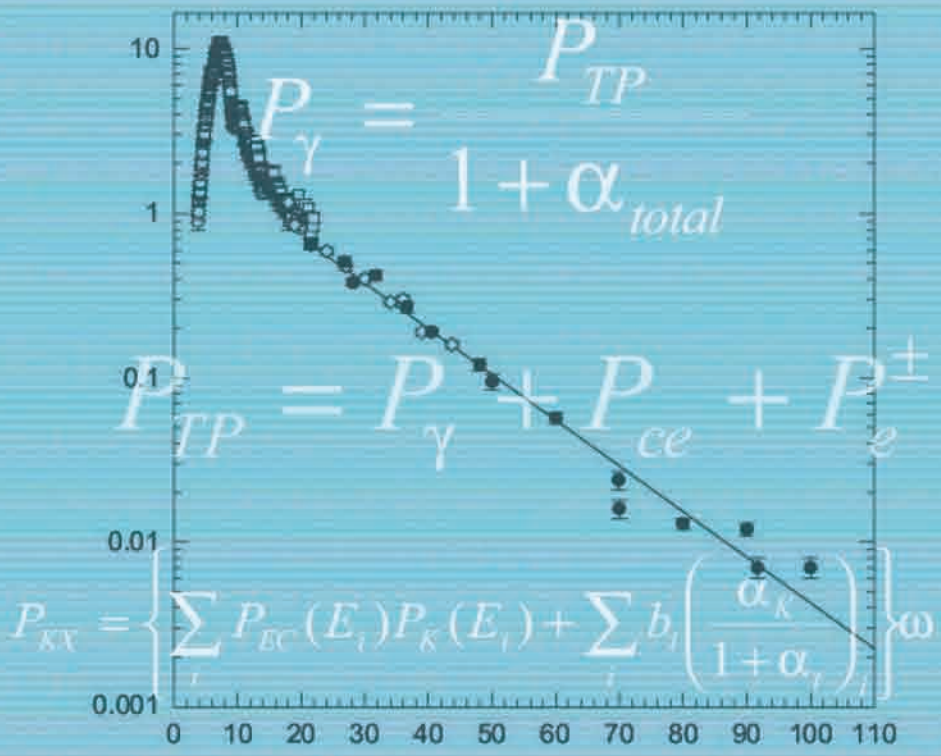
Update of X Ray and Gamma Ray Decay Data Standards for Detector Calibration and Other Applications

Volume 1:
Recommended Decay Data, High Energy Gamma Ray Standards and Angular Correlation Coefficients



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UPDATE OF X RAY AND GAMMA RAY DECAY DATA STANDARDS FOR DETECTOR CALIBRATION AND OTHER APPLICATIONS

VOLUME 1

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UPDATE OF X RAY AND GAMMA RAY DECAY DATA STANDARDS FOR DETECTOR CALIBRATION AND OTHER APPLICATIONS

In two volumes

VOLUME 1

RECOMMENDED DECAY DATA,
HIGH ENERGY GAMMA RAY STANDARDS AND
ANGULAR CORRELATION COEFFICIENTS

INTERNATIONAL ATOMIC ENERGY AGENCY
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FOREWORD

Various groups around the world are engaged in the compilation and evaluation of decay data for either all known or specific radionuclides. Many evaluators operate independently and recommend slightly different values for the same parameter. Even small deviations in the recommended data can have a significant impact on the definition of the decay characteristics of radionuclides used as standards in detector efficiency calibrations and subsequent applications (e.g. in nuclear medicine and environmental monitoring). Under such circumstances, these differences can be propagated into the measurements of decay data for other radioactive nuclides, and may also bring into question the efficacy of adopting specific radionuclides in diagnostic and therapeutic treatments. High quality decay data are essential for the efficiency calibration of X and γ ray detectors that are used to quantify the radionuclidic content of a sample by determining the intensities of any resulting X and γ rays.

A major objective of the IAEA nuclear data programme is to promote improvements in the quality of nuclear data used in science and technology. Hence the IAEA established a Coordinated Research Project (CRP) in 1986 on the Measurements and Evaluation of X and Gamma Ray Standards for Detector Efficiency Calibration, with the aim of reducing the discrepancies and uncertainties in those decay data parameters judged to be important in such work. This CRP was completed in 1990 and the results of the work were assembled as a database and presented in IAEA-TECDOC-619, X-ray and Gamma-ray Standards for Detector Calibration. Recommended values for the half-lives and photon emission probabilities were given for a selected set of radionuclides that had been judged to be suitable for detector efficiency calibration (X rays from 5 to 90 keV, and γ rays from 30 to about 3000 keV). Many important experimental studies were catalysed by the demands of this earlier CRP, and a significant fraction of these new data were not published until the 1990s nor included in the associated evaluation process. New efforts were judged to be necessary in order to incorporate these data and update the existing database, along with extending these files to encompass the related needs of a number of important applications such as environmental monitoring and nuclear medicine. Therefore, the IAEA established a CRP in 1998 (Update of X Ray and Gamma Ray Decay Data Standards for Detector Calibration and Other Applications). Members of this CRP completed an agreed work programme in 2005, and the results are presented in this report.

Recommended half-lives and X and γ ray emission probabilities are listed in Volume 1 for a carefully selected set of radionuclides and nuclear reactions that are suitable for detector efficiency calibration and other applications. This selection process was based on consultations with γ ray spectroscopists and specialists in the various fields of application, along with extensive debate within the CRP. The evaluation procedures used to obtain the recommended values and their uncertainties are detailed in Volume 2 of this report, along with comments on the remaining discrepancies. Consideration is also given to the coincidence method of determining absolute γ ray detection efficiencies and the statistical correlation of decay data. An appropriate set of suitable X and γ ray standards have been derived, with the expectation that the recommended values will be recognized as international reference standards.

The IAEA is grateful to the members of the Decay Data Evaluation Project (DDEP) and laboratories affiliated with the International Committee for Radionuclide Metrology (ICRM) for their assistance in the work and support of the CRP meetings. Both O.A.M. Helene and V.R. Vanin wish to thank their State and Federal funding agencies (FAPESP and CNPq) for financial support during the course of their evaluation studies. The IAEA officers responsible for this publication were M. Herman and A.L. Nichols (ex AEA Technology) of the IAEA Division of Physical and Chemical Sciences. Participants in this evaluation study dedicate their work and results to the memory of their co-workers: R.G. Helmer (United States of America), G.L. Molnár (Hungary) and S.A. Woods (United Kingdom).

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EDITORIAL NOTE

CONTENTS

1. INTRODUCTION

1.1. BACKGROUND

As recommended at an IAEA Consultants Meeting in 1997 [1], a Coordinated Research Project (CRP) on Update of X Ray and Gamma Ray Decay Data Standards for Detector Calibration and Other Applications was established by the IAEA in the late 1990s to discuss the quality of the relevant data and define a suitable programme to resolve various issues. The participants in the CRP were specialists in γ ray spectroscopy and in the related areas of decay data standards and evaluations. Their objective was to produce a recommended set of decay parameters for selected radionuclides and nuclear reactions judged to be important for the efficiency calibration of equipment used to detect and quantify X and γ ray emissions over a range of applications.

1.2. SCOPE

The participants in the CRP reviewed and modified the list of radionuclides most suited for detector calibration and were able to include some of the specific needs of such nuclear applications as safeguards, material analysis, environmental monitoring, nuclear medicine, waste management, dosimetry and basic spectroscopy. A final set of recommended half-lives and X and γ ray emission probabilities were agreed upon after much evaluation. All evaluations were based on the available experimental data, supplemented with the judicious use of well established theory. Three types of data (half-lives, energies, and emission probabilities) were compiled and evaluated. Consideration was also given to the use of the γ–γ coincidence technique for efficiency calibrations, as well as adopting a number of prompt high energy γ rays from specific nuclear reactions. A well defined evaluation procedure was strictly applied to determine the recommended half-lives and emission probabilities for all prominent X and γ rays emitted by each selected radionuclide.

The recommendations and report of this work are published in two volumes:

Volume 1 — Recommended Decay Data, High Energy Gamma Ray Standards and Angular Correlation Coefficients;
Volume 2 — Data Selection, Assessment and Evaluation Procedures.

Volume 1 is a self-contained assembly of the recommended decay data covering half-lives and the X ray and γ ray emission probabilities of the selected radionuclides, and listings of various high energy γ ray standards and a set of angular correlation coefficients; these data are presented in a concise manner for rapid and easy access. More detailed technical features of the CRP are described in Volume 2, including the evaluation procedures adopted and extensive traceable explanations of the origins of the nuclear data used to produce the recommended values listed in Volume 1. This detail was judged to be essential in order to record and demonstrate the quality of the resulting data files and allow the reader to trace the origins of the nuclear data used to determine the recommended values.

1.3. OBJECTIVES

A major aim has been to redefine a set of data files that would be internationally accepted so as to improve the uniformity of subsequent measurements of photon emission probabilities. More specifically, the CRP has also aided in the definition of an evaluation methodology that provides consistent, high quality results. A primary aim is for γ ray spectroscopists to accept the decay data standards presented in this report and use the recommended values in their work.

2. RECOMMENDED DECAY DATA

Lists are given of the values of the decay parameters used for X and γ ray detector efficiency calibration and other applications, as recommended by the CRP.

The data uncertainties are defined as standard deviations corresponding to the 1σ confidence level.

TABLE 1. Recommended half-lives of radionuclides;

TABLE 2. Recommended X ray energies and emission probabilities ordered by radionuclide;

TABLE 3. Recommended gamma ray energies and emission probabilities ordered by radionuclide;

TABLE 4. Recommended gamma ray energies and emission probabilities ordered by energy.

Note: The recommended decay data given in the following tables are available from the IAEA Nuclear Data Section at the following web site:

http://www-nds.iaea.org/xgamma_standards/
or through: http://www-nds.iaea.org

TABLE ENTRIES:

Half-lives:	expressed in terms of days for all radionuclides (1 year = 365.2422 days);
Emission probabilities:	all P_X and P_γ values are expressed as the absolute probability of the emission of a photon per decay;
Branching fraction:	defined such that the total decay probability for all modes of decay is equal to 1.

TABLE 1. RECOMMENDED HALF-LIVES OF RADIONUCLIDES

Nuclide	Half-life (d)	
	Value	Uncertainty
11-Na-22	950.57	±0.23
11-Na-24	0.62329	±0.00006
19-K-40	(4.563	±0.013) 10^{11}
21-Sc-46	83.79	±0.04
24-Cr-51	27.7009	±0.0020
25-Mn-54	312.29	±0.26
25-Mn-56	0.107449	±0.000019
26-Fe-55	1002.7	±2.3
26-Fe-59	44.494	±0.013
27-Co-56	77.236	±0.026
27-Co-57	271.80	±0.05
27-Co-58	70.86	±0.06
27-Co-60	1925.23	±0.27
29-Cu-64	0.52929	±0.00018
30-Zn-65	243.86	±0.20
31-Ga-66	0.3889	±0.0034
31-Ga-67	3.2616	±0.0004
31-Ga-68	0.04703	±0.00007
34-Se-75	119.778	±0.029
36-Kr-85	3927	±8
38-Sr-85	64.851	±0.005
39-Y-88	106.625	±0.024

TABLE 1. RECOMMENDED HALF-LIVES OF RADIONUCLIDES (cont.)

Nuclide	Half-life (d)	
	Value	Uncertainty
41-Nb-93m	(5.73	±0.22) 10^3
41-Nb-94	(7.3	±0.9) 10^6
41-Nb-95	34.985	±0.012
42-Mo-99	2.7478	±0.0007
43-Tc-99m	0.250281	±0.000022
44-Ru-103	39.247	±0.013
44-Ru-106	371.8	±1.8
45-Rh-106	0.000348	±0.000004
47-Ag-110m	249.85	±0.10
48-Cd-109	461.4	±1.2
49-In-111	2.8049	±0.0006
50-Sn-113	115.09	±0.04
51-Sb-125	1007.48	±0.21
52-Te-123m	119.45	±0.25
53-I-123	0.55098	±0.00009
53-I-125	59.402	±0.014
53-I-129	(5.89	±0.23) 10^9
53-I-131	8.0228	±0.0024
55-Cs-134	753.5	±1.0
55-Cs-137	(1.099	±0.004) 10^4
56-Ba-133	3848.7	±1.2
58-Ce-139	137.642	±0.020
58-Ce-141	32.503	±0.014
58-Ce-144	285.1	±0.6
62-Sm-153	1.938	±0.010
63-Eu-152	4941	±7
63-Eu-154	3138.1	±1.4
63-Eu-155	1736	±6
67-Ho-166	1.1165	±0.0013
67-Ho-166m	(4.4	±0.7) 10^5
69-Tm-170	127.8	±0.8
70-Yb-169	32.016	±0.006
77-Ir-192	73.822	±0.009
79-Au-198	2.6950	±0.0007
80-Hg-203	46.594	±0.012
81-Tl-201	3.0422	±0.0017
83-Bi-207	(1.18	±0.03) 10^4
88-Ra-226	(5.862	±0.022) 10^5
90-Th-228	698.60	±0.23
91-Pa-234m	0.000805	±0.000011
95-Am-241	(1.5785	±0.0023) 10^5
95-Am-243	(2.692	±0.008) 10^6

Note: 1 a = 365.2422 d.

TABLE 2. RECOMMENDED X RAY ENERGIES AND EMISSION PROBABILITIES ORDERED BY RADIONUCLIDE

Nuclide	Origin		Energy (keV)		Emission probability per decay	
			E_X	Uncertainty	P_X	Uncertainty
19-K-40	Ar	K	2.96–3.19		0.00997	±0.00022
21-Sc-46	Ti	K	4.51		0.000047	±0.000002
24-Cr-51	V	Kα	4.94–4.95		0.202	±0.003
24-Cr-51	V	Kβ	5.43–5.46		0.0269	±0.0007
25-Mn-54	Cr	Kα	5.405–5.415		0.227	±0.003
25-Mn-54	Cr	Kβ	5.947		0.0305	±0.0007
26-Fe-55	Mn	L	0.556–0.721		0.0066	±0.0010
26-Fe-55	Mn	$Kα_2$	5.8877		0.0845	±0.0014
26-Fe-55	Mn	$Kα_1$	5.8988		0.1656	±0.0027
26-Fe-55	Mn	$Kβ_1'$	6.49–6.54		0.0340	±0.0007
26-Fe-59	Co	Kα	6.92		0.000177	±0.000003
27-Co-56	Fe	$Kα_2$	6.39091	±0.00005	0.0753	±0.0010
27-Co-56	Fe	$Kα_1$	6.40391	±0.00003	0.1475	±0.0017
27-Co-56	Fe	$Kβ_1'$	7.058–7.108		0.0305	±0.0005
27-Co-57	Fe	L	0.61–0.79		0.0155	±0.0013
27-Co-57	Fe	$Kα_2$	6.39084		0.168	±0.003
27-Co-57	Fe	$Kα_1$	6.40384		0.332	±0.005
27-Co-57	Fe	$Kβ_1'$	7.058–7.108		0.071	±0.002
27-Co-58	Fe	Kα	6.40		0.235	±0.003
27-Co-58	Fe	Kβ	7.06		0.0320	±0.0010
27-Co-60	Ni	Kα	7.46–7.48		0.000098	±0.000003
27-Co-60	Ni	Kβ	8.26–8.33		0.0000136	±0.0000005
29-Cu-64	Ni	Kα	7.46–7.48		0.1415	±0.0017
29-Cu-64	Ni	Kβ	8.26–8.33		0.0195	±0.0004
30-Zn-65	Cu	Kα	8.03–8.05		0.347	±0.003
30-Zn-65	Cu	Kβ	8.90–8.98		0.0482	±0.0007
31-Ga-66	Zn	$Kα_2$	8.61587	±0.00005	0.058	±0.003
31-Ga-66	Zn	$Kα_1$	8.63896	±0.00005	0.113	±0.006
31-Ga-66	Zn	$Kβ_1'$	9.57–9.65		0.0242	±0.0012
31-Ga-67	Zn	L	0.884–1.107		0.0182	±0.0012
31-Ga-67	Zn	$Kα_2$	8.61587	±0.00005	0.170	±0.006
31-Ga-67	Zn	$Kα_1$	8.63896	±0.00005	0.330	±0.011
31-Ga-67	Zn	$Kβ_1'$	9.57–9.65		0.0709	±0.0020
31-Ga-68	Zn	$Kα_2$	8.61587	±0.00005	0.01389	±0.00007
31-Ga-68	Zn	$Kα_1$	8.63896	±0.00005	0.02701	±0.00024
34-Se-75	As	L	1.28		0.0206	±0.0007
34-Se-75	As	$Kα_2$	10.5080		0.1659	±0.0023

TABLE 2. RECOMMENDED X RAY ENERGIES AND EMISSION PROBABILITIES ORDERED BY RADIONUCLIDE (cont.)

Nuclide	Origin		Energy (keV)		Emission probability per decay	
			E_X	Uncertainty	P_X	Uncertainty
34-Se-75	As	$K\alpha_1$	10.5437		0.322	±0.004
34-Se-75	As	Kβ	11.72–11.86		0.0764	±0.0012
36-Kr-85	Te	Kα	13.356		0.0000158	±0.0000028
38-Sr-85	Rb	L	1.58–2.20		0.0255	±0.0007
38-Sr-85	Rb	$K\alpha_2$	13.3359	±0.0002	0.1716	±0.0017
38-Sr-85	Rb	$K\alpha_1$	13.3955	±0.0001	0.3304	±0.0029
38-Sr-85	Rb	$K\beta_1'$	14.95–15.09		0.0804	±0.0010
38-Sr-85	Rb	$K\beta_2'$	15.19–15.21		0.0093	±0.0004
39-Y-88	Sr	L	1.6–2.2		0.0277	±0.0008
39-Y-88	Sr	$K\alpha_2$	14.0980	±0.0001	0.1730	±0.0022
39-Y-88	Sr	$K\alpha_1$	14.1652	±0.0002	0.332	±0.004
39-Y-88	Sr	$K\beta_1'$	15.8359	±0.0004	0.0821	±0.0012
39-Y-88	Sr	$K\beta_2'$	16.0847	±0.0006	0.0107	±0.0004
41-Nb-93m	Nb	L	1.90–2.66		0.0289	±0.0013
41-Nb-93m	Nb	$K\alpha_2$	16.5213		0.0316	±0.0007
41-Nb-93m	Nb	$K\alpha_1$	16.6152		0.0604	±0.0012
41-Nb-93m	Nb	$K\beta_1'$	18.618		0.0156	±0.0005
41-Nb-93m	Nb	$K\beta_2'$	18.953		0.0023	±0.0001
41-Nb-95	Mo	L	2.01–2.83		0.000055	±0.000009
41-Nb-95	Mo	$K\alpha_2$	17.374		0.000286	±0.000009
41-Nb-95	Mo	$K\alpha_1$	17.479		0.000546	±0.000017
41-Nb-95	Mo	$K\beta_1'$	19.59–19.77		0.000143	±0.000005
41-Nb-95	Mo	$K\beta_2'$	19.96–20.00		0.0000220	±0.0000011
42-Mo-99/43-Tc-99m	Tc	L	2.424–2.537		0.00697	±0.00017
42-Mo-99/43-Tc-99m	Tc	$K\alpha_2$	18.2510		0.0319	±0.0009
42-Mo-99/43-Tc-99m	Tc	$K\alpha_1$	18.3672		0.0606	±0.0016
42-Mo-99/43-Tc-99m	Tc	$K\beta_1'$	20.60–20.79		0.0161	±0.0005
42-Mo-99/43-Tc-99m	Tc	$K\beta_2'$	21.00–21.04		0.00254	±0.00011
43-Tc-99m	Tc	L	2.424–2.537		0.00482	±0.00012
43-Tc-99m	Tc	$K\alpha_2$	18.2510		0.0222	±0.0007
43-Tc-99m	Tc	$K\alpha_1$	18.3672		0.0421	±0.0012
43-Tc-99m	Tc	$K\beta_1'$	20.60–20.79		0.0112	±0.0004
43-Tc-99m	Tc	$K\beta_2'$	21.00–21.04		0.00177	±0.00008
44-Ru-103	Rh	L	2.38–3.36		0.0412	±0.0019
44-Ru-103	Rh	$K\alpha_2$	20.074		0.0248	±0.0015
44-Ru-103	Rh	$K\alpha_1$	20.216		0.047	±0.003
44-Ru-103	Rh	$K\beta_1'$	22.699–22.911		0.0128	±0.0008
44-Ru-103	Rh	$K\beta_2'$	23.172–23.217		0.00212	±0.00015

TABLE 2. RECOMMENDED X RAY ENERGIES AND EMISSION PROBABILITIES ORDERED BY RADIONUCLIDE (cont.)

Nuclide	Origin		Energy (keV)		Emission probability per decay	
			E_X	Uncertainty	P_X	Uncertainty
47-Ag-110m	Ag	$K\alpha_2$	21.9906		0.00198	±0.00012
47-Ag-110m	Ag	$K\alpha_1$	22.1632		0.00372	±0.00022
47-Ag-110m	Ag	$K\beta_1'$	24.912–25.146		0.00103	±0.00007
47-Ag-110m	Ag	$K\beta_2'$	25.457–25.512		0.000179	±0.000012
47-Ag-110m	Cd	$K\alpha_2$	22.9843		0.00153	±0.00009
47-Ag-110m	Cd	$K\alpha_1$	23.1738		0.00288	±0.00016
47-Ag-110m	Cd	$K\beta_1'$	26.061–26.304		0.00080	±0.00005
47-Ag-110m	Cd	$K\beta_2'$	26.64–26.70		0.000146	±0.000009
48-Cd-109	Ag	L	2.63–3.75		0.1034	±0.0026
48-Cd-109	Ag	$K\alpha_2$	21.9906	±0.0002	0.2899	±0.0025
48-Cd-109	Ag	$K\alpha_1$	22.1632	±0.0001	0.547	±0.004
48-Cd-109	Ag	$K\beta_1'$	24.912–25.146		0.1514	±0.0018
48-Cd-109	Ag	$K\beta_2'$	25.457–25.512		0.0263	±0.0010
49-In-111	Cd	L	2.76–3.95		0.068	±0.002
49-In-111	Cd	$K\alpha_2$	22.9843		0.236	±0.002
49-In-111	Cd	$K\alpha_1$	23.1738		0.444	±0.003
49-In-111	Cd	$K\beta_1'$	26.061–26.304		0.124	±0.004
49-In-111	Cd	$K\beta_2'$	26.64–26.70		0.023	±0.001
50-Sn-113	In	L	2.90–4.23		0.086	±0.003
50-Sn-113	In	$K\alpha_2$	24.0020		0.2785	±0.0022
50-Sn-113	In	$K\alpha_1$	24.2097		0.522	±0.004
50-Sn-113	In	$K\beta_1'$	27.238–27.499		0.1460	±0.0012
50-Sn-113	In	$K\beta_2'$	27.861–27.940		0.0284	±0.0002
51-Sb-125	Te	$K\alpha_2$	27.2020	±0.0002	0.191	±0.007
51-Sb-125	Te	$K\alpha_1$	27.4726	±0.0002	0.357	±0.012
51-Sb-125	Te	$K\beta_1'$	30.945–31.236		0.102	±0.004
51-Sb-125	Te	$K\beta_2'$	31.701–31.774		0.0221	±0.0010
52-Te-123m	Te	L	3.34–4.93		0.0826	±0.0021
52-Te-123m	Te	$K\alpha_2$	27.2020		0.140	±0.005
52-Te-123m	Te	$K\alpha_1$	27.4726		0.260	±0.009
52-Te-123m	Te	$K\beta_1'$	30.945–31.241		0.0743	±0.0026
52-Te-123m	Te	$K\beta_2'$	31.701–31.812		0.0161	±0.0007
53-I-123	Te	L	3.34–4.93		0.0772	±0.0016
53-I-123	Te	$K\alpha_2$	27.2020		0.2469	±0.0020
53-I-123	Te	$K\alpha_1$	27.4726		0.4598	±0.0029
53-I-123	Te	$K\beta_1'$	30.945–31.241		0.1316	±0.0017
53-I-123	Te	$K\beta_2'$	31.701–31.812		0.0386	±0.0008
53-I-125	Te	L	3.34–4.93		0.149	±0.007

TABLE 2. RECOMMENDED X RAY ENERGIES AND EMISSION PROBABILITIES ORDERED BY RADIONUCLIDE (cont.)

Nuclide	Origin		Energy (keV)		Emission probability per decay	
			E_X	Uncertainty	P_X	Uncertainty
53-I-125	Te	$K\alpha_2$	27.2020	±0.0002	0.397	±0.006
53-I-125	Te	$K\alpha_1$	27.4726	±0.0002	0.740	±0.011
53-I-125	Te	$K\beta_1'$	30.945–31.241		0.212	±0.004
53-I-125	Te	$K\beta_2'$	31.701–31.812		0.0459	±0.0014
53-I-129	Xe	L	3.6–5.4		0.079	±0.004
53-I-129	Xe	$K\alpha_2$	29.459	±0.002	0.201	±0.003
53-I-129	Xe	$K\alpha_1$	29.779	±0.001	0.372	±0.006
53-I-129	Xe	$K\beta_1'$	33.56–33.88		0.103	±0.004
53-I-129	Xe	$K\beta_2'$	34.41–34.55		0.0230	±0.0013
53-I-131	Xe	Kα	29.70		0.044	±0.014
53-I-131	Xe	Kβ	33.56–34.55		0.01025	±0.00011
55-Cs-137	Ba	L	3.954–5.973		0.0090	±0.0005
55-Cs-137	Ba	$K\alpha_2$	31.8174		0.0195	±0.0004
55-Cs-137	Ba	$K\alpha_1$	32.1939		0.0359	±0.0007
55-Cs-137	Ba	$K\beta_1'$	36.31–36.67		0.01055	±0.00022
55-Cs-137	Ba	$K\beta_2'$	37.26–37.43		0.00266	±0.00008
56-Ba-133	Cs	L	3.80–5.70		0.160	±0.008
56-Ba-133	Cs	$K\alpha_2$	30.625		0.340	±0.004
56-Ba-133	Cs	$K\alpha_1$	30.973		0.628	±0.007
56-Ba-133	Cs	$K\beta_1'$	34.92–35.26		0.182	±0.002
56-Ba-133	Cs	$K\beta_2'$	35.82–35.97		0.046	±0.001
58-Ce-139	La	L	4.124–6.252		0.120	±0.006
58-Ce-139	La	$K\alpha_2$	33.0344	±0.0002	0.225	±0.003
58-Ce-139	La	$K\alpha_1$	33.4421	±0.0001	0.412	±0.004
58-Ce-139	La	$K\beta_1'$	37.721–38.095		0.1230	±0.0018
58-Ce-139	La	$K\beta_2'$	38.730–38.910		0.0311	±0.0006
58-Ce-141	Pr	L	4.45–6.81		0.0243	±0.0010
58-Ce-141	Pr	$K\alpha_2$	35.5506	±0.0002	0.0474	±0.0011
58-Ce-141	Pr	$K\alpha_1$	36.0267	±0.0002	0.0865	±0.0012
58-Ce-141	Pr	$K\beta_1'$	40.65–41.05		0.0263	±0.0005
58-Ce-141	Pr	$K\beta_2'$	41.77–41.97		0.00674	±0.00018
58-Ce-144/59-Pr-144	Pr	L	4.45–6.81		0.0142	±0.0014
58-Ce-144/59-Pr-144	Pr	$K\alpha_2$	35.5506	±0.0003	0.0256	±0.0011
58-Ce-144/59-Pr-144	Pr	$K\alpha_1$	36.0267	±0.0004	0.0469	±0.0019
58-Ce-144/59-Pr-144	Pr	$K\beta_1'$	40.65–41.05		0.0141	±0.0006
58-Ce-144/59-Pr-144	Pr	$K\beta_2'$	41.77–41.97		0.00360	±0.00015
62-Sm-153	Eu	L	5.18–8.03		0.1004	±0.0015
62-Sm-153	Eu	$K\alpha_2$	40.9024		0.163	±0.003

TABLE 2. RECOMMENDED X RAY ENERGIES AND EMISSION PROBABILITIES ORDERED BY RADIONUCLIDE (cont.)

Nuclide	Origin		Energy (keV)		Emission probability per decay	
			E_X	Uncertainty	P_X	Uncertainty
62-Sm-153	Eu	$K\alpha_1$	41.5427		0.293	±0.004
62-Sm-153	Eu	$K\beta_1'$	46.90–48.27		0.0920	±0.0014
62-Sm-153	Eu	$K\beta_2'$	48.39–48.50		0.0236	±0.0011
63-Eu-152	Sm	L	5.61–7.18		0.130	±0.004
63-Eu-152	Sm	$K\alpha_2$	39.5229		0.208	±0.003
63-Eu-152	Sm	$K\alpha_1$	40.1186		0.377	±0.005
63-Eu-152	Sm	$K\beta_1'$	45.289–45.731		0.1178	±0.0019
63-Eu-152	Sm	$K\beta_2'$	46.575–46.813		0.0304	±0.0008
63-Eu-154	Gd	L	5.36–8.10		0.071	±0.003
63-Eu-154	Gd	$K\alpha_2$	42.3093		0.072	±0.002
63-Eu-154	Gd	$K\alpha_1$	42.9967		0.130	±0.003
63-Eu-154	Gd	$K\beta_1'$	48.556–49.053		0.041	±0.001
63-Eu-154	Gd	$K\beta_2'$	49.961–50.219		0.0108	±0.0003
63-Eu-155	Gd	L	5.36–8.10		0.075	±0.005
63-Eu-155	Gd	$K\alpha_2$	42.3093		0.0670	±0.0013
63-Eu-155	Gd	$K\alpha_1$	42.9967		0.1205	±0.0023
63-Eu-155	Gd	$K\beta_1'$	48.556–49.053		0.0384	±0.0011
63-Eu-155	Gd	$K\beta_2'$	49.961–50.219		0.0098	±0.0003
67-Ho-166	Er	L	6.15–9.43		0.076	±0.004
67-Ho-166	Er	$K\alpha_2$	48.2215	±0.0003	0.0291	±0.0010
67-Ho-166	Er	$K\alpha_1$	49.1282	±0.0004	0.0516	±0.0017
67-Ho-166	Er	$K\beta_1'$	55.50–56.04		0.0168	±0.0006
67-Ho-166	Er	$K\beta_2'$	57.21–57.46		0.00436	±0.00018
67-Ho-166m	Er	L	6.15–9.43		0.201	±0.009
67-Ho-166m	Er	$K\alpha_2$	48.2215	±0.0003	0.1071	±0.0018
67-Ho-166m	Er	$K\alpha_1$	49.1282	±0.0004	0.190	±0.003
67-Ho-166m	Er	$K\beta_1'$	55.50–56.04		0.0617	±0.0012
67-Ho-166m	Er	$K\beta_2'$	57.21–57.46		0.0161	±0.0005
69-Tm-170	Yb	L	6.55–10.14		0.0322	±0.0013
69-Tm-170	Yb	$K\alpha_2$	51.3541		0.0095	±0.0004
69-Tm-170	Yb	$K\alpha_1$	52.3887		0.0167	±0.0007
69-Tm-170	Yb	$K\beta_1'$	59.1593–59.8045		0.0055	±0.0003
69-Tm-170	Yb	$K\beta_2'$	60.962–61.309		0.00144	±0.00007
70-Yb-169	Tm	L	6.34–9.78		0.494	±0.008
70-Yb-169	Tm	$K\alpha_2$	49.773		0.529	±0.008
70-Yb-169	Tm	$K\alpha_1$	50.742		0.935	±0.013
70-Yb-169	Tm	$K\beta_1'$	57.304–57.925		0.306	±0.006
70-Yb-169	Tm	$K\beta_2'$	59.100–59.357		0.0795	±0.0021

TABLE 2. RECOMMENDED X RAY ENERGIES AND EMISSION PROBABILITIES ORDERED BY RADIONUCLIDE (cont.)

Nuclide	Origin		Energy (keV)		Emission probability per decay	
			E_X	Uncertainty	P_X	Uncertainty
77-Ir-192	Os	L	7.82–12.92		0.01525	±0.00025
77-Ir-192	Os	$K\alpha_2$	61.4873	±0.0007	0.01211	±0.00025
77-Ir-192	Os	$K\alpha_1$	63.0011	±0.0006	0.0209	±0.0005
77-Ir-192	Os	$K\beta_1'$	71.078–71.895		0.00710	±0.00021
77-Ir-192	Os	$K\beta_2'$	73.387–73.808		0.00180	±0.00006
77-Ir-192	Pt	L	9.4–13.8		0.0396	±0.0006
77-Ir-192	Pt	$K\alpha_2$	65.123	±0.004	0.0266	±0.0005
77-Ir-192	Pt	$K\alpha_1$	66.833	±0.002	0.0455	±0.0008
77-Ir-192	Pt	$K\beta_1'$	75.369–76.234		0.0158	±0.0003
77-Ir-192	Pt	$K\beta_2'$	77.786–78.341		0.00411	±0.00010
79-Au-198	Hg	L	8.72–14.85		0.0120	±0.0005
79-Au-198	Hg	$K\alpha_2$	68.8952	±0.0012	0.00809	±0.00008
79-Au-198	Hg	$K\alpha_1$	70.8196	±0.0012	0.01372	±0.00012
79-Au-198	Hg	$K\beta_1'$	79.82–80.76		0.00466	±0.00008
79-Au-198	Hg	$K\beta_2'$	82.43–83.03		0.00136	±0.00004
80-Hg-203	Tl	L	8.953–14.738		0.0543	±0.0009
80-Hg-203	Tl	$K\alpha_2$	70.8325	±0.0008	0.0375	±0.0004
80-Hg-203	Tl	$K\alpha_1$	72.8725	±0.0008	0.0633	±0.0006
80-Hg-203	Tl	$K\beta_1'$	82.118–83.115		0.0215	±0.0004
80-Hg-203	Tl	$K\beta_2'$	84.838–85.530		0.0064	±0.0002
81-Tl-201	Hg	L	8.72–14.85		0.427	±0.018
81-Tl-201	Hg	$K\alpha_2$	68.8952	±0.0011	0.273	±0.005
81-Tl-201	Hg	$K\alpha_1$	70.8196	±0.0012	0.464	±0.007
81-Tl-201	Hg	$K\beta_1'$	79.82–80.76		0.157	±0.004
81-Tl-201	Hg	$K\beta_2'$	82.43–83.03		0.0461	±0.0013
83-Bi-207	Pb	L	9.18–15.84		0.332	±0.014
83-Bi-207	Pb	$K\alpha_2$	72.805		0.2169	±0.0024
83-Bi-207	Pb	$K\alpha_1$	74.970		0.365	±0.004
83-Bi-207	Pb	$K\beta_1'$	84.451–85.470		0.1246	±0.0023
83-Bi-207	Pb	$K\beta_2'$	87.238–88.003		0.0376	±0.0010
90-Th-228 decay chain	Ra	Ll	10.622		0.00166	±0.00009
90-Th-228 decay chain	Ra	$L\alpha$	12.196–12.339		0.0286	±0.0015
90-Th-228 decay chain	Ra	$L\beta\eta$	13.662–15.447		0.047	±0.003
90-Th-228 decay chain	Ra	$L\gamma$	17.848–18.412		0.0102	±0.0006
90-Th-228 decay chain	Bi	L	9.420–15.709		0.145	±0.004
90-Th-228 decay chain	Bi	$K\alpha_2$	74.8157	±0.0009	0.107	±0.003
90-Th-228 decay chain	Bi	$K\alpha_1$	77.1088	±0.0010	0.179	±0.005
90-Th-228 decay chain	Bi	$K\beta_1'$	86.835–87.862		0.0612	±0.0020
90-Th-228 decay chain	Bi	$K\beta_2'$	89.732–90.522		0.0187	±0.0007

TABLE 2. RECOMMENDED X RAY ENERGIES AND EMISSION PROBABILITIES ORDERED BY RADIONUCLIDE (cont.)

Nuclide	Origin		Energy (keV)		Emission probability per decay	
			E_X	Uncertainty	P_X	Uncertainty
90-Th-228 decay chain	Pb	L	9.184–15.216		0.0104*	±0.0002
90-Th-228 decay chain	Pb	$K\alpha_2$	72.8049	±0.0008	0.0077*	±0.0002
90-Th-228 decay chain	Pb	$K\alpha_1$	74.9700	±0.0009	0.0130*	±0.0003
90-Th-228 decay chain	Pb	$K\beta_1'$	84.451–85.470		0.0044*	±0.0002
90-Th-228 decay chain	Pb	$K\beta_2'$	87.238–88.003		0.00134*	±0.00005
90-Th-228 decay chain	Tl	Ll	8.953		0.00169	±0.00009
90-Th-228 decay chain	Tl	Lα	10.172–10.268		0.0326	±0.0017
90-Th-228 decay chain	Tl	Lβη	10.994–12.643		0.0272	±0.0015
90-Th-228 decay chain	Tl	Lγ	14.291–14.738		0.0050	±0.0002
95-Am-241	Np	Ll	11.89	±0.02	0.00848	±0.00010
95-Am-241	Np	Lα	13.90	±0.02	0.1303	±0.0010
95-Am-241	Np	Lβη	17.81	±0.02	0.1886	±0.0015
95-Am-241	Np	Lγ	20.82	±0.02	0.0481	±0.0004
95-Am-243	Np	Ll	11.871		0.00445	±0.00014
95-Am-243	Np	Lα	13.761–13.946		0.0705	±0.0020
95-Am-243	Np	Lη	15.861		0.00126	±0.00004
95-Am-243	Np	Lβ	16.109–17.992		0.0818	±0.0016
95-Am-243	Np	Lγ	20.784–21.491		0.0197	±0.0004

* Adjusted for ^{212}Bi α branching fraction in order to express per ^{228}Th decay.

TABLE 3. RECOMMENDED GAMMA RAY ENERGIES AND EMISSION PROBABILITIES ORDERED BY RADIONUCLIDE

Nuclide	Energy (keV)		Emission probability per decay		Comments
	E_γ	Uncertainty	P_γ	Uncertainty	
11-Na-22	511	—	1.798	±0.002	Annihilation radiation
11-Na-22	1274.537	±0.003	0.99940	±0.00014	
11-Na-24	1368.626	±0.005	0.999935	±0.000005	
11-Na-24	2754.007	±0.011	0.99872	±0.00008	
19-K-40	1460.822	±0.006	0.1066	±0.0013	
21-Sc-46	889.271	±0.002	0.999833	±0.000005	
21-Sc-46	1120.537	±0.003	0.99986	+0.00004 –0.00036	
24-Cr-51	320.0835	±0.0004	0.0987	±0.0005	
25-Mn-54	834.838	±0.005	0.999746	±0.000011	

TABLE 3. RECOMMENDED GAMMA RAY ENERGIES AND EMISSION PROBABILITIES ORDERED BY RADIONUCLIDE (cont.)

Nuclide	Energy (keV)		Emission probability per decay		Comments
	E_γ	Uncertainty	P_γ	Uncertainty	
25-Mn-56	846.7638	±0.0019	0.9885	±0.0003	
25-Mn-56	1810.726	±0.004	0.269	±0.004	
25-Mn-56	2113.092	±0.006	0.142	±0.003	
25-Mn-56	2523.06	±0.05	0.0102	±0.0002	
26-Fe-59	142.651	±0.002	0.00972	±0.00015	
26-Fe-59	192.349	±0.005	0.0292	±0.0003	
26-Fe-59	1099.245	±0.003	0.5659	±0.0021	
26-Fe-59	1291.590	±0.006	0.4321	±0.0025	
27-Co-56	846.7638	±0.0019	0.999399	±0.000023	
27-Co-56	977.363	±0.004	0.01422	±0.00007	
27-Co-56	1037.8333	±0.0024	0.1403	±0.0005	
27-Co-56	1175.0878	±0.0022	0.02249	±0.00009	
27-Co-56	1238.2736	±0.0022	0.6641	±0.0016	
27-Co-56	1360.196	±0.004	0.04280	±0.00013	
27-Co-56	1771.327	±0.003	0.1545	±0.0004	
27-Co-56	2015.176	±0.005	0.03017	±0.00014	
27-Co-56	2034.752	±0.005	0.07741	±0.00013	
27-Co-56	2598.438	±0.004	0.1696	±0.0004	
27-Co-56	3009.559	±0.004	0.01038	±0.00019	
27-Co-56	3201.930	±0.011	0.03203	±0.00013	
27-Co-56	3253.402	±0.005	0.0787	±0.0003	
27-Co-56	3272.978	±0.006	0.01855	±0.00009	
27-Co-56	3451.119	±0.004	0.00942	±0.00006	
27-Co-57	14.41295	±0.00031	0.0915	±0.0017	
27-Co-57	122.06065	±0.00012	0.8551	±0.0006	
27-Co-57	136.47356	±0.00029	0.1071	±0.0015	
27-Co-58	511	—	0.300	±0.004	Annihilation radiation
27-Co-58	810.759	±0.002	0.9945	±0.0001	
27-Co-60	1173.228	±0.003	0.9985	±0.0003	
27-Co-60	1332.492	±0.004	0.999826	±0.000006	
29-Cu-64	511	—	0.3572	±0.0028	Annihilation radiation
29-Cu-64	1345.77	±0.16	0.00475	±0.00010	
30-Zn-65	511	—	0.0284	±0.0004	Annihilation radiation
30-Zn-65	1115.539	±0.002	0.5060	±0.0022	
31-Ga-66	833.5324	±0.0021	0.059	±0.005	
31-Ga-66	1039.220	±0.003	0.37	±0.03	
31-Ga-66	1333.112	±0.005	0.0117	±0.0009	
31-Ga-66	1418.754	±0.005	0.0061	±0.0005	

TABLE 3. RECOMMENDED GAMMA RAY ENERGIES AND EMISSION PROBABILITIES ORDERED BY RADIONUCLIDE (cont.)

Nuclide	Energy (keV)		Emission probability per decay		Comments
	E_γ	Uncertainty	P_γ	Uncertainty	
31-Ga-66	1508.158	±0.007	0.0055	±0.0004	
31-Ga-66	1898.823	±0.008	0.0039	±0.0003	
31-Ga-66	1918.329	±0.005	0.0199	±0.0016	
31-Ga-66	2189.616	±0.006	0.053	±0.004	
31-Ga-66	2422.525	±0.007	0.0188	±0.0015	
31-Ga-66	2751.835	±0.005	0.227	±0.018	
31-Ga-66	3228.800	±0.006	0.0151	±0.0012	
31-Ga-66	3380.850	±0.006	0.0146	±0.0012	
31-Ga-66	3422.040	±0.008	0.0086	±0.0007	
31-Ga-66	3791.004	±0.008	0.0109	±0.0009	
31-Ga-66	4085.853	±0.009	0.0127	±0.0010	
31-Ga-66	4295.187	±0.010	0.038	±0.003	
31-Ga-66	4461.202	±0.009	0.0084	±0.0007	
31-Ga-66	4806.007	±0.009	0.0186	±0.0015	
31-Ga-67	91.265	±0.005	0.0307	±0.0011	
31-Ga-67	93.310	±0.005	0.378	±0.009	
31-Ga-67	184.576	±0.010	0.209	±0.007	
31-Ga-67	208.950	±0.010	0.0237	±0.0008	
31-Ga-67	300.217	±0.010	0.168	±0.006	
31-Ga-67	393.527	±0.010	0.0466	±0.0016	
31-Ga-68	511	—	1.7828	±0.0022	Annihilation radiation
31-Ga-68	1077.34	±0.05	0.0322	±0.0003	
34-Se-75	66.0518	±0.0008	0.01112	±0.00012	
34-Se-75	96.7340	±0.0009	0.0342	±0.0003	
34-Se-75	121.1155	±0.0011	0.172	±0.003	
34-Se-75	136.0001	±0.0006	0.582	±0.007	
34-Se-75	198.6060	±0.0012	0.0148	±0.0004	
34-Se-75	264.6576	±0.0009	0.589	±0.003	
34-Se-75	279.5422	±0.0010	0.2499	±0.0013	
34-Se-75	303.9236	±0.0010	0.01316	±0.00008	
34-Se-75	400.6572	±0.0008	0.1147	±0.0009	
36-Kr-85	513.997	±0.005	0.00435	±0.00010	
38-Sr-85	514.0048	±0.0022	0.985	±0.004	
39-Y-88	898.036	±0.004	0.9390	±0.0023	
39-Y-88	1836.052	±0.013	0.9938	±0.0003	
41-Nb-93m	30.77	±0.02	(5.59	±0.16) 10^{-6}	
41-Nb-94	702.639	±0.004	0.99815	±0.00006	
41-Nb-94	871.114	±0.003	0.99892	±0.00003	

TABLE 3. RECOMMENDED GAMMA RAY ENERGIES AND EMISSION PROBABILITIES ORDERED BY RADIONUCLIDE (cont.)

Nuclide	Energy (keV)		Emission probability per decay		Comments
	E_γ	Uncertainty	P_γ	Uncertainty	
41-Nb-95	765.803	±0.006	0.99808	±0.00007	
42-Mo-99/43-Tc-99m	40.58323	±0.00017	0.01022	±0.00027	
42-Mo-99/43-Tc-99m	140.511	±0.001	0.896	±0.017	
42-Mo-99/43-Tc-99m	181.094	±0.002	0.0601	±0.0011	
42-Mo-99/43-Tc-99m	366.421	±0.015	0.01194	±0.00023	
42-Mo-99/43-Tc-99m	739.500	±0.017	0.1212	±0.0015	
42-Mo-99/43-Tc-99m	777.921	±0.020	0.0428	±0.0008	
43-Tc-99m	140.511	±0.001	0.885	±0.002	
43-Tc-99m	142.683	±0.001	0.00023	±0.00002	
44-Ru-103	39.760	±0.010	0.00071	±0.00003	
44-Ru-103	53.275	±0.010	0.00384	±0.00006	
44-Ru-103	294.98	±0.02	0.00289	±0.00006	
44-Ru-103	443.80	±0.02	0.00344	±0.00003	
44-Ru-103	497.08	±0.02	0.9131	±0.0007	
44-Ru-103	557.04	±0.02	0.00855	±0.00005	
44-Ru-103	610.33	±0.02	0.0578	±0.0003	
44-Ru-106/45-Rh-106	511.8534	±0.0023	0.2050	±0.0021	
44-Ru-106/45-Rh-106	616.22	±0.09	0.00724	±0.00013	
44-Ru-106/45-Rh-106	621.93	±0.06	0.0986	±0.0011	
44-Ru-106/45-Rh-106	873.49	±0.05	0.00435	±0.00008	
44-Ru-106/45-Rh-106	1050.41	±0.06	0.01488	±0.00022	
44-Ru-106/45-Rh-106	1128.07	±0.05	0.00399	±0.00006	
47-Ag-110m	446.812	±0.003	0.0365	±0.0005	with ^{110}Ag
47-Ag-110m	620.3553	±0.0017	0.0272	±0.0008	with ^{110}Ag
47-Ag-110m	657.7600	±0.0011	0.9438	±0.0008	with ^{110}Ag
47-Ag-110m	677.6217	±0.0012	0.1056	±0.0006	with ^{110}Ag
47-Ag-110m	687.0091	±0.0018	0.0645	±0.0003	with ^{110}Ag
47-Ag-110m	706.6760	±0.0015	0.1648	±0.0008	with ^{110}Ag
47-Ag-110m	744.2755	±0.0018	0.0471	±0.0003	with ^{110}Ag
47-Ag-110m	763.9424	±0.0017	0.2231	±0.0009	with ^{110}Ag
47-Ag-110m	818.0244	±0.0018	0.0733	±0.0004	with ^{110}Ag
47-Ag-110m	884.6781	±0.0013	0.740	±0.012	with ^{110}Ag
47-Ag-110m	937.483	±0.003	0.3451	±0.0027	with ^{110}Ag
47-Ag-110m	1384.2931	±0.0020	0.247	±0.005	with ^{110}Ag
47-Ag-110m	1475.7792	±0.0023	0.0403	±0.0005	with ^{110}Ag
47-Ag-110m	1505.0280	±0.0020	0.1316	±0.0016	with ^{110}Ag
47-Ag-110m	1562.294	±0.018	0.0121	±0.0003	with ^{110}Ag
48-Cd-109	88.0336	±0.0011	0.03626	±0.00020	

TABLE 3. RECOMMENDED GAMMA RAY ENERGIES AND EMISSION PROBABILITIES ORDERED BY RADIONUCLIDE (cont.)

Nuclide	Energy (keV)		Emission probability per decay		Comments
	E_γ	Uncertainty	P_γ	Uncertainty	
49-In-111	171.28	±0.03	0.9066	±0.0025	
49-In-111	245.35	±0.04	0.9409	±0.0006	
50-Sn-113	255.134	±0.010	0.0211	±0.0008	
50-Sn-113	391.698	±0.003	0.6494	±0.0017	
51-Sb-125	176.314	±0.002	0.0682	±0.0007	
51-Sb-125	380.452	±0.008	0.01520	±0.00015	
51-Sb-125	427.874	±0.004	0.2955	±0.0024	
51-Sb-125	463.365	±0.004	0.1048	±0.0009	
51-Sb-125	600.597	±0.002	0.1776	±0.0018	
51-Sb-125	606.713	±0.003	0.0502	±0.0005	
51-Sb-125	635.950	±0.003	0.1132	±0.0010	
51-Sb-125	671.441	±0.006	0.01783	±0.00016	
52-Te-123m	158.97	±0.05	0.8399	±0.0008	
53-I-123	158.97	±0.05	0.8325	±0.0021	
53-I-123	528.96	±0.05	0.0132	±0.0008	
53-I-125	35.4919	±0.0005	0.0667	±0.0017	
53-I-129	39.578	±0.004	0.0742	±0.0008	
53-I-131	80.1850	±0.0019	0.02607	±0.00027	
53-I-131	284.305	±0.005	0.0606	±0.0006	
53-I-131	364.489	±0.005	0.812	±0.008	
53-I-131	636.989	±0.004	0.0726	±0.0008	
53-I-131	722.911	±0.005	0.01796	±0.00020	
55-Cs-134	563.243	±0.003	0.0837	±0.0003	
55-Cs-134	569.327	±0.003	0.1538	±0.0004	
55-Cs-134	604.720	±0.003	0.97650	±0.00018	
55-Cs-134	795.83	±0.03	0.855	±0.003	
55-Cs-134	801.945	±0.004	0.0870	±0.0003	
55-Cs-134	1365.186	±0.004	0.03017	±0.00012	
55-Cs-137	661.657	±0.003	0.8499	±0.0020	
56-Ba-133	53.1622	±0.0006	0.0214	±0.0003	
56-Ba-133	79.6142	±0.0012	0.0265	±0.0005	
56-Ba-133	80.9979	±0.0011	0.329	±0.003	
56-Ba-133	276.3989	±0.0012	0.0716	±0.0005	
56-Ba-133	302.8508	±0.0005	0.1834	±0.0013	
56-Ba-133	356.0129	±0.0007	0.6205	±0.0019	
56-Ba-133	383.8485	±0.0012	0.0894	±0.0006	
58-Ce-139	165.8575	±0.0011	0.7990	±0.0004	

TABLE 3. RECOMMENDED GAMMA RAY ENERGIES AND EMISSION PROBABILITIES ORDERED BY RADIONUCLIDE (cont.)

Nuclide	Energy (keV)		Emission probability per decay		Comments
	E_γ	Uncertainty	P_γ	Uncertainty	
58-Ce-141	145.4433	±0.0014	0.4829	±0.0020	
58-Ce-144/59-Pr-144	33.568	±0.010	0.00235	±0.00012	^{144}Ce
58-Ce-144/59-Pr-144	40.98	±0.10	0.0041	±0.0025	^{144}Ce
58-Ce-144/59-Pr-144	80.12	±0.05	0.0152	±0.0010	^{144}Ce
58-Ce-144/59-Pr-144	133.515	±0.004	0.1109	±0.0016	^{144}Ce
58-Ce-144/59-Pr-144	696.505	±0.004	0.01342	±0.00014	^{144}Pr–per ^{144}Ce decay
58-Ce-144/59-Pr-144	1489.148	±0.003	0.00296	±0.00005	^{144}Pr–per ^{144}Ce decay
58-Ce-144/59-Pr-144	2185.645	±0.005	0.00680	±0.00018	^{144}Pr–per ^{144}Ce decay
62-Sm-153	69.67301	±0.00018	0.0473	±0.0003	
62-Sm-153	83.36716	±0.00017	0.00192	±0.00007	
62-Sm-153	89.48593	±0.00021	0.00158	±0.00015	
62-Sm-153	97.43095	±0.00017	0.00772	±0.00018	
62-Sm-153	103.18007	±0.00013	0.293	±0.003	
62-Sm-153	172.85295	±0.00021	0.000737	±0.000020	
63-Eu-152	121.7817	±0.0003	0.2841	±0.0013	ε
63-Eu-152	244.6974	±0.0008	0.0755	±0.0004	ε
63-Eu-152	344.2785	±0.0012	0.2658	±0.0012	β^-
63-Eu-152	411.1165	±0.0012	0.02237	±0.00010	β^-
63-Eu-152	443.965	±0.003	0.03125	±0.00014	ε
63-Eu-152	778.9045	±0.0024	0.1296	±0.0006	β^-
63-Eu-152	867.380	±0.003	0.04241	±0.00023	ε
63-Eu-152	964.072	±0.018	0.1462	±0.0006	ε
63-Eu-152	1085.837	±0.010	0.1013	±0.0006	ε
63-Eu-152	1089.737	±0.005	0.01731	±0.00010	β^-
63-Eu-152	1112.076	±0.003	0.1340	±0.0006	ε
63-Eu-152	1212.948	±0.011	0.01415	±0.00009	ε
63-Eu-152	1299.142	±0.008	0.01632	±0.00009	β^-
63-Eu-152	1408.013	±0.003	0.2085	±0.0009	ε
63-Eu-154	123.0706	±0.0009	0.404	±0.005	
63-Eu-154	247.9288	±0.0007	0.0689	±0.0007	
63-Eu-154	591.755	±0.003	0.0495	±0.0005	
63-Eu-154	692.4205	±0.0018	0.0179	±0.0003	
63-Eu-154	723.3014	±0.0022	0.2005	±0.0021	
63-Eu-154	756.8020	±0.0023	0.0453	±0.0005	
63-Eu-154	873.1834	±0.0023	0.1217	±0.0012	
63-Eu-154	996.262	±0.006	0.1050	±0.0010	
63-Eu-154	1004.725	±0.007	0.1785	±0.0017	
63-Eu-154	1246.121	±0.004	0.00862	±0.00008	
63-Eu-154	1274.429	±0.004	0.349	±0.003	

TABLE 3. RECOMMENDED GAMMA RAY ENERGIES AND EMISSION PROBABILITIES ORDERED BY RADIONUCLIDE (cont.)

Nuclide	Energy (keV)		Emission probability per decay		Comments
	E_γ	Uncertainty	P_γ	Uncertainty	
63-Eu-154	1596.4804	±0.0028	0.01783	±0.00017	
63-Eu-155	26.531	±0.021	0.00316	±0.00022	
63-Eu-155	45.2990	±0.0010	0.0131	±0.0005	
63-Eu-155	60.0086	±0.0010	0.0122	±0.0005	
63-Eu-155	86.0591	±0.0010	0.00154	±0.00017	
63-Eu-155	86.5479	±0.0010	0.307	±0.003	
63-Eu-155	105.3083	±0.0010	0.211	±0.006	
67-Ho-166	80.576	±0.002	0.0655	±0.0008	
67-Ho-166	1379.437	±0.006	0.00933	±0.00016	
67-Ho-166	1581.833	±0.007	0.00186	±0.00004	
67-Ho-166	1662.439	±0.006	0.00118	±0.00005	
67-Ho-166m	80.5725	±0.0013	0.1266	±0.0023	
67-Ho-166m	184.4107	±0.0011	0.725	±0.005	
67-Ho-166m	215.871	±0.007	0.0266	±0.0017	
67-Ho-166m	259.736	±0.010	0.01078	±0.00010	
67-Ho-166m	280.4630	±0.0023	0.2954	±0.0025	
67-Ho-166m	300.741	±0.003	0.0373	±0.0004	
67-Ho-166m	365.768	±0.006	0.0246	±0.0004	
67-Ho-166m	410.956	±0.003	0.1135	±0.0018	
67-Ho-166m	451.540	±0.004	0.02915	±0.00014	
67-Ho-166m	464.798	±0.006	0.0125	±0.0004	
67-Ho-166m	529.825	±0.004	0.094	±0.004	
67-Ho-166m	570.995	±0.005	0.0543	±0.0020	
67-Ho-166m	611.579	±0.006	0.0131	±0.0021	
67-Ho-166m	670.526	±0.004	0.0534	±0.0021	
67-Ho-166m	691.253	±0.007	0.0132	±0.0007	
67-Ho-166m	711.697	±0.003	0.549	±0.012	
67-Ho-166m	752.280	±0.004	0.122	±0.003	
67-Ho-166m	810.286	±0.004	0.573	±0.011	
67-Ho-166m	830.565	±0.004	0.0972	±0.0018	
67-Ho-166m	950.988	±0.004	0.02744	±0.00019	
69-Tm-170	78.59	±0.02	0.000034	±0.000003	
69-Tm-170	84.25474	±0.00008	0.0248	±0.0009	
70-Yb-169	63.12044	±0.00004	0.4405	±0.0024	
70-Yb-169	93.61447	±0.00008	0.02571	±0.00017	
70-Yb-169	109.77924	±0.00004	0.1736	±0.0009	
70-Yb-169	118.18940	±0.00014	0.01870	±0.00010	
70-Yb-169	130.52293	±0.00006	0.1138	±0.0005	
70-Yb-169	177.21307	±0.00006	0.2232	±0.0010	

TABLE 3. RECOMMENDED GAMMA RAY ENERGIES AND EMISSION PROBABILITIES ORDERED BY RADIONUCLIDE (cont.)

Nuclide	Energy (keV)		Emission probability per decay		Comments
	E_γ	Uncertainty	P_γ	Uncertainty	
70-Yb-169	197.95675	±0.00007	0.3593	±0.0012	
70-Yb-169	261.07712	±0.00009	0.01687	±0.00008	
70-Yb-169	307.73586	±0.00010	0.10046	±0.00045	
77-Ir-192	205.79430	±0.00009	0.0334	±0.0004	
77-Ir-192	295.95650	±0.00015	0.2872	±0.0014	
77-Ir-192	308.45507	±0.00017	0.2968	±0.0015	
77-Ir-192	316.50618	±0.00017	0.8275	±0.0021	
77-Ir-192	468.06885	±0.00026	0.4781	±0.0024	
77-Ir-192	484.5751	±0.0004	0.03189	±0.00024	
77-Ir-192	588.5810	±0.0007	0.04517	±0.00022	
77-Ir-192	604.41105	±0.00025	0.0820	±0.0004	
77-Ir-192	612.46215	±0.00026	0.0534	±0.0008	
79-Au-198	411.80205	±0.00017	0.9554	±0.0007	
79-Au-198	675.8836	±0.0007	0.00806	±0.00007	
79-Au-198	1087.6842	±0.0007	0.00159	±0.00003	
80-Hg-203	279.1952	±0.0010	0.8148	±0.0008	
81-Tl-201	135.312	±0.034	0.02604	±0.00022	
81-Tl-201	167.450	±0.030	0.1000	±0.0010	
81-Tl-208	277.37	±0.03	0.0237	±0.0011	per ^{228}Th decay–^{228}Th decay chain
81-Tl-208	583.187	±0.002	0.3055	±0.0017	per ^{228}Th decay–^{228}Th decay chain
81-Tl-208	860.56	±0.03	0.0448	±0.0004	per ^{228}Th decay–^{228}Th decay chain
81-Tl-208	2614.511	±0.010	0.3585	±0.0007	per ^{228}Th decay–^{228}Th decay chain
82-Pb-212	115.183	±0.005	0.00623	±0.00022	^{228}Th decay chain
82-Pb-212	238.632	±0.002	0.436	±0.003	^{228}Th decay chain
82-Pb-212	300.09	±0.01	0.0318	±0.0013	^{228}Th decay chain
82-Pb-214	53.2275	±0.0021	0.01066	±0.00014	^{226}Ra decay chain
82-Pb-214	241.997	±0.003	0.0719	±0.0006	^{226}Ra decay chain
82-Pb-214	295.224	±0.002	0.1828	±0.0014	^{226}Ra decay chain
82-Pb-214	351.932	±0.002	0.3534	±0.0027	^{226}Ra decay chain
83-Bi-207	569.698	±0.002	0.9776	±0.0003	
83-Bi-207	1063.656	±0.003	0.7458	±0.0049	
83-Bi-207	1770.228	±0.009	0.0687	±0.0003	
83-Bi-212	727.33	±0.01	0.0674	±0.0012	^{228}Th decay chain
83-Bi-212	785.37	±0.09	0.0111	±0.0001	^{228}Th decay chain
83-Bi-212	1620.74	±0.01	0.0151	±0.0003	^{228}Th decay chain

TABLE 3. RECOMMENDED GAMMA RAY ENERGIES AND EMISSION PROBABILITIES ORDERED BY RADIONUCLIDE (cont.)

Nuclide	Energy (keV)		Emission probability per decay		Comments
	E_γ	Uncertainty	P_γ	Uncertainty	
83-Bi-214	609.316	±0.003	0.4516	±0.0033	^{226}Ra decay chain
83-Bi-214	665.453	±0.022	0.01521	±0.00011	^{226}Ra decay chain
83-Bi-214	768.367	±0.011	0.04850	±0.00038	^{226}Ra decay chain
83-Bi-214	806.185	±0.011	0.01255	±0.00011	^{226}Ra decay chain
83-Bi-214	934.061	±0.012	0.03074	±0.00025	^{226}Ra decay chain
83-Bi-214	1120.287	±0.010	0.1478	±0.0011	^{226}Ra decay chain
83-Bi-214	1155.19	±0.02	0.01624	±0.00014	^{226}Ra decay chain
83-Bi-214	1238.110	±0.012	0.05785	±0.00045	^{226}Ra decay chain
83-Bi-214	1280.96	±0.02	0.01425	±0.00012	^{226}Ra decay chain
83-Bi-214	1377.669	±0.012	0.03954	±0.00033	^{226}Ra decay chain
83-Bi-214	1401.516	±0.014	0.01324	±0.00011	^{226}Ra decay chain
83-Bi-214	1407.993	±0.007	0.02369	±0.00019	^{226}Ra decay chain
83-Bi-214	1509.217	±0.008	0.02108	±0.00021	^{226}Ra decay chain
83-Bi-214	1661.316	±0.013	0.01037	±0.00010	^{226}Ra decay chain
83-Bi-214	1729.640	±0.012	0.02817	±0.00023	^{226}Ra decay chain
83-Bi-214	1764.539	±0.015	0.1517	±0.0012	^{226}Ra decay chain
83-Bi-214	1847.420	±0.025	0.02000	±0.00018	^{226}Ra decay chain
83-Bi-214	2118.536	±0.008	0.01148	±0.00011	^{226}Ra decay chain
83-Bi-214	2204.071	±0.021	0.0489	±0.0010	^{226}Ra decay chain
83-Bi-214	2447.673	±0.010	0.01536	±0.00015	^{226}Ra decay chain
86-Rn-220	549.76	±0.04	0.00115	±0.00015	^{228}Th decay chain
88-Ra-224	240.986	±0.006	0.0412	±0.0004	^{228}Th decay chain
88-Ra-226	186.211	±0.013	0.03533	±0.00028	^{226}Ra decay chain
90-Th-228	84.373	±0.003	0.0117	±0.0005	^{228}Th decay chain
90-Th-228	131.612	±0.004	0.00124	±0.00006	^{228}Th decay chain
90-Th-228	215.985	±0.004	0.00226	±0.00020	^{228}Th decay chain
91-Pa-234m	258.24	±0.07	0.000726	±0.000009	Daughter of ^{234}Th (^{238}U)
91-Pa-234m	742.814	±0.022	0.00096	±0.00003	Daughter of ^{234}Th (^{238}U)
91-Pa-234m	766.358	±0.020	0.00318	±0.00005	Daughter of ^{234}Th (^{238}U)
91-Pa-234m	786.272	±0.022	0.00054	±0.00001	Daughter of ^{234}Th (^{238}U)
91-Pa-234m	1001.025	±0.022	0.00832	±0.00010	Daughter of ^{234}Th (^{238}U)
95-Am-241	26.3446	±0.0002	0.0240	±0.0003	
95-Am-241	33.1963	±0.0003	0.00121	±0.00003	
95-Am-241	59.5409	±0.0001	0.3578	±0.0009	

TABLE 3. RECOMMENDED GAMMA RAY ENERGIES AND EMISSION PROBABILITIES ORDERED BY RADIONUCLIDE (cont.)

Nuclide	Energy (keV)		Emission probability per decay		Comments
	E_γ	Uncertainty	P_γ	Uncertainty	
95-Am-243	43.53	±0.02	0.0589	±0.0010	
95-Am-243	74.66	±0.02	0.672	±0.012	

TABLE 4. RECOMMENDED GAMMA RAY ENERGIES AND EMISSION PROBABILITIES ORDERED BY ENERGY

Energy (keV)		Emission probability per decay		Nuclide	Comments
E_γ	Uncertainty	P_γ	Uncertainty		
14.41295	±0.00031	0.0915	±0.0017	27-Co-57	
26.3446	±0.0002	0.0240	±0.0003	95-Am-241	
26.531	±0.021	0.00316	±0.00022	63-Eu-155	
30.77	±0.02	(5.59	±0.16) 10^{-6}	41-Nb-93m	
33.1963	±0.0003	0.00121	±0.00003	95-Am-241	
33.568	±0.010	0.00235	±0.00012	58-Ce-144	
35.4919	±0.0005	0.0667	±0.0017	53-I-125	
39.578	±0.004	0.0742	±0.0008	53-I-129	
39.760	±0.010	0.00071	±0.00003	44-Ru-103	
40.58323	±0.00017	0.01022	±0.00027	42-Mo-99/43-Tc-99m	
40.98	±0.10	0.0041	±0.0025	58-Ce-144	
43.53	±0.02	0.0589	±0.0010	95-Am-243	
45.2990	±0.0010	0.0131	±0.0005	63-Eu-155	
53.1622	±0.0006	0.0214	±0.0003	56-Ba-133	
53.2275	±0.0021	0.01066	±0.00014	82-Pb-214	^{226}Ra decay chain
53.275	±0.010	0.00384	±0.00006	44-Ru-103	
59.5409	±0.0001	0.3578	±0.0009	95-Am-241	
60.0086	±0.0010	0.0122	±0.0005	63-Eu-155	
63.12044	±0.00004	0.4405	±0.0024	70-Yb-169	
66.0518	±0.0008	0.01112	±0.00012	34-Se-75	
69.67301	±0.00018	0.0473	±0.0003	62-Sm-153	
74.66	±0.02	0.672	±0.012	95-Am-243	
78.59	±0.02	0.000034	±0.000003	69-Tm-170	
79.6142	±0.0012	0.0265	±0.0005	56-Ba-133	
80.12	±0.05	0.0152	±0.0010	58-Ce-144	
80.1850	±0.0019	0.02607	±0.00027	53-I-131	
80.5725	±0.0013	0.1266	±0.0023	67-Ho-166m	
80.576	±0.002	0.0655	±0.0008	67-Ho-166	
80.9979	±0.0011	0.329	±0.003	56-Ba-133	

TABLE 4. RECOMMENDED GAMMA RAY ENERGIES AND EMISSION PROBABILITIES ORDERED BY ENERGY (cont.)

Energy (keV)		Emission probability per decay		Nuclide	Comments
E_γ	Uncertainty	P_γ	Uncertainty		
83.36716	±0.00017	0.00192	±0.00007	62-Sm-153	
84.25474	±0.00008	0.0248	±0.0009	69-Tm-170	
84.373	±0.003	0.0117	±0.0005	90-Th-228	^{228}Th decay chain
86.0591	±0.0010	0.00154	±0.00017	63-Eu-155	
86.5479	±0.0010	0.307	±0.003	63-Eu-155	
88.0336	±0.0011	0.03626	±0.00020	48-Cd-109	
89.48593	±0.00021	0.00158	±0.00015	62-Sm-153	
91.265	±0.005	0.0307	±0.0011	31-Ga-67	
93.310	±0.005	0.378	±0.009	31-Ga-67	
93.61447	±0.00008	0.02571	±0.00017	70-Yb-169	
96.7340	±0.0009	0.0342	±0.0003	34-Se-75	
97.43095	±0.00017	0.00772	±0.00018	62-Sm-153	
103.18007	±0.00013	0.293	±0.003	62-Sm-153	
105.3083	±0.0010	0.211	±0.006	63-Eu-155	
109.77924	±0.00004	0.1736	±0.0009	70-Yb-169	
115.183	±0.005	0.00623	±0.00022	82-Pb-212	^{228}Th decay chain
118.18940	±0.00014	0.01870	±0.00010	70-Yb-169	
121.1155	±0.0011	0.172	±0.003	34-Se-75	
121.7817	±0.0003	0.2841	±0.0013	63-Eu-152	ε
122.06065	±0.00012	0.8551	±0.0006	27-Co-57	
123.0706	±0.0009	0.404	±0.005	63-Eu-154	
130.52293	±0.00006	0.1138	±0.0005	70-Yb-169	
131.612	±0.004	0.00124	±0.00006	90-Th-228	^{228}Th decay chain
133.515	±0.004	0.1109	±0.0016	58-Ce-144	
135.312	±0.034	0.02604	±0.00022	81-Tl-201	
136.0001	±0.0006	0.582	±0.007	34-Se-75	
136.47356	±0.00029	0.1071	±0.0015	27-Co-57	
140.511	±0.001	0.896	±0.017	42-Mo-99/43-Tc-99m	
140.511	±0.001	0.885	±0.002	43-Tc-99m	
142.651	±0.002	0.00972	±0.00015	26-Fe-59	
142.683	±0.001	0.00023	±0.00002	43-Tc-99m	
145.4433	±0.0014	0.4829	±0.0020	58-Ce-141	
158.97	±0.05	0.8399	±0.0008	52-Te-123m	
158.97	±0.05	0.8325	±0.0021	53-I-123	
165.8575	±0.0011	0.7990	±0.0004	58-Ce-139	
167.450	±0.030	0.1000	±0.0010	81-Tl-201	
171.28	±0.03	0.9066	±0.0025	49-In-111	
172.85295	±0.00021	0.000737	±0.000020	62-Sm-153	
176.314	±0.002	0.0682	±0.0007	51-Sb-125	
177.21307	±0.00006	0.2232	±0.0010	70-Yb-169	

TABLE 4. RECOMMENDED GAMMA RAY ENERGIES AND EMISSION PROBABILITIES ORDERED BY ENERGY (cont.)

Energy (keV)		Emission probability per decay		Nuclide	Comments
E_γ	Uncertainty	P_γ	Uncertainty		
181.094	±0.002	0.0601	±0.0011	42-Mo-99/43-Tc-99m	
184.4107	±0.0011	0.725	±0.005	67-Ho-166m	
184.576	±0.010	0.209	±0.007	31-Ga-67	
186.211	±0.013	0.03533	±0.00028	88-Ra-226	^{226}Ra decay chain
192.349	±0.005	0.0292	±0.0003	26-Fe-59	
197.95675	±0.00007	0.3593	±0.0012	70-Yb-169	
198.6060	±0.0012	0.0148	±0.0004	34-Se-75	
205.79430	±0.00009	0.0334	±0.0004	77-Ir-192	
208.950	±0.010	0.0237	±0.0008	31-Ga-67	
215.871	±0.007	0.0266	±0.0017	67-Ho-166m	
215.985	±0.004	0.00226	±0.00020	90-Th-228	^{228}Th decay chain
238.632	±0.002	0.436	±0.003	82-Pb-212	^{228}Th decay chain
240.986	±0.006	0.0412	±0.0004	88-Ra-224	^{228}Th decay chain
241.997	±0.003	0.0719	±0.0006	82-Pb-214	^{226}Ra decay chain
244.6974	±0.0008	0.0755	±0.0004	63-Eu-152	ε
245.35	±0.04	0.9409	±0.0006	49-In-111	
247.9288	±0.0007	0.0689	±0.0007	63-Eu-154	
255.134	±0.010	0.0211	±0.0008	50-Sn-113	
258.24	±0.07	0.000726	±0.000009	91-Pa-234m	Daughter of ^{234}Th (^{238}U)
259.736	±0.010	0.01078	±0.00010	67-Ho-166m	
261.07712	±0.00009	0.01687	±0.00008	70-Yb-169	
264.6576	±0.0009	0.589	±0.003	34-Se-75	
276.3989	±0.0012	0.0716	±0.0005	56-Ba-133	
277.37	±0.03	0.0237	±0.0011	81-Tl-208	per ^{228}Th decay–^{228}Th decay chain
279.1952	±0.0010	0.8148	±0.0008	80-Hg-203	
279.5422	±0.0010	0.2499	±0.0013	34-Se-75	
280.4630	±0.0023	0.2954	±0.0025	67-Ho-166m	
284.305	±0.005	0.0606	±0.0006	53-I-131	
294.98	±0.02	0.00289	±0.00006	44-Ru-103	
295.224	±0.002	0.1828	±0.0014	82-Pb-214	^{226}Ra decay chain
295.95650	±0.00015	0.2872	±0.0014	77-Ir-192	
300.09	±0.01	0.0318	±0.0013	82-Pb-212	^{228}Th decay chain
300.217	±0.010	0.168	±0.006	31-Ga-67	
300.741	±0.003	0.0373	±0.0004	67-Ho-166m	
302.8508	±0.0005	0.1834	±0.0013	56-Ba-133	
303.9236	±0.0010	0.01316	±0.00008	34-Se-75	
307.73586	±0.00010	0.10046	±0.00045	70-Yb-169	
308.45507	±0.00017	0.2968	±0.0015	77-Ir-192	
316.50618	±0.00017	0.8275	±0.0021	77-Ir-192	

TABLE 4. RECOMMENDED GAMMA RAY ENERGIES AND EMISSION PROBABILITIES ORDERED BY ENERGY (cont.)

Energy (keV)		Emission probability per decay		Nuclide	Comments
E_γ	Uncertainty	P_γ	Uncertainty		
320.0835	±0.0004	0.0987	±0.0005	24-Cr-51	
344.2785	±0.0012	0.2658	±0.0012	63-Eu-152	β^-
351.932	±0.002	0.3534	±0.0027	82-Pb-214	^{226}Ra decay chain
356.0129	±0.0007	0.6205	±0.0019	56-Ba-133	
364.489	±0.005	0.812	±0.008	53-I-131	
365.768	±0.006	0.0246	±0.0004	67-Ho-166m	
366.421	±0.015	0.01194	±0.00023	42-Mo-99/43-Tc-99m	
380.452	±0.008	0.01520	±0.00015	51-Sb-125	
383.8485	±0.0012	0.0894	±0.0006	56-Ba-133	
391.698	±0.003	0.6494	±0.0017	50-Sn-113	
393.527	±0.010	0.0466	±0.0016	31-Ga-67	
400.6572	±0.0008	0.1147	±0.0009	34-Se-75	
410.956	±0.003	0.1135	±0.0018	67-Ho-166m	
411.1165	±0.0012	0.02237	±0.00010	63-Eu-152	β^-
411.80205	±0.00017	0.9554	±0.0007	79-Au-198	
427.874	±0.004	0.2955	±0.0024	51-Sb-125	
443.80	±0.02	0.00344	±0.00003	44-Ru-103	
443.965	±0.003	0.03125	±0.00014	63-Eu-152	ε
446.812	±0.003	0.0365	±0.0005	47-Ag-110m	with ^{110}Ag
451.540	±0.004	0.02915	±0.00014	67-Ho-166m	
463.365	±0.004	0.1048	±0.0009	51-Sb-125	
464.798	±0.006	0.0125	±0.0004	67-Ho-166m	
468.06885	±0.00026	0.4781	±0.0024	77-Ir-192	
484.5751	±0.0004	0.03189	±0.00024	77-Ir-192	
497.08	±0.02	0.9131	±0.0007	44-Ru-103	
511	—	1.798	±0.002	11-Na-22	Annihilation radiation
511	—	0.300	±0.004	27-Co-58	Annihilation radiation
511	—	0.3572	±0.0028	29-Cu-64	Annihilation radiation
511	—	0.0284	±0.0004	30-Zn-65	Annihilation radiation
511	—	1.7828	±0.0022	31-Ga-68	Annihilation radiation
511.8534	±0.0023	0.2050	±0.0021	44-Ru-106/45-Rh-106	
513.997	±0.005	0.00435	±0.00010	36-Kr-85	
514.0048	±0.0022	0.985	±0.004	38-Sr-85	
528.96	±0.05	0.0132	±0.0008	53-I-123	
529.825	±0.004	0.094	±0.004	67-Ho-166m	
549.76	±0.04	0.00115	±0.00015	86-Rn-220	^{228}Th decay chain
557.04	±0.02	0.00855	±0.00005	44-Ru-103	
563.243	±0.003	0.0837	±0.0003	55-Cs-134	
569.327	±0.003	0.1538	±0.0004	55-Cs-134	
569.698	±0.002	0.9776	±0.0003	83-Bi-207	

TABLE 4. RECOMMENDED GAMMA RAY ENERGIES AND EMISSION PROBABILITIES ORDERED BY ENERGY (cont.)

Energy (keV)		Emission probability per decay		Nuclide	Comments
E_γ	Uncertainty	P_γ	Uncertainty		
570.995	±0.005	0.0543	±0.0020	67-Ho-166m	
583.187	±0.002	0.3055	±0.0017	81-Tl-208	per ^{228}Th decay–^{228}Th decay chain
588.5810	±0.0007	0.04517	±0.00022	77-Ir-192	
591.755	±0.003	0.0495	±0.0005	63-Eu-154	
600.597	±0.002	0.1776	±0.0018	51-Sb-125	
604.41105	±0.00025	0.0820	±0.0004	77-Ir-192	
604.720	±0.003	0.97650	±0.00018	55-Cs-134	
606.713	±0.003	0.0502	±0.0005	51-Sb-125	
609.316	±0.003	0.4516	±0.0033	83-Bi-214	^{226}Ra decay chain
610.33	±0.02	0.0578	±0.0003	44-Ru-103	
611.579	±0.006	0.0131	±0.0021	67-Ho-166m	
612.46215	±0.00026	0.0534	±0.0008	77-Ir-192	
616.22	±0.09	0.00724	±0.00013	44-Ru-106/45-Rh-106	
620.3553	±0.0017	0.0272	±0.0008	47-Ag-110m	with ^{110}Ag
621.93	±0.06	0.0986	±0.0011	44-Ru-106/45-Rh-106	
635.950	±0.003	0.1132	±0.0010	51-Sb-125	
636.989	±0.004	0.0726	±0.0008	53-I-131	
657.7600	±0.0011	0.9438	±0.0008	47-Ag-110m	with ^{110}Ag
661.657	±0.003	0.8499	±0.0020	55-Cs-137	
665.453	±0.022	0.01521	±0.00011	83-Bi-214	^{226}Ra decay chain
670.526	±0.004	0.0534	±0.0021	67-Ho-166m	
671.441	±0.006	0.01783	±0.00016	51-Sb-125	
675.8836	±0.0007	0.00806	±0.00007	79-Au-198	
677.6217	±0.0012	0.1056	±0.0006	47-Ag-110m	with ^{110}Ag
687.0091	±0.0018	0.0645	±0.0003	47-Ag-110m	with ^{110}Ag
691.253	±0.007	0.0132	±0.0007	67-Ho-166m	
692.4205	±0.0018	0.0179	±0.0003	63-Eu-154	
696.505	±0.004	0.01342	±0.00014	59-Pr-144	per ^{144}Ce decay
702.639	±0.004	0.99815	±0.00006	41-Nb-94	
706.6760	±0.0015	0.1648	±0.0008	47-Ag-110m	with ^{110}Ag
711.697	±0.003	0.549	±0.012	67-Ho-166m	
722.911	±0.005	0.01796	±0.00020	53-I-131	
723.3014	±0.0022	0.2005	±0.0021	63-Eu-154	
727.33	±0.01	0.0674	±0.0012	83-Bi-212	^{228}Th decay chain
739.500	±0.017	0.1212	±0.0015	42-Mo-99/43-Tc-99m	
742.814	±0.022	0.00096	±0.00003	91-Pa-234m	Daughter of ^{234}Th (^{238}U)
744.2755	±0.0018	0.0471	±0.0003	47-Ag-110m	with ^{110}Ag
752.280	±0.004	0.122	±0.003	67-Ho-166m	
756.8020	±0.0023	0.0453	±0.0005	63-Eu-154	

TABLE 4. RECOMMENDED GAMMA RAY ENERGIES AND EMISSION PROBABILITIES ORDERED BY ENERGY (cont.)

Energy (keV)		Emission probability per decay		Nuclide	Comments
E_γ	Uncertainty	P_γ	Uncertainty		
763.9424	±0.0017	0.2231	±0.0009	47-Ag-110m	with ^{110}Ag
765.803	±0.006	0.99808	±0.00007	41-Nb-95	
766.358	±0.020	0.00318	±0.00005	91-Pa-234m	Daughter of ^{234}Th (^{238}U)
768.367	±0.011	0.04850	±0.00038	83-Bi-214	^{226}Ra decay chain
777.921	±0.020	0.0428	±0.0008	42-Mo-99/43-Tc-99m	
778.9045	±0.0024	0.1296	±0.0006	63-Eu-152	β^-
785.37	±0.09	0.0111	±0.0001	83-Bi-212	^{228}Th decay chain
786.272	±0.022	0.00054	±0.00001	91-Pa-234m	Daughter of ^{234}Th (^{238}U)
795.83	±0.03	0.855	±0.003	55-Cs-134	
801.945	±0.004	0.0870	±0.0003	55-Cs-134	
806.185	±0.011	0.01255	±0.00011	83-Bi-214	^{226}Ra decay chain
810.286	±0.004	0.573	±0.011	67-Ho-166m	
810.759	±0.002	0.9945	±0.0001	27-Co-58	
818.0244	±0.0018	0.0733	±0.0004	47-Ag-110m	with ^{110}Ag
830.565	±0.004	0.0972	±0.0018	67-Ho-166m	
833.5324	±0.0021	0.059	±0.005	31-Ga-66	
834.838	±0.005	0.999746	±0.000011	25-Mn-54	
846.7638	±0.0019	0.9885	±0.0003	25-Mn-56	
846.7638	±0.0019	0.999399	±0.000023	27-Co-56	
860.56	±0.03	0.0448	±0.0004	81-Tl-208	per ^{228}Th decay–^{228}Th decay chain
867.380	±0.003	0.04241	±0.00023	63-Eu-152	ε
871.114	±0.003	0.99892	±0.00003	41-Nb-94	
873.1834	±0.0023	0.1217	±0.0012	63-Eu-154	
873.49	±0.05	0.00435	±0.00008	44-Ru-106/45-Rh-106	
884.6781	±0.0013	0.740	±0.012	47-Ag-110m	with ^{110}Ag
889.271	±0.002	0.999833	±0.000005	21-Sc-46	
898.036	±0.004	0.9390	±0.0023	39-Y-88	
934.061	±0.012	0.03074	±0.00025	83-Bi-214	^{226}Ra decay chain
937.483	±0.003	0.3451	±0.0027	47-Ag-110m	with ^{110}Ag
950.988	±0.004	0.02744	±0.00019	67-Ho-166m	
964.072	±0.018	0.1462	±0.0006	63-Eu-152	ε
977.363	±0.004	0.01422	±0.00007	27-Co-56	
996.262	±0.006	0.1050	±0.0010	63-Eu-154	
1001.025	±0.022	0.00832	±0.00010	91-Pa-234m	Daughter of ^{234}Th (^{238}U)
1004.725	±0.007	0.1785	±0.0017	63-Eu-154	
1037.8333	±0.0024	0.1403	±0.0005	27-Co-56	
1039.220	±0.003	0.37	±0.03	31-Ga-66	
1050.41	±0.06	0.01488	±0.00022	44-Ru-106/45-Rh-106	
1063.656	±0.003	0.7458	±0.0049	83-Bi-207	

TABLE 4. RECOMMENDED GAMMA RAY ENERGIES AND EMISSION PROBABILITIES ORDERED BY ENERGY (cont.)

Energy (keV)		Emission probability per decay		Nuclide	Comments
E_γ	Uncertainty	P_γ	Uncertainty		
1077.34	±0.05	0.0322	±0.0003	31-Ga-68	
1085.837	±0.010	0.1013	±0.0006	63-Eu-152	ε
1087.6842	±0.0007	0.00159	±0.00003	79-Au-198	
1089.737	±0.005	0.01731	±0.00010	63-Eu-152	β^-
1099.245	±0.003	0.5659	±0.0021	26-Fe-59	
1112.076	±0.003	0.1340	±0.0006	63-Eu-152	ε
1115.539	±0.002	0.5060	±0.0022	30-Zn-65	
1120.287	±0.010	0.1478	±0.0011	83-Bi-214	^{226}Ra decay chain
1120.537	±0.003	0.99986	+0.00004 –0.00036	21-Sc-46	
1128.07	±0.05	0.00399	±0.00006	44-Ru-106/45-Rh-106	
1155.19	±0.02	0.01624	±0.00014	83-Bi-214	^{226}Ra decay chain
1173.228	±0.003	0.9985	±0.0003	27-Co-60	
1175.0878	±0.0022	0.02249	±0.00009	27-Co-56	
1212.948	±0.011	0.01415	±0.00009	63-Eu-152	ε
1238.110	±0.012	0.05785	±0.00045	83-Bi-214	^{226}Ra decay chain
1238.2736	±0.0022	0.6641	±0.0016	27-Co-56	
1246.121	±0.004	0.00862	±0.00008	63-Eu-154	
1274.429	±0.004	0.349	±0.003	63-Eu-154	
1274.537	±0.003	0.99940	±0.00014	11-Na-22	
1280.96	±0.02	0.01425	±0.00012	83-Bi-214	^{226}Ra decay chain
1291.590	±0.006	0.4321	±0.0025	26-Fe-59	
1299.142	±0.008	0.01632	±0.00009	63-Eu-152	β^-
1332.492	±0.004	0.999826	±0.000006	27-Co-60	
1333.112	±0.005	0.0117	±0.0009	31-Ga-66	
1345.77	±0.16	0.00475	±0.00010	29-Cu-64	
1360.196	±0.004	0.04280	±0.00013	27-Co-56	
1365.186	±0.004	0.03017	±0.00012	55-Cs-134	
1368.626	±0.005	0.999935	±0.000005	11-Na-24	
1377.669	±0.012	0.03954	±0.00033	83-Bi-214	^{226}Ra decay chain
1379.437	±0.006	0.00933	±0.00016	67-Ho-166	
1384.2931	±0.0020	0.247	±0.005	47-Ag-110m	with ^{110}Ag
1401.516	±0.014	0.01324	±0.00011	83-Bi-214	^{226}Ra decay chain
1407.993	±0.007	0.02369	±0.00019	83-Bi-214	^{226}Ra decay chain
1408.013	±0.003	0.2085	±0.0009	63-Eu-152	ε
1418.754	±0.005	0.0061	±0.0005	31-Ga-66	
1460.822	±0.006	0.1066	±0.0013	19-K-40	
1475.7792	±0.0023	0.0403	±0.0005	47-Ag-110m	with ^{110}Ag
1489.148	±0.003	0.00296	±0.00005	59-Pr-144	per ^{144}Ce decay
1505.0280	±0.0020	0.1316	±0.0016	47-Ag-110m	with ^{110}Ag

TABLE 4. RECOMMENDED GAMMA RAY ENERGIES AND EMISSION PROBABILITIES ORDERED BY ENERGY (cont.)

Energy (keV)		Emission probability per decay		Nuclide	Comments
E_γ	Uncertainty	P_γ	Uncertainty		
1508.158	±0.007	0.0055	±0.0004	31-Ga-66	
1509.217	±0.008	0.02108	±0.00021	83-Bi-214	^{226}Ra decay chain
1562.294	±0.018	0.0121	±0.0003	47-Ag-110m	with ^{110}Ag
1581.833	±0.007	0.00186	±0.00004	67-Ho-166	
1596.4804	±0.0028	0.01783	±0.00017	63-Eu-154	
1620.74	±0.01	0.0151	±0.0003	83-Bi-212	^{228}Th decay chain
1661.316	±0.013	0.01037	±0.00010	83-Bi-214	^{226}Ra decay chain
1662.439	±0.006	0.00118	±0.00005	67-Ho-166	
1729.640	±0.012	0.02817	±0.00023	83-Bi-214	^{226}Ra decay chain
1764.539	±0.015	0.1517	±0.0012	83-Bi-214	^{226}Ra decay chain
1770.228	±0.009	0.0687	±0.0003	83-Bi-207	
1771.327	±0.003	0.1545	±0.0004	27-Co-56	
1810.726	±0.004	0.269	±0.004	25-Mn-56	
1836.052	±0.013	0.9938	±0.0003	39-Y-88	
1847.420	±0.025	0.02000	±0.00018	83-Bi-214	^{226}Ra decay chain
1898.823	±0.008	0.0039	±0.0003	31-Ga-66	
1918.329	±0.005	0.0199	±0.0016	31-Ga-66	
2015.176	±0.005	0.03017	±0.00014	27-Co-56	
2034.752	±0.005	0.07741	±0.00013	27-Co-56	
2113.092	±0.006	0.142	±0.003	25-Mn-56	
2118.536	±0.008	0.01148	±0.00011	83-Bi-214	^{226}Ra decay chain
2185.645	±0.005	0.00680	±0.00018	59-Pr-144	per ^{144}Ce decay
2189.616	±0.006	0.053	±0.004	31-Ga-66	
2204.071	±0.021	0.0489	±0.0010	83-Bi-214	^{226}Ra decay chain
2422.525	±0.007	0.0188	±0.0015	31-Ga-66	
2447.673	±0.010	0.01536	±0.00015	83-Bi-214	^{226}Ra decay chain
2523.06	±0.05	0.0102	±0.0002	25-Mn-56	
2598.438	±0.004	0.1696	±0.0004	27-Co-56	
2614.511	±0.010	0.3585	±0.0007	81-Tl-208	per ^{228}Th decay–^{228}Th decay chain
2751.835	±0.005	0.227	±0.018	31-Ga-66	
2754.007	±0.011	0.99872	±0.00008	11-Na-24	
3009.559	±0.004	0.01038	±0.00019	27-Co-56	
3201.930	±0.011	0.03203	±0.00013	27-Co-56	
3228.800	±0.006	0.0151	±0.0012	31-Ga-66	
3253.402	±0.005	0.0787	±0.0003	27-Co-56	
3272.978	±0.006	0.01855	±0.00009	27-Co-56	
3380.850	±0.006	0.0146	±0.0012	31-Ga-66	
3422.040	±0.008	0.0086	±0.0007	31-Ga-66	
3451.119	±0.004	0.00942	±0.00006	27-Co-56	

TABLE 4. RECOMMENDED GAMMA RAY ENERGIES AND EMISSION PROBABILITIES ORDERED BY ENERGY (cont.)

Energy (keV)		Emission probability per decay		Nuclide	Comments
E_γ	Uncertainty	P_γ	Uncertainty		
3791.004	±0.008	0.0109	±0.0009	31-Ga-66	
4085.853	±0.009	0.0127	±0.0010	31-Ga-66	
4295.187	±0.010	0.038	±0.003	31-Ga-66	
4461.202	±0.009	0.0084	±0.0007	31-Ga-66	
4806.007	±0.009	0.0186	±0.0015	31-Ga-66	

3. HIGH ENERGY GAMMA RAY STANDARDS

Data uncertainties are defined as standard deviations corresponding to the 1σ confidence level. These uncertainties are expressed in terms of the last digits of the recommended value, for example:

12.3(4) means 12.3 ± 0.4, and 43.2(15) means 43.2 ± 1.5

Details of references within the tables can be found in Volume 2, Annex III of this report.

TABLE 5. ^{66}Ga decay: Recommended absolute emission probabilities per decay and relative probabilities.

TABLE 6. Recommended thermal capture cross-sections ($\sigma_{\gamma i}$) for selected γ rays from the ^{14}N(n, γ)^{15}N reaction, and corresponding γ ray emission probabilities ($P_{\gamma i}$(abs)) per neutron capture.

TABLE 7. Recommended thermal capture cross-sections ($\sigma_{\gamma i}$) for selected γ rays from the ^{35}Cl(n, γ) ^{36}Cl reaction, and corresponding γ ray emission probabilities ($P_{\gamma i}$(abs)) per neutron capture.

TABLE 8. Recommended thermal capture cross-sections ($\sigma_{\gamma i}$) for selected γ rays from the ^{48}Ti(n, γ)^{49}Ti reaction, and corresponding γ ray emission probabilities ($P_{\gamma i}$(abs)) per neutron capture.

TABLE 9. Emission probabilities of γ rays from thermal neutron capture in natural titanium relative to the 1381.7 keV γ ray.

TABLE 10. Emission probabilities of γ rays from thermal neutron capture by natural chromium relative to the 835 keV γ ray.

TABLE 11. Evaluated proton capture cross-sections ($\sigma_{\gamma i}$) for selected γ_i rays from the ^{14}N(p, γ)^{15}O reaction at resonance energy E_p = 1058 keV, and corresponding emission probabilities $P_{\gamma i}$ (per proton capture).

TABLE 12. Evaluated proton capture cross-sections ($\sigma_{\gamma i}$) for selected γ_i rays from the ^{23}Na(p, γ)^{24}Mg reaction at resonance energy E_p = 1417 keV, and corresponding emission probabilities $P_{\gamma i}$ (per proton capture).

TABLE 13. Evaluated proton capture cross-sections ($\sigma_{\gamma i}$) for selected γ_i rays from the ^{27}Al(p, γ)^{28}Si reaction at resonance energy E_p = 992 keV, and corresponding emission probabilities $P_{\gamma i}$ (per proton

TABLE 5. ^{66}Ga DECAY: RECOMMENDED ABSOLUTE EMISSION PROBABILITIES PER DECAY AND RELATIVE PROBABILITIES

E_γ (keV)	$P_{\gamma i}$ *	$P_{\gamma i}/P_{\gamma 1039keV}$
686.080(6)	0.00252(22)	0.00681(20)
833.5324(21)	0.059(5)	0.1595(6)
1039.220(3)	0.37(3)	1.000(3)
1333.112(5)	0.0117(9)	0.03162(13)
1418.754(5)	0.0061(5)	0.01649(8)
1508.158(7)	0.0055(4)	0.01486(7)
1898.823(8)	0.0039(3)	0.01054(8)
1918.329(5)	0.0199(16)	0.05378(23)
2189.616(6)	0.053(4)	0.1432(6)
2422.525(7)	0.0188(15)	0.05081(24)
2751.835(5)	0.227(18)	0.6135(26)
3228.800(6)	0.0151(12)	0.04081(22)
3380.850(6)	0.0146(12)	0.03946(23)
3422.040(8)	0.0086(7)	0.02324(16)
3432.309(7)	0.00288(24)	0.00778(10)
3766.850(9)	0.00149(13)	0.00403(15)
3791.004(8)	0.0109(9)	0.02946(24)
4085.853(9)	0.0127(10)	0.03432(20)
4295.187(10)	0.038(3)	0.1027(8)
4461.202(9)	0.0084(7)	0.0227(3)
4806.007(9)	0.0186(15)	0.0503(3)

* Uncertainties of $P_{\gamma i}$ are relative to the uncertainty of $P_{\gamma 1039keV}$.

TABLE 6. RECOMMENDED THERMAL CAPTURE CROSS-SECTIONS ($\sigma_{\gamma i}$) FOR SELECTED γ RAYS FROM THE $^{14}N(n, \gamma)^{15}N$ REACTION, AND CORRESPONDING γ RAY EMISSION PROBABILITIES ($P_{\gamma i}$(abs)) PER NEUTRON CAPTURE

$E_{\gamma i}$ (keV)	$P_{\gamma i}$(abs)				$\sigma_{\gamma i}$ (mb)
	Kennett et al. (1986)	Jurney et al. (1997)	UWM	LWM recommended	
1678.293(25)	0.0723(18)	0.0796(9)*	0.076(4)	0.076(4)	6.1(3)
1681.228(50)	0.0154(15)	0.0164(4)	0.0159(5)	0.0163(4)	1.31(3)
1884.780(18)	0.1866(25)	0.1877(20)	0.1872(20)	0.1873(20)	15.04(20)
1999.679(27)	0.0399(9)	0.0411(5)	0.0405(6)	0.0408(5)	3.28(5)
2520.443(22)	0.0579(7)	0.0558(9)	0.0569(11)	0.0571(10)	4.59(8)
2830.805(36)	0.0173(3)	0.0171(4)	0.0172(3)	0.0172(3)	1.38(3)
3531.982(20)	0.0924(9)	0.0894(11)	0.0909(15)	0.0912(15)	7.32(13)
3677.737(17)	0.1489(15)	0.1452(16)	0.1471(19)	0.1472(19)	11.82(18)
4508.783(14)	0.1654(17)	0.1671(17)	0.1663(17)	0.1663(17)	13.35(17)
5269.162(17)	0.3003(20)	0.2986(30)	0.2995(20)	0.2998(20)	24.07(24)
5297.826(20)	0.2131(18)	0.2123(22)	0.2127(18)	0.2128(18)	17.08(19)
5533.391(18)	0.1975(21)	0.1958(21)	0.1967(21)	0.1967(21)	15.80(21)
5562.059(21)	0.1065(12)	0.1068(12)	0.1067(12)	0.1067(12)	8.57(12)
6322.433(16)	0.1867(14)	0.1823(22)	0.1845(22)	0.1854(20)	14.89(20)
7298.980(32)	0.0973(9)	0.0939(12)	0.0956(17)	0.0961(16)	7.72(14)
8310.156(39)	0.0422(5)	0.0412(9)	0.0417(5)	0.0420(5)	3.37(5)
9148.95(9)	0.0148(6)	0.0148(6)	0.0148(6)	0.0148(6)	1.19(5)
10829.110(59)	0.1365(21)	0.143(6)	0.1398(33)	0.1372(21)	11.02(19)

* Uncertainty adjusted to (18) based on chi-squared test.

TABLE 7. RECOMMENDED THERMAL CAPTURE CROSS-SECTIONS ($\sigma_{\gamma i}$) FOR SELECTED γ RAYS FROM THE $^{35}Cl(n, \gamma)^{36}Cl$ REACTION, AND CORRESPONDING γ RAY EMISSION PROBABILITIES ($P_{\gamma i}$(abs)) PER NEUTRON CAPTURE

$E_{\gamma i}$ (keV)	$P_{\gamma i}$(rel)[a]					$P_{\gamma i}$(abs)	$\sigma_{\gamma i}$ (b)
	Coceva et al. (1996)	Venturini and Pecequilo (1997)	Raman et al. (2000)	Molnár et al. (2004)	LWM recommended		
517.07006(23)	125.32(722)	—	117.82(248)	119.83(78)	119.71(78)	0.2316(18)	10.10(13)
786.2970(4)	54.25(180)	—	51.49(149)	54.03(47)	53.83(51)	0.1042(11)	4.54(7)
788.4230(4)	84.17(186)	—	81.19(198)	85.63(78)	84.9(10)	0.1643(18)	7.16(11)
1131.244(12)	9.86(29)	—	—	9.90(5)	9.90(5)	0.0192(1)	0.837(10)
1164.8579(5)	140.28(371)	—	134.65(248)	140.86(62)	140.5(10)	0.2719(17)	11.85(15)
1601.068(17)	17.97(46)	—	19.01(30)	19.13(11)	19.06(18)	0.0369(4)	1.61(2)
1951.1278(14)	100(3)	100(3)	100(2)	100.0(6)	100.0(6)	0.1935(12)	8.44(10)
1959.343(8)	64.78(144)	67.16(200)	64.36(149)	64.76(47)	64.84(47)	0.1255(10)	5.51(7)
2676.31(3)	8.11(20)	7.91(25)	—	8.42(6)	8.37(10)	0.0162(2)	0.706(11)
2863.82(3)	29.76(57)	32.64(70)	27.92(45)	28.74(16)[b]	29.09(76)	0.0563(14)	2.45(7)
2975.25(4)	5.39(13)	5.92(15)	—	5.95(7)[c]	5.78(18)	0.0112(4)	0.488(18)
3061.83(4)	18.16(34)	18.21(40)	17.08(30)	17.81(11)	17.79(16)	0.0344(3)	1.500(21)
4440.38(5)	5.40(12)	5.50(13)	—	5.95(6)[d]	5.70(25)	0.0110(5)	0.480(22)
4979.72(5)	18.65(50)	18.61(40)	—	19.47(16)	19.29(24)	0.0373(5)	1.63(3)
5517.21(6)	8.71(22)	8.46(20)	—	8.84(7)	8.79(8)	0.0170(2)	0.741(12)
5715.20(6)	27.39(77)	27.61(55)	26.39(50)	28.74(26)[e]	27.88(86)	0.0539(17)	2.35(8)
5902.69(6)	5.69(16)	—	—	5.87(7)	5.84(7)	0.0113(1)	0.493(7)
6110.80(6)	106.14(335)	101.00(199)	102.97(198)	104.22(94)	103.66(94)	0.2006(20)	8.75(13)
6619.57(7)	40.38(83)	40.45(95)	37.57(74)	39.98(36)	39.71(53)	0.0768(11)	3.35(6)
6627.78(7)	24.19(57)	24.63(65)	21.98(45)	23.17(26)[f]	23.20(49)	0.0449(10)	1.96(5)
6977.79(7)	11.81(33)	11.24(25)	11.09(25)	11.71(16)	11.50(16)	0.0223(3)	0.972(17)
7413.92(8)	54.25(124)	51.24(109)	49.50(124)	52.00(73)	51.80(80)	0.1002(16)	4.37(8)

TABLE 7. RECOMMENDED THERMAL CAPTURE CROSS-SECTIONS ($\sigma_{\gamma i}$) FOR SELECTED γ RAYS FROM THE $^{35}Cl(n, \gamma)^{36}Cl$ REACTION, AND CORRESPONDING γ RAY EMISSION PROBABILITIES ($P_{\gamma i}$(abs)) PER NEUTRON CAPTURE (cont.)

$E_{\gamma i}$ (keV)	$P_{\gamma i}$(rel)[a]					$P_{\gamma i}$(abs)	$\sigma_{\gamma i}$ (b)
	Coceva et al. (1996)	Venturini and Pecequilo (1997)	Raman et al. (2000)	Molnár et al. (2004)	LWM recommended		
7790.28(8)	42.86(98)	41.04(95)	40.84(109)	42.01(52)	41.83(52)	0.0809(11)	3.53(6)
8578.53(9)	14.13(29)	13.73(35)	13.51(35)	13.95(21)	13.89(21)	0.0269(4)	1.173(21)

[a] Relative to the 1951.1 keV γ ray.
[b] Uncertainty adjusted to (32) based on chi-squared test.
[c] Uncertainty adjusted to (10) based on chi-squared test.
[d] Uncertainty adjusted to (9) based on chi-squared test.
[e] Uncertainty adjusted to (33) based on chi-squared test.
[f] Uncertainty adjusted to (31) based on chi-squared test.

TABLE 8. RECOMMENDED THERMAL CAPTURE CROSS-SECTIONS ($\sigma_{\gamma i}$) FOR SELECTED γ RAYS FROM THE $^{48}Ti(n, \gamma)^{49}Ti$ REACTION, AND CORRESPONDING γ RAY EMISSION PROBABILITIES ($P_{\gamma i}$(abs)) PER NEUTRON CAPTURE

$E_{\gamma i}$ (keV)	$\sigma_{\gamma i}$ (b)	$P_{\gamma i}$
341.69(3)	2.13(5)	0.250(2)
1381.72(3)	7.33(25)	0.862(21)
1498.63(3)	0.419(15)	0.0493(13)
1585.95(3)	0.88(3)	0.1029(30)
1761.96(3)	0.459(17)	0.0540(16)
4881.32(5)	0.387(10)	0.0455(5)
6418.38(7)	2.62(7)	0.308(3)
6555.83(7)	0.436(11)	0.0513(5)
6760.06(7)	3.97(10)	0.467(4)

TABLE 9. EMISSION PROBABILITIES OF γ RAYS FROM THERMAL NEUTRON CAPTURE IN NATURAL TITANIUM RELATIVE TO THE 1381.7 keV γ RAY

$E_{\gamma i}$ (keV)	Target	$P_{\gamma i}/P_{\gamma 1382keV}$
137.46(3)	^{48}Ti	0.01218(10)
341.69(3)	^{48}Ti	0.3786(14)
983.50(4)	^{47}Ti	0.02275(19)
1381.72(3)	^{48}Ti	1.000(4)
1498.63(3)	^{48}Ti	0.0570(3)
1553.79(4)	^{49}Ti	0.01882(23)
1585.95(3)	^{48}Ti	0.1178(6)
1761.96(3)	^{48}Ti	0.0600(4)
1793.47(3)	^{48}Ti	0.02928(24)
2943.12(4)	^{48}Ti	0.01221(13)
3026.76(4)	^{48}Ti	0.02674(24)
3475.62(4)	^{48}Ti	0.01950(18)
3733.75(5)	^{48}Ti	0.01612(18)
3920.44(5)	^{48}Ti	0.01629(18)
4881.32(5)	^{48}Ti	0.0559(5)
4966.74(5)	^{48}Ti	0.0365(4)
6418.38(7)	^{48}Ti	0.343(3)
6555.83(7)	^{48}Ti	0.0574(7)
6760.06(7)	^{48}Ti	0.518(5)

TABLE 10. EMISSION PROBABILITIES OF γ RAYS FROM THERMAL NEUTRON CAPTURE BY NATURAL CHROMIUM RELATIVE TO THE 835 keV γ RAY

$E_{\gamma i}$ (keV)	Target	$P_{\gamma i}/P_{835keV}$
564.35(6)	^{52}Cr	0.0819(4)
749.32(6)	^{50}Cr	0.4137(17)
835.03(6)	^{53}Cr	1.000(4)
1150.06(5)	^{50}Cr	0.01525(11)
1784.69(5)	^{53}Cr	0.1284(6)
1899.25(5)	^{50}Cr	0.0619(4)
2239.16(5)	^{53}Cr	0.1354(7)
2321.09(5)	^{52}Cr	0.0968(5)
2376.84(5)	^{50}Cr	0.02588(13)
2670.20(5)	^{52}Cr	0.02006(12)
3616.88(8)	^{52}Cr	0.01886(11)
3719.77(6)	^{53}Cr	0.04674(24)
4322.43(8)	^{52}Cr	0.02096(12)
5268.92(12)	^{52}Cr	0.0333(3)
5618.13(11)	^{52}Cr	0.0949(8)
5998.63(11)	^{53}Cr	0.0569(5)
6135.39(13)	^{50}Cr	0.0466(10)
6644.47(14)	^{53}Cr	0.1229(11)
7098.84(19)	^{53}Cr	0.0963(9)
7361.99(17)	^{50}Cr	0.0643(6)
7374.68(17)	^{52}Cr	0.0557(5)
7938.65(18)	^{52}Cr	0.294(3)
8511.55(20)	^{50}Cr	0.1555(21)
8882.88(22)	^{53}Cr	0.562(7)
9717.5(3)	^{53}Cr	0.200(3)

TABLE 11. EVALUATED PROTON CAPTURE CROSS-SECTIONS ($\sigma_{\gamma i}$) FOR SELECTED γ_i RAYS FROM THE $^{14}N(p, \gamma)^{15}O$ REACTION AT RESONANCE ENERGY E_p = 1058 keV, AND CORRESPONDING EMISSION PROBABILITIES $P_{\gamma i}$ (PER PROTON CAPTURE)

$E_{\gamma i}$ (keV)	$\sigma_{\gamma i}$ (mb)	$P_{\gamma i}$
3042.8(6)	0.290(50)	0.422(5)
5239.9(3)	0.299(52)	0.434(6)
8281.5(5)	0.366(62)	0.5320(25)

TABLE 12. EVALUATED PROTON CAPTURE CROSS-SECTIONS ($\sigma_{\gamma i}$) FOR SELECTED γ_i RAYS FROM THE $^{23}Na(p, \gamma)^{24}Mg$ REACTION AT RESONANCE ENERGY E_p = 1417 keV, AND CORRESPONDING EMISSION PROBABILITIES $P_{\gamma i}$ (PER PROTON CAPTURE)

$E_{\gamma i}$ (keV)	$\sigma_{\gamma i}$ (mb)	$P_{\gamma i}$
2754.028	71(28)	0.94(1)
8925.55	70(28)	0.93(1)

TABLE 13. EVALUATED PROTON CAPTURE CROSS-SECTIONS ($\sigma_{\gamma i}$) FOR SELECTED γ_i RAYS FROM THE $^{27}Al(p, \gamma)^{28}Si$ REACTION AT RESONANCE ENERGY E_p = 992 keV, AND CORRESPONDING EMISSION PROBABILITIES $P_{\gamma i}$ (PER PROTON CAPTURE)

$E_{\gamma i}$ (keV)	$\sigma_{\gamma i}$ (mb)	$P_{\gamma i}$
1778.969(12)	77(17)	0.948(15)
10762.9	62(14)	0.766(15)

4. ANGULAR CORRELATION COEFFICIENTS

^{24}Na

Selected γ rays in transitions between levels
$4^+ \rightarrow 2^+ \rightarrow 0^+$

E_γ (keV)	P_γ per decay	Multipolarity
2754.0	0.99872 (8)	E2(+M3)
1368.6	0.999935 (5)	E2

Angular correlation coefficients:

$A_{22} = 0.10204$
$A_{44} = 0.00907$

^{46}Sc

Selected γ rays in transitions between levels
$4^+ \rightarrow 2^+ \rightarrow 0^+$

E_γ (keV)	P_γ per decay	Multipolarity
1120.5	0.99986 (+4 –36)	E2
889.3	0.999833 (5)	E2

Angular correlation coefficients:

$A_{22} = 0.10204$
$A_{44} = 0.00907$

^{60}Co

Selected γ rays in transitions between levels
$4^+ \rightarrow 2^+ \rightarrow 0^+$

E_γ (keV)	P_γ per decay	Multipolarity
1173.2	0.9985 (3)	E2(+M3)
1332.5	0.999826 (6)	E2

Angular correlation coefficients:

$A_{22} = 0.10204$
$A_{44} = 0.00907$

^{66}Ga

Selected γ rays in transitions between levels
$1^+ \rightarrow 2^+ \rightarrow 0^+$

E_γ (keV)	P_γ per decay	Multipolarity
2751.8	0.227 (18)	M1+E2
1039.2	0.37 (3)	E2

Angular correlation coefficients:

$A_{22} = –0.24552$
$A_{44} = –0.00001$

^{75}Se

Selected γ rays in transitions between levels
$5/2^+ \rightarrow 3/2^- \rightarrow 3/2^-$

E_γ (keV)	P_γ per decay	Multipolarity
136.0	0.582 (7)	E1
264.7	0.589 (3)	M1+E2

Angular correlation coefficients:

$A_{22} = –0.03312$
$A_{44} = 0.0000$

^{88}Y

Selected γ rays in transitions between levels
$3^- \rightarrow 2^+ \rightarrow 0^+$

E_γ (keV)	P_γ per decay	Multipolarity
898.0	0.9390 (23)	E1
1836.1	0.9938 (3)	E2

Angular correlation coefficients:

$A_{22} = –0.0714$
$A_{44} = 0.0000$

^{94}Nb

Selected γ rays in transitions between levels
$4^+ \rightarrow 2^+ \rightarrow 0^+$

E_γ (keV)	P_γ per decay	Multipolarity
702.6	0.99815 (6)	E2
871.1	0.99892 (3)	E2

Angular correlation coefficients:

$A_{22} = 0.10204$
$A_{44} = 0.00907$

^{111}In

Selected γ rays in transitions between levels
$7/2^+ \rightarrow 5/2^+ \rightarrow 1/2^+$

E_γ (keV)	P_γ per decay	Multipolarity
171.3	0.9066 (25)	M1 + E2
245.4	0.9409 (6)	E2

Angular correlation coefficients:

$A_{22} = -0.0714$
$A_{44} = 0.0000$

^{134}Cs

Selected γ rays in transitions between levels
$4^+ \rightarrow 2^+ \rightarrow 0^+$

E_γ (keV)	P_γ per decay	Multipolarity
795.8	0.855 (3)	E2
604.7	0.97650 (18)	E2

Angular correlation coefficients:

$A_{22} = 0.10204$
$A_{44} = 0.00907$

^{152}Eu

Selected γ rays in transitions between levels
$3^- \rightarrow 2^+ \rightarrow 0^+$

E_γ (keV)	P_γ per decay	Multipolarity
778.9	0.1296 (6)	E1(+E2)
344.3	0.2658 (12)	E2

Angular correlation coefficients:

$A_{22} = -0.0730$
$A_{44} = 0.0000$

^{207}Bi

Selected γ rays in transitions between levels
$13/2^+ \rightarrow 5/2^- \rightarrow 1/2^-$

E_γ (keV)	P_γ per decay	Multipolarity
1063.7	0.7458 (49)	M4 + E5
569.7	0.9776 (3)	E2

Angular correlation coefficients:

$A_{22} = 0.22078$
$A_{44} = -0.01798$

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Various groups around the world are engaged in the compilation and evaluation of decay data for either all known or specific radionuclides. Many evaluators operate independently and recommend slightly different values for the same parameter. Even small deviations in the recommended data can have a significant impact on the definition of the decay characteristics of radionuclides used as standards in detector efficiency calibrations and various applications. High quality decay data are essential for the efficiency calibration of X and gamma ray detectors that are used to quantify the radionuclidic content of a sample by determining the intensities of any resulting X and gamma rays. A major objective of the IAEA nuclear data programme is to promote improvements in the quality of nuclear data used in science and technology. This report presents the results of a coordinated research project on X Ray and Gamma Ray Decay Data Standards for Detector Calibration and Other Applications. Recommended half-lives and X and gamma ray emission probabilities are listed in Volume 1 of this report for a carefully selected set of radionuclides and nuclear reactions that are suitable for detector efficiency calibration and other applications. The recommendations and report of this work are published in two parts, Recommended Decay Data, High Energy Gamma Ray Standards and Angular Correlation Coefficients (Volume 1); and Data Selection, Assessment and Evaluation Procedures (Volume 2).

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