

Update of the BIPM comparison BIPM.RI(II)-K1.Sn-113 of activity measurements of the radionuclide ^{113}Sn to include the 2010 results of the PTB (Germany) and the LNE-LNHB (France), and the 2011 result of the CIEMAT (Spain)

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Abstract

Since 1975, seven national metrology institutes (NMI) have submitted eleven samples of known activity of ^{113}Sn to the International Reference System (SIR) for activity comparison at the Bureau International des Poids et Mesures (BIPM), with comparison identifier BIPM.RI(II)-K1.Sn-113. The values of the activity submitted were between about 0.7 MBq and 22 MBq. The present primary standardization results for the PTB, Germany and the LNE-LNHB, France, replace their earlier results of 1989 and 1992, respectively. A key comparison reference value (KCRV) has been evaluated for the first time for ^{113}Sn . There are only three results remaining in the BIPM.RI(II)-K1.Sn-113 comparison, all the previously published ones being outdated. The degrees of equivalence between each of these three equivalent activities measured in the SIR and the KCRV have been calculated and the results are given in the form of a table. A graphical presentation is also given.

1. Introduction

The SIR for activity measurements of γ -ray-emitting radionuclides was established in 1976. Each national metrology institute (NMI) may request a standard ampoule from the BIPM that is then filled with 3.6 g of the radioactive solution. For radioactive gases, a different standard ampoule is used. Each NMI completes a submission form that details the standardization method used to determine the absolute activity of the radionuclide and the full uncertainty budget for the evaluation. The ampoules are sent to the BIPM where they are compared with standard sources of ^{226}Ra using pressurized ionization chambers. Details of the SIR method, experimental set-up and the determination of the equivalent activity, A_e , are all given in [1].

From its inception until 31 December 2014, the SIR has measured 985 ampoules to give 740 independent results for 67 different radionuclides. The SIR makes it possible for national laboratories to check the reliability of their activity measurements at any time. This is achieved by the determination of the equivalent activity of the radionuclide and by comparison of the result with the key comparison

reference value determined from the results of primary standardizations. These comparisons are described as BIPM ongoing comparisons and the results form the basis of the BIPM key comparison database (KCDB) of the Comité International des Poids et Mesures Mutual Recognition Arrangement (CIPM MRA) [2]. The comparison described in this report is known as the BIPM.RI(II)-K1.Sn-113 key comparison and includes results published previously [3].

2. Participants

In addition to the two ampoules submitted by the PTB and the LNE-LNHB in 2010, which replace their earlier SIR submissions, the CIEMAT has submitted an ampoule for inclusion in this comparison. The laboratory details are given in Table 1, with the earlier submissions being taken from [3]. In cases where the laboratory has changed its name since the original submission, both the earlier and the current acronyms are given, as it is the latter that are used in the KCDB. The dates of measurement in the SIR given in Table 1 are used in the KCDB and all references in this report.

Table 1. Details of the participants in the BIPM.RI(II)-K1.Sn-113

NMI	Former acronym	Full name	Country	Regional metrology organization	Date of measurement at the BIPM YYYY-MM-DD
NIST	NBS	National Institute of Standards and Technology	United States	SIM	1975-09-15 1980-10-24
CMI-IIR	UVVVR	Český Metrologický Institut/Czech Metrological Institute, Inspectorate for Ionizing Radiation	Czech Republic	EUROMET	1981-12-16
MKEH	–	Országos Mérésügyi Hivatal	Hungary	EUROMET	1988-09-19
PTB	–	Physikalisch-Technische Bundesanstalt	Germany	EUROMET	1989-04-12 2010-03-31
LNE-LNHB	LPRI	Laboratoire national de métrologie et d'essais - Laboratoire national Henri Becquerel	France	EUROMET	1992-02-21 2010-08-02
CNEA	–	Comision Nacional de Energia Atomica	Argentina	SIM	1994-02-28
CIEMAT	–	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas	Spain	EURAMET	2011-12-07

3. NMI standardization methods

Each NMI that submits ampoules to the SIR has measured the activity either by a primary standardization method or by using a secondary method, for example a calibrated ionization chamber. In the latter case, the traceability of the calibration needs to be clearly identified to ensure that appropriate correlations are taken into account.

A brief description of the standardization methods used by the laboratories, the activities submitted, the relative standard uncertainties ($k = 1$) and the half-life used by the participants are given in Table 2. The uncertainty budgets for the three new submissions are given in Appendix 1 attached to this report; no detailed uncertainty budgets have been submitted for the earlier submissions. The list of acronyms used to summarize the methods is given in Appendix 2.

The half-life used by the BIPM is 114.9(1) days [4] which is in agreement within two standard uncertainties with the value evaluated by the DDEP [5]. This difference in half-life value would result in a relative change of only 5×10^{-4} for the largest time difference noted between a reference date and the measurement at the BIPM (about 50 days for the CIEMAT). Consequently, the equivalent activity results in Table 4 have not been modified.

Details regarding the solutions submitted are shown in Table 3, including any impurities, when present, as identified by the laboratories. When given, the standard uncertainties on the evaluations are shown. The BIPM standard method for evaluating the activity of impurities using a calibrated Ge(Li) spectrometer is described in [7]. The CCRI(II) agreed in 1999 [8] that this method should be followed according to the protocol described in [9] when an NMI makes such a request or when there appear to be discrepancies. Impurity measurement was carried out for the LNE-LNHB, 2010, solution and no impurity other than those reported in Table 3 could be identified. A first order evaluation of the activity ratio of the $^{110\text{m}}\text{Ag}$ impurity was in agreement within $k = 2$ with the LNE-LNHB value. However, no impurity measurement has needed to be carried out at the BIPM for the PTB, 2010 and CIEMAT, 2011 submissions.

Table 2. Standardization methods of the participants for ^{113}Sn

NMI	Method used and acronym (see Appendix 2)	Half-life / d	Activity A_i / kBq	Reference date YYYY-MM-DD	Relative standard uncertainty / 10^{-2} by method of evaluation	
					A	B
NIST	Pressurized IC * 4P-IC-GR-00-00-00	[4]	7 891	1975-07-01 17 h UT	2.9	
		–	4 738 [†]	1980-10-15 19 h UT	0.01	1.07
CMI-IIR	$4\pi\epsilon_c$ -x coincidence 4P-PC-CE-NA-XR-CO and $4\pi\epsilon_c$ counting 4P-PC-CE-00-00-00	115.1	3 922	1981-11-24 11 h UT	0.13	0.70
MKEH	Ge(Li) γ counting UA-GL-GR-00-00-00	115.08(3) [6]	10 350	1988-10-01 12 h UT	0.2	1.0
PTB	Pressurized IC ** 4P-IC-GR-00-00-00	–	21 620	1989-02-01 0 h UT	0.2	1.0
	CIEMAT/NIST 4P-LS-MX-00-00-CN TDCR 4P-LS-MX-00-00-TD	115.09(3) [5]	1 258.4 [§]	2010-03-01 0 h UT	0.15 ^{§§}	1.25 ^{§§}
LNE-LNHB	HP-Ge spectrometry [#] UA-GH-GR-00-00-00	115.08(3) [6]	1 135.9 ^{††} 1 138.4	1992-01-28 12 h UT	0.03	0.36
	4π NaI(Tl) counting 4P-NA-PH-00-00-HE	115.09(3) [5]	1 175.5	2010-07-01 12 h UT	0.41	0.32
CNEA	HP-Ge spectrometry UA-GH-GR-00-00-00	115.09	914	1994-01-01 12 h UT	0.28	0.76
CIEMAT	4π NaI(Tl) counting 4P-NA-GR-00-00-HE	115.09(3) [5]	724.2	2011-10-20 10 h UT	0.10	0.61
	$4\pi\epsilon_c$ -x coincidence 4P-PP-CE-NA-XR-CO		724.8		0.87	0.24

[†] corresponding to a 392 keV γ -ray emission rate of $3.075 \times 10^6 \text{ s}^{-1}$

^{††} two ampoules submitted

* calibrated for ^{113}Sn by NaI and Ge(Li) photopeak counting UA-NA-GR-00-00-00 and UA-GL-GR-00-00-00

** calibrated in 1980 by efficiency calculation and Ge spectrometry UA-GL-GR-00-00-00

[§] weighted mean of the two results obtained with both methods

^{§§} from CIEMAT/NIST method only

[#] calibrated in 1990 using about 80 energy points not including those of ^{113}Sn gamma transitions.

Table 3. Details of each solution of ^{113}Sn submitted

NMI / SIR year	Chemical composition	Solvent conc. / (mol dm^{-3})	Carrier: conc. / ($\mu\text{g g}^{-1}$)	Density / (g cm^{-3})	Relative activity of any impurity [†]
NIST 1975	SnCl_4 in HCl	4	–	1.064(2)	–
1980	Sn in HCl	4	Sn : 2	1.066(2)*	$^{114}\text{In}^{\text{m}}$: 3.6(7) % ^{125}Sb : 0.12(2) %
CMI-IIR 1981	Hexachloro-stannate in HCl	6	–	–	$^{114}\text{In}^{\text{m}}$: 0.90(5) % ^{125}Sb : 0.040(5) %
MKEH 1988	Sn + In in HCl	6	Sn : 28 In : 17	–	$^{114}\text{In}^{\text{m}}$: 0.056(5) % ^{124}Sb : 0.0010(3) %
PTB 1989	SnCl_2 in HCl	3	SnCl_2 : 50	1.05	–
2010	$\text{SnCl}_2 \cdot 2\text{H}_2\text{O}$ in HCl	4	$\text{SnCl}_2 \cdot 2\text{H}_2\text{O}$: 47.4	1.050	$^{114}\text{In}^{\text{m}}$: 0.15(5) % ^{75}Se : 0.022(9) % $^{110\text{m}}\text{Ag}$: $5.7(14) \times 10^{-3}$ %
LNE-LNHB 1992	SnCl_4 in HCl	2	SnCl_4 : 740	1.035	^{125}Sb : 0.06(1) % ^{60}Co : 0.002(1) %
2010	SnCl_4 in HCl	6	Sn : 10	1.098	$^{114}\text{In}^{\text{m}}$: 0.051(8) % $^{110\text{m}}\text{Ag}$: 0.011(1) %
CNEA 1994	SnCl_2	–	Sn : 32.6	0.9969	–
CIEMAT 2011	SnCl_4 in HCl	6	SnCl_4 : 10	1.09	–

[†] the ratio of the activity of the impurity to the activity of ^{113}Sn at the reference date

* at 22.8 °C.

4. Results

All the submissions to the SIR since its inception in 1976 are maintained in a database known as the "master-file". The recent submissions have added three ampoules for the activity measurements for ^{113}Sn giving rise to eleven ampoules in total. The SIR equivalent activity, A_{ei} , for each ampoule for the previous and new results is given in Table 4 for each NMI, i . The relative standard uncertainties arising from the measurements in the SIR are also shown. This uncertainty is additional to that declared by the NMI for the activity measurement shown in Table 2. Although submitted activities are compared with a given source of ^{226}Ra , all the SIR results are normalized to the radium source number 5 [1].

The assumption is made that the daughter radionuclide ^{113}In ($T_{1/2}$ of 99 min) was in equilibrium with the parent at the reference dates.

Table 4. Results of SIR measurements of ^{113}Sn

NMI / SIR year	Mass of solution m_i / g	Activity submitted A_i / kBq	N° of Ra source used	SIR $A_{e,i}$ / kBq	Relative uncertainty from SIR	Combined standard uncertainty u_i / kBq
NIST 1975 1980	5.368 1	7 891	3	58 980	9×10^{-4}	1700
	3.909 6 [†]		2	58 790 [†]	12×10^{-4}	1700
	3.865 63	4 738	3	58 850	22×10^{-4} *	640
CMI-IIR 1981	3.634 91	3 922	3	58 950	9×10^{-4}	420
MKEH 1988	3.650 2	10 350	4	58 790	7×10^{-4}	620
PTB 1989 2010	3.628 7	21 620	4	58 200	8×10^{-4}	600
	3.821 33	1 258.4	1	59 090	16×10^{-4}	750
LNE-LNHB 1992 2010	3.703 5	1 135.9 ^{††}	2	58 255	11×10^{-4}	220
	3.711 6	1 138.4		58 307	10×10^{-4}	220
	3.976 8(6)	1 175.5	1	57 110	15×10^{-4}	310
CNEA 1994	3.672 32	914	1	58 350	13×10^{-4}	480
CIEMAT 2011	3.621 3	724.2 [#]	1	58 410 ^{##}	16×10^{-4}	310
		724.8				

[†] after transfer and weighing at the BIPM of part of the NIST solution

* mainly due to the uncertainty of the impurity activities as given by the NIST.

activity values corresponding to the two methods mentioned in Table 2.

evaluated using the weighted mean activity measurement result as computed by the CIEMAT: 724.4(37) kBq. The SIR result, when using the coincidence method result only, is 58 440(530) kBq and is used for the evaluation of the key comparison reference value.

The PTB 2010 ampoule contained 3.821 33 g of solution which is slightly outside the usual range for the SIR (3.4 g – 3.8 g). The effect on the SIR result, evaluated from a study of the mass dependence measured for Np-237, should be of about 5×10^{-4} and is thus negligible.

For the LNE-LNHB ampoule in 2010, measurements repeated at the BIPM after periods of up to two weeks later do not show any trend and have a standard deviation of 1.7 parts in 1000. The impurity correction for the first SIR measurements (1.00132) is mainly due to the $^{110\text{m}}\text{Ag}$ impurity whose activity was confirmed at the BIPM (see above).

Other significant SIR corrections for impurities are 1.0127 and 1.0031 for the NIST (1980) and CMI-IIR respectively.

In principle, the chemical composition of the solutions could have an influence on the SIR measurements owing to the intense x-ray emission from ^{113}Sn . However, using the efficiency curve of the SIR [10], the contribution of the x-rays to the ionization current is estimated to be negligible. In consequence, the influence of the chemical composition on the SIR measurements can also probably be neglected in this case although a more detailed study could be performed.

No recent submission has been identified as a pilot study so the most recent result of each NMI is normally eligible for Appendix B of the MRA.

No international or regional comparison for this radionuclide has been held to date so no linking data are identified.

4.1 The key comparison reference value

In May 2013 the CCRI(II) decided to no longer calculate the key comparison reference value (KCRV) by using an unweighted mean but rather by using the power-moderated weighted mean [11]. This type of weighted mean is similar to a Mandel-Paule mean in that the NMIs' uncertainties may be increased until the reduced chi-squared value is one. In addition, it allows for a power smaller than two in the weighting factor. Therefore, all SIR key comparison results can be selected for the KCRV with the following provisions:

- a) only results for solutions standardized by primary techniques are accepted, with the exception of radioactive gas standards (for which results from transfer instrument measurements that are directly traceable to a primary measurement in the laboratory may be included);
- b) each NMI or other laboratory has only one result (normally the most recent result or the mean if more than one ampoule is submitted);
- c) possible outliers can be identified on a mathematical basis and excluded from the KCRV using the normalized error test with a test value of 2.5 and using the modified uncertainties;
- d) results can also be excluded for technical reasons; and
- e) the CCRI(II) is always the final arbiter regarding excluding any data from the calculation of the KCRV.

The data set used for the evaluation of the KCRVs is known as the "KCRV file" and is a reduced data set from the SIR master-file. Although the KCRV may be modified when other NMIs participate, on the advice of the Key Comparison Working Group of the CCRI(II), such modifications are made only by the CCRI(II) during one of its biennial meetings as for the case of ^{113}Sn in March 2015, or by consensus through electronic means (e.g., email) as discussed at the CCRI(II) meeting in 2013.

Consequently, the KCRV for ^{113}Sn has been calculated as 58 810(310) kBq on the basis of the SIR results from the CMI-IIR, PTB (2010) and the CIEMAT (coincidence result only). This can be compared with the value of 58 730(190) kBq obtained using the SIRIC efficiency curve of the SIR [10].

4.2 Degrees of equivalence

Every participant in a comparison is entitled to have one result included in the KCDB as long as the NMI is a signatory or designated institute listed in the CIPM MRA, and the result is valid (i.e., not older than 20 years). Normally, the most recent result is the one included. An NMI may withdraw its result only if all other participants agree.

The degree of equivalence of a given measurement standard is the degree to which this standard is consistent with the KCRV [2]. The degree of equivalence is expressed quantitatively in terms of the deviation from the key comparison reference value and the expanded uncertainty of this deviation ($k = 2$). The degree of equivalence between any pair of national measurement standards is expressed in terms of their difference and the expanded uncertainty of this difference and is independent of the choice of key comparison reference value.

4.2.1 *Comparison of a given NMI result with the KCRV*

The degree of equivalence of the result of a particular NMI, i , with the key comparison reference value is expressed as the difference D_i between the values

$$D_i = A_{ei} - \text{KCRV} \quad (1)$$

and the expanded uncertainty ($k = 2$) of this difference, U_i , known as the equivalence uncertainty; hence

$$U_i = 2u(D_i). \quad (2)$$

When the result of the NMI i is included in the KCRV with a weight w_i , then

$$u^2(D_i) = (1-2w_i) u_i^2 + u^2(\text{KCRV}). \quad (3)$$

However, when the result of the NMI i is not included in the KCRV, then

$$u^2(D_i) = u_i^2 + u^2(\text{KCRV}). \quad (4)$$

4.2.2 *Comparison between pairs of NMI results*

The degree of equivalence between the results of any pair of NMIs, i and j , is expressed as the difference D_{ij} in the values

$$D_{ij} = D_i - D_j = A_{ei} - A_{ej} \quad (5)$$

and the expanded uncertainty ($k = 2$) of this difference, $U_{ij} = 2u(D_{ij})$, where

$$u_{D_{ij}}^2 = u_i^2 + u_j^2 - 2u(A_{ei}, A_{ej}) \quad (6)$$

where any obvious correlations between the NMIs (such as a traceable calibration, or correlations normally coming from the SIR or from the linking factor in the case of linked comparison) are subtracted using the covariance $u(A_{ei}, A_{ej})$ (see [12] for more detail). However, the CCRI decided in 2011 that these “pair-wise degrees of equivalence” no longer need to be published as long as the methodology is explained.

Table 5 shows the matrix of all the degrees of equivalence as they will appear in the KCDB. It should be noted that for consistency within the KCDB, a simplified level of nomenclature is used with A_{ei} replaced by x_i . The introductory text is that agreed for the comparison. The graph of the results in Table 5, corresponding to the degrees of equivalence with respect to the KCRV (identified as x_R in the KCDB), is shown in Figure 1. This graphical representation indicates in part the degree of equivalence between the NMIs but obviously does not take into account the correlations between the different NMIs. It should be noted that the final data in this paper, while correct at the time of publication, will become out-of-date as NMIs make new comparisons. The formal results under the CIPM MRA [2] are those available in the KCDB.

Conclusion

The BIPM ongoing key comparison for ^{113}Sn , BIPM.RI(II)-K1.Sn-113 currently comprises three results that replace two earlier results in the KCDB.

The results have been analysed with respect to the first KCRV determined for this radionuclide, providing degrees of equivalence for the three national metrology institutes. The degrees of equivalence have been approved by the CCRI(II) and are published in the BIPM key comparison database. Other results may be added when other NMIs contribute ^{113}Sn activity measurements to this comparison or take part in other linked comparisons.

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Table 5. **Introductory text for ^{113}Sn and table of degrees of equivalence**

Key comparison BIPM.RI(II)-K1.Sn-113

MEASURAND : **Equivalent activity of ^{113}Sn**

**Key comparison reference value: the SIR reference value for this radionuclide is $x_R = 58\,810\text{ kBq}$ with a standard uncertainty, $u_R = 310\text{ kBq}$ (see Section 4.1 of the Final Report).
The value x_i is the equivalent activity for laboratory i .**

The degree of equivalence of each laboratory with respect to the reference value is given by a pair of terms:

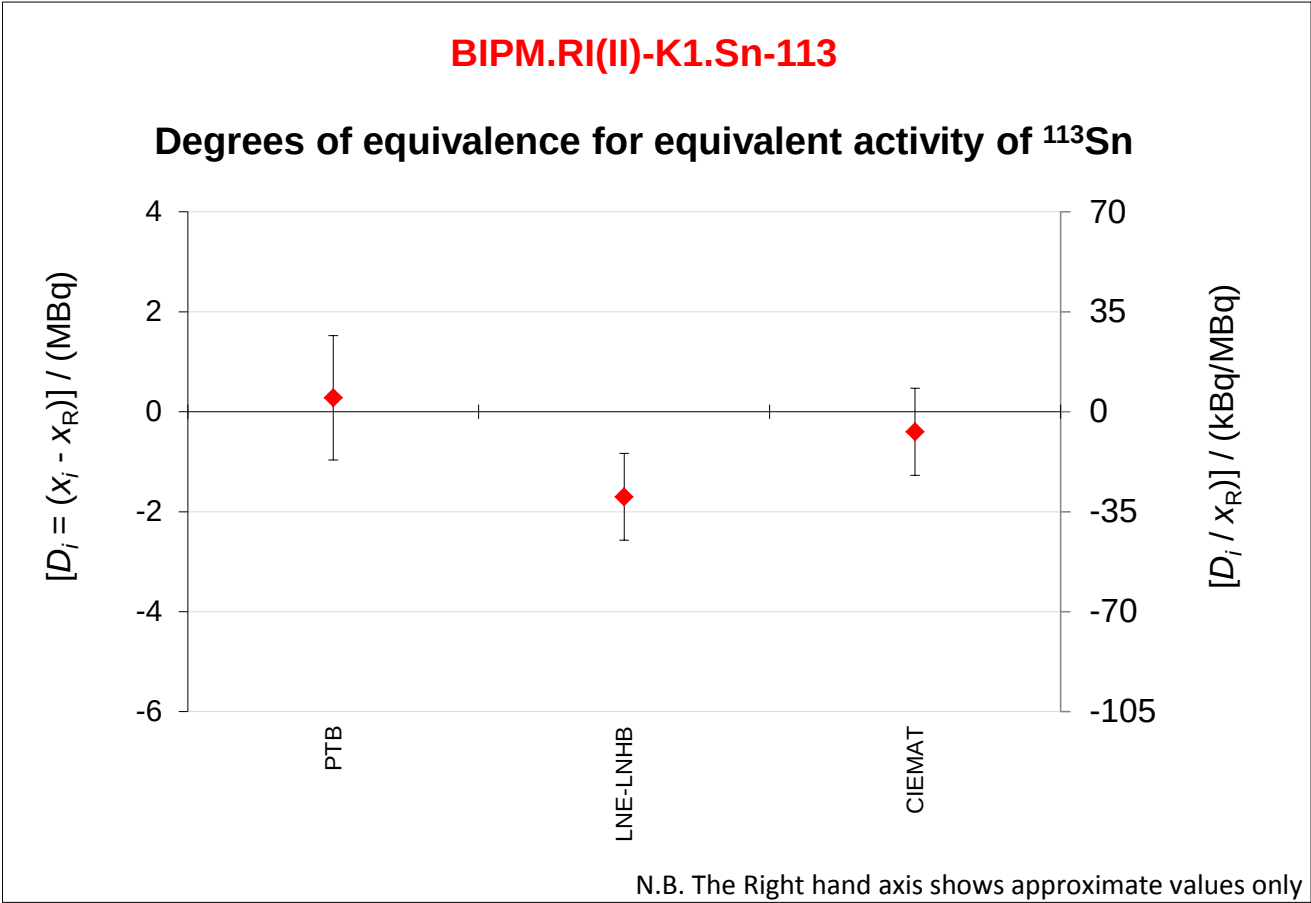
$D_i = (x_i - x_R)$ and U_i , its expanded uncertainty ($k = 2$), both expressed in MBq, and

$U_i = 2((1 - 2w_i)u_i^2 + u_R^2)^{1/2}$ where w_i is the weight of laboratory i contributing to the calculation of x_R .

Lab i

	D_i	U_i
	/ MBq	
PTB	0.28	1.25
LNE-LNHB	-1.70	0.87
CIEMAT	-0.40	0.87

Figure 1. Graph of degrees of equivalence with the KCRV for ^{113}Sn
(as it appears in Appendix B of the MRA)



Appendix 1. Uncertainty budgets for the activity of ^{113}Sn submitted to the SIR**LNE-LNHB, 2010, 4P-NA-PH-00-00-HE**

Relative standard uncertainties	$u_i \times 10^4$ evaluated by method	
Contributions due to	A	B
counting statistics	8	—
weighing and source dispersion	—	5
live time	1	—
background	5	—
radionuclide impurities	—	10
half-life	—	negligible
efficiency calculation	—	30
extrapolation	40	—
Quadratic summation	41	32
Relative combined standard uncertainty, u_c	52	

PTB, 2010, 4P-LS-MX-00-00-CN

Relative standard uncertainties	Comment	$u_i \times 10^4$ evaluated by method	
Contributions due to		A	B
counting statistics	Std deviation of the mean of 7 samples	14	—
weighing		—	19
dead time		—	10
background		5	—
counting time		—	1
adsorption		—	5
radionuclide impurities	Impurities were taken into account	—	5
half-life		—	< 1
tracer	Incl. interpolation from calibration curve	—	20
input parameters and statistical model	Incl. decay scheme parameters	—	110
ionization quenching and kB (model)		—	50
quenching (indicator)		—	5
PMT asymmetry			5
Quadratic summation		15	125
Relative combined standard uncertainty, u_c		130	

PTB, 2010, 4P-LS-MX-00-00-TD

Relative standard uncertainties	Comment	$u_i \times 10^4$ evaluated by method	
Contributions due to		A	B
counting statistics	Std deviation of the mean of 4 samples	24	—
weighing		—	18
dead time		—	3
background		5	—
counting time		—	1
adsorption		—	5
radionuclide impurities	Impurities were taken into account	—	10
half-life		—	< 1
TDCR value	Incl. interpolation from calibration curve	—	3
input parameters and statistical model	Incl. decay scheme parameters	—	110
ionization quenching and k_B (model)		—	100
PMT asymmetry		—	5
Quadratic summation		25	150
Relative combined standard uncertainty, u_c		150	

CIEMAT, 2011, 4P-NA-GR-00-00-HE

Relative standard uncertainties	$u_i \times 10^4$ evaluated by method	
Contributions due to	A	B
counting statistics	9	—
weighing	—	10
dead time	—	1
background	4	—
counting time	—	1
half-life	—	< 1
input parameters and statistical model [§]	—	60
zero-energy extrapolation	—	4
decay-scheme parameters	—	4
Quadratic summation	10	61
Relative combined standard uncertainty, u_c	62	

[§] Monte-Carlo model and simulation statistics

CIEMAT, 2011, 4P-NA-GR-00-00-HE

Relative standard uncertainties	$u_i \times 10^4$ evaluated by method	
Contributions due to	A	B
counting statistics and extrapolation	63	–
weighing	–	12
dead time	–	1.2
background (Compton under x-ray peaks)	60	–
counting time	–	1
resolving time	–	3.1
half-life	–	< 1
decay-scheme parameters	–	20
Quadratic summation	87	24
Relative combined standard uncertainty, u_c	90	

Appendix 2. Acronyms used to identify different measurement methods

Each acronym has six components, geometry-detector (1)-radiation (1)-detector (2)-radiation (2)-mode. When a component is unknown, ?? is used and when it is not applicable 00 is used.

Geometry	acronym	Detector	acronym
4π	4P	proportional counter	PC
defined solid angle	SA	press. prop counter	PP
2π	2P	liquid scintillation counting	LS
undefined solid angle	UA	NaI(Tl)	NA
		Ge(HP)	GH
		Ge(Li)	GL
		Si(Li)	SL
		CsI(Tl)	CS
		ionization chamber	IC
		grid ionization chamber	GC
		Cerenkov detector	CD
		Calorimeter	CA
		plastic scintillator	SP
		PIPS detector	PS
Radiation	acronym	Mode	acronym
positron	PO	efficiency tracing	ET
beta particle	BP	internal gas counting	IG
Auger electron	AE	CIEMAT/NIST	CN
conversion electron	CE	sum counting	SC
mixed electrons	ME	coincidence	CO
bremsstrahlung	BS	anti-coincidence	AC
gamma rays	GR	coincidence counting with efficiency tracing	CT
X - rays	XR	anti-coincidence counting with efficiency tracing	AT
photons ($x + \gamma$)	PH	triple-to-double coincidence ratio counting	TD
alpha - particle	AP	selective sampling	SS
mixture of various radiation	MX	high efficiency	HE

Examples

method	acronym
$4\pi(\text{PC})\beta\text{-}\gamma$ -coincidence counting	4P-PC-BP-NA-GR-CO
$4\pi(\text{PPC})\beta\text{-}\gamma$ -coincidence counting eff. trac.	4P-PP-MX-NA-GR-CT
defined solid angle α -particle counting with a PIPS detector	SA-PS-AP-00-00-00
$4\pi(\text{PPC})\text{AX-}\gamma(\text{GeHP})$ -anticoincidence counting	4P-PP-MX-GH-GR-AC
4π CsI- β ,AX, γ counting	4P-CS-MX-00-00-HE
calibrated IC	4P-IC-GR-00-00-00
internal gas counting	4P-PC-BP-00-00-IG