

Update of the BIPM comparison BIPM.RI(II)-K1.Sr-85 of activity measurements of the radionuclide ^{85}Sr to include the 2018 result of the PTB (Germany)

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Abstract Since 1975, 10 laboratories have submitted 28 samples of ^{85}Sr 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.Sr-85. Recently, the PTB (Germany) participated in the comparison and the key comparison reference value (KCRV) has been updated. The degrees of equivalence between each equivalent activity measured in the SIR and the updated 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 2019, the SIR has been used to measure 1016 ampoules to give 771 independent results for 72 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 continuous 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.Sr-85 key comparison. The results of earlier participations in this key comparison were published previously [3–5].

2. Participants

Laboratory details are given in Table 1, with the earlier submissions being taken from [3–5]. 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.Sr-85.

NMI or laboratory	Previous acronyms	Full name	Country	RMO	Date of SIR measurement yyyy-mm-dd
BIPM	-	Bureau International des Poids et Mesures			1975-12-03
BKFH	OMH, MKEH	Government Office of the Capital City Budapest	Hungary	EURAMET	1980-04-16 1990-09-06 1991-10-18 1994-05-05
CMI-IIR	UVVVR	Czech Metrological Institute - Inspectorate for Ionizing Radiation	Czech Republic	EURAMET	1978-11-24 1982-11-15
LNE-LNHB	LMRI, LPRI, BNM-LNHB	Laboratoire National de métrologie et d'Essais - Laboratoire National Henri Becquerel	France	EURAMET	1984-02-27 1995-03-10
NIRH	-	National Institute of Radiation Hygiene	Denmark	EURAMET	1996-11-21
NIST	NBS	National Institute of Standards and Technology	United States	SIM	1977-05-16 1983-07-18 2001-11-22
NMIJ	ETL	National Metrology Institute of Japan	Japan	APMP	1976-11-17 1994-12-05 2004-03-15
NPL	-	National Physical Laboratory	United Kingdom	EURAMET	1981-10-06

... Continuation of Table 1.

NMI or laboratory	Previous acronyms	Full name	Country	RMO	Date of SIR measurement yyyy-mm-dd
POLATOM	IBJ, RC	National Centre for Nuclear Research Radioisotope Centre POLATOM	Poland	EURAMET	2009-01-30
PTB	-	Physikalisch-Technische Bundesanstalt	Germany	EURAMET	1976-11-10 1994-09-15 1998-10-23 2018-12-13

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 and the half-life used by the participants are given in Table 2. The uncertainty budget for the new submission is given in Appendix D attached to this report; previous uncertainty budgets are given in the earlier K1 reports [3–5]. The list of acronyms used to summarize the methods is given in Appendix E.

Since 2004, the half-life used by the BIPM is 64.850(7) days as published in BIPM Monographie 5 vol. 1 [6]. The half-life of 64.85(3) days [7] was used for the earlier results.

Table 2: Standardization methods of the participants for ^{85}Sr .

NMI or laboratory	Method used and the acronym	Activity A_i/kBq	Relative standard uncertainty / 10^{-2}		Reference date yyyy-mm-dd	Half-life /d
			A	B		
BIPM	$4\pi\text{PC}-\gamma$ coincidence (4P-PC-MX-NA-GR-CO)	4623	0.05	1.12	1975-04-21 13:00 UT	64.85(3)
BKFH	$4\pi(x, e_x)-\gamma$ coincidence (4P-PP-MX-NA-GR-CO)	759.5	0.14	0.85	1980-04-15 12:00 UT	64.73(2) [8]
	$4\pi(x, e_x)-\gamma$ anti-coincidence (4P-PP-MX-NA-GR-AC)	825.9	0.02	0.26	1990-09-15 12:00 UT	64.85(2) [9]
	$4\pi(x, e_x)-\gamma$ coincidence (4P-PP-MX-NA-GR-CO)	206	0.02	0.26	1991-11-01 12:00 UT	[9]

... Continuation of Table 2.

NMI or laboratory	Method used and the acronym	Activity A_i /kBq	Relative standard uncertainty / 10^{-2}		Reference date yyyy-mm-dd	Half-life /d
			A	B		
	4π PPC- γ coincidence (4P-PP-MX-NA-GR-AC)	790	0.05	0.32	1994-05-15 00:00 UT	64.849(4)
CMI-IIR	$4\pi(x, e_A)$ - γ coincidence (4P-PC-MX-NA-GR-CO)	3961	0.2	0.53	1978-10-13 11:00 UT	65
	4π PC- γ coincidence (4P-PC-MX-NA-GR-CO)	6732	0.14	0.43	1982-11-15 00:00 UT	64.77
LNE-LNHB	4π PPC- γ anti-coincidence (4P-PP-XR-NA-GR-AC)	2662.0 ^a	0.08	0.08	1983-11-28 12:00 UT	-
		2647.6	0.08	0.08		
	$4\pi\beta$ - γ anti-coincidence (4P-PP-XR-NA-GR-AC)	3461.7 ^a	0.07	0.22	1995-02-16 12:00 UT	
		3450.9	0.07	0.22		
NIRH	ionization chamber (4P-IC-GR-00-00-00)	5800	0.6	0.9	1996-10-15 08:00 UT	
NIST	ionization chamber calibrated by $4\pi(x, e)$ - γ coincidence in 1975 (4P-IC-GR-00-00-00 calibrated by 4P-PP-MX-NA-GR-CO in 1975)	3998 ^a	0.01	1.37	1977-04-20 17:00 UT	
		4011	0.01	1.37		
	ionization chamber calibrated by $4\pi(x, e)$ - γ coincidence in 1975 (4P-IC-GR-00-00-00 calibrated by 4P-PP-MX-NA-GR-CO in 1975)	9466	0.03	0.26	1983-06-13 17:00 UT	
	ionization chamber calibrated by $4\pi(x, e)$ - γ coincidence in 1975 (4P-IC-GR-00-00-00 calibrated by 4P-PP-MX-NA-GR-CO in 1975)	948.6	0.1	0.27	2001-11-15 12:00 UT	64.84(2)
NMIJ	4π x- γ coincidence (4P-PC-MX-NA-GR-CO)	972.1 ^a	0.04	0.86	1976-11-01 12:00 UT	-
		965.4	0.04	0.86		
	$4\pi e(x)$ - γ coincidence (4P-PC-MX-NA-GR-CO)	1156.2	0.19	0.41	1994-12-01 12:00 UT	
	ionization chamber traceable to 1994 submission (4P-IC-GR-00-00-00)	827	0.07	0.46	2004-02-01 00:00 UT	64.84

... Continuation of Table 2.

NMI or laboratory	Method used and the acronym	Activity A_i /kBq	Relative standard uncertainty / 10^{-2}		Reference date yyyy-mm-dd	Half-life /d
			A	B		
NPL	ionization chamber calibrated from 1969-1972 (4P-IC-GR-00-00-00 calibrated by 4P-PP-MX-NA-GR-CO in 1969-72)	1723.1	0.02	0.66	1981-10-05 00:00 UT	-
POLATOM	4 π (LS)- γ coincidence and anti-coincidence (4P-LS-MX-NA-GR-CO & 4P-LS-MX-NA-GR-AC)	18 545	0.24	0.52	2009-01-01 11:00 UT	64.85
PTB	4 π PPC- γ coincidence (4P-PP-MX-NA-GR-CO)	2795 ^a	0.05	0.78	1976-10-01 00:00 UT	-
		2795	0.05	0.78		
	ionization chamber (4P-IC-GR-00-00-00)	4729	0.03	0.45	1994-08-01 00:00 UT	
	ionization chamber calibrated by 4 π PCC- γ coincidence in 1998 (4P-IC-GR-00-00-00 calibrated by 4P-PP-MX-NA-GR-CO)	3786.5 ^a	0.04	0.16	1998-08-01 00:00 UT	64.849(4)
		3792.8	0.04	0.16		
	4 $\pi\beta$ (LS)- γ anti-coincidence counting (4P-LS-BP-??-GR-AC)	4610.8	0.16	0.32	2019-02-01 00:00 UT	

^a Several samples submitted

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.

Table 3: Details of each solution of ⁸⁵Sr submitted.

NMI or laboratory / SIR year	Chemical composition	Solvent conc. /(mol dm ⁻³)	Carrier conc. /(μ g g ⁻¹)	Density /(g cm ⁻³)	Relative activity of any impurity ^a
BIPM 1975	Sr in HCl	3	-	1.045	-
BKFH 1980 1990	Sr in HCl	0.1	Sr:25	-	⁸⁴ Rb: 1.2(3)x10 ⁻² %
	SrCl ₂ in HCl	0.1	SrCl ₂ :28	-	⁸⁴ Rb: 5.3(13)x10 ⁻² % ⁸⁶ Rb: 3(1)x10 ⁻⁴ %
1991	SrCl ₂ in HCl	0.1	SrCl ₂ :30	-	⁸⁴ Rb: 1.1(3)x10 ⁻² % ⁸⁶ Rb: 2.0(6)x10 ⁻⁴ %
1994	SrCl ₂ in HCl	0.1	SrCl ₂ :25	-	⁸⁴ Rb: 1.5(3)x10 ⁻² % ⁸⁶ Rb: 2.0(6)x10 ⁻⁴ %
CMI-IIR 1978	SrCl ₂ in HCl	0.08	SrCl ₂ :20	-	< 0.1 %

... Continuation of Table 3.

NMI or laboratory / SIR year	Chemical composition	Solvent conc. /(mol dm ⁻³)	Carrier conc. /(µg g ⁻¹)	Density /(g cm ⁻³)	Relative activity of any impurity ^a
1982	SrCl ₂ in HCl	0.1	SrCl ₂ :20	-	⁸⁴ Rb: 4.7(5)x10 ⁻² % ⁸⁶ Rb: 5(1)x10 ⁻³ % ⁸⁹ Sr: 1.9(8)x10 ⁻¹ %
LNE-LNHB 1984	SrCl ₂ in HCl	0.1	SrCl ₂ :10	0.999	⁸⁹ Sr: 4.6(3)x10 ⁻¹ %
1995	SrCl ₂ in HCl	1	SrCl ₂ :90	1.016	⁸⁴ Rb: 5.5(10)x10 ⁻² %
NIRH 1996	SrCl ₂	-	-	-	-
NIST 1977	Sr in HCl	1	Sr:29	1.016(2)	⁸⁴ Rb: 9.5(19)x10 ⁻² % ⁸⁶ Rb: 1.7(3)x10 ⁻¹ %
1983	SrCl ₂ in HCl	1	SrCl ₂ :36	1.016	-
2001	SrCl ₂ in HCl	1	SrCl ₂ :46000	1.057(1)	-
NMIJ 1976	SrCl ₂ in HCl	1	SrCl ₂ :50	-	-
1994	SrCl ₂ in HCl	0.1	SrCl ₂ :50	1	-
2004	SrCl ₂ in HCl	0.1	SrCl ₂ :100	1.002	-
NPL 1981	SrCl ₂ in HCl	0.1	SrCl ₂ :30	1.0015	-
POLATOM 2009	SrCl ₂ in HCl	0.1	SrCl ₂ :45	1	< 0.1 %
PTB 1976	SrCl ₂ in HCl	0.1	SrCl ₂ :30	-	< 6x10 ⁻² %
1994	SrCl ₂ in HCl	0.1	SrCl ₂ :30	1	-
1998	SrCl ₂ in HCl	0.1	SrCl ₂ :30	0.9985	-
2018	SrCl ₂ in HCl	0.1	SrCl ₂ .6H ₂ O:50	1	⁸⁴ Rb: 1.79(7)x10 ⁻² % ²² Na: 1.06(4)x10 ⁻² % ⁵⁹ Fe: 1.25(27)x10 ⁻³ %

^a the ratio of the activity of the impurity to the activity of ⁸⁵Sr at the reference date

4. Results

All the submissions to the SIR since its inception in 1976 are maintained in a database known as the "master-file". The latest submission has added 1 ampoule for the activity measurements for ⁸⁵Sr giving rise to 28 ampoules in total. The SIR equivalent activity, A_{ei} , for each ampoule received from each NMI, i , including both previous and new results, is given in Table 4.

The relative standard uncertainties arising from the measurements in the SIR are also shown. This uncertainty is additional to that declared by the NMI ($u(A_i)$) for the activity measurement shown in Table 2. Although submitted activities are compared with a given source of ²²⁶Ra, all the SIR results are normalized to the radium source number 5 [1]. No recent submission has been identified as a pilot study so the most recent result of each NMI is normally eligible for inclusion on the KCDB platform of

the CIPM MRA [2].

Table 4: Results of SIR measurement of ^{85}Sr .

NMI or laboratory	m_i	A_i	^{226}Ra source	A_{ei}	Relative uncert. from SIR	u_{ci}	A_{ei} for KCRV
/ SIR year	/g	/kBq		/kBq	/ 10^{-4}	/kBq	/kBq
BIPM 1975	3.755 77	4623	1	29 970	16	340	29 970(340)
BKFH 1980	3.602 9	759.5	2	29 920	9	260	-
1990	3.600 1	825.9	2	30 208	9	84	-
1991	3.609 9	206	3	30 201	7	82	-
1994	3.617 3	790	2	30 150	10	100	30 150(100)
CMI-IIR 1978	3.627 54	3961	3	30 190	7	170	-
1982	3.650 7	6732	4	29 890	6	140	29 890(140)
LNE-LNHB 1984	3.683 9	2662.0	2	29 952	11	49	-
1995	3.664 0	2647.6	2	29 963	10	47	-
	3.608 9	3461.7	3	29 812	6	71	29 782(71) ^b
	3.597 7	3450.9	3	29 752	7	71	-
NIRH 1996	3.571 6	5800	3	30 290	6	340	-
NIST 1977	3.733 22	3998	3	30 026	7	410	-
	3.744 79	4011	3	30 017	7	410	-
1983	3.668 09	9466	4	30 000	6	79	30 000(79)
2001	3.795 2(2)	948.6	2	30 086	9	91	-
NMIJ 1976	3.718 91	972.1	2	30 215	8	260	-
	3.693 20	965.4	2	30 203	8	260	-
1994	3.598 5	1156.2	2	29 850	8	140	29 850(140)
2004	3.598 68	827	1	30 130	17	150	-
NPL 1981	3.668 6	1723.1	3	29 920	7	200	29 920(200)
POLATOM 2009	3.619 9	18 545	4	30 130	6	170	30 130(170)
PTB 1976	3.613 6(1)	2795	2	29 935	8	230	-
	3.613 0(1)	2795	2	29 942	8	230	-
1994	3.663	4729	3	29 880	7	140	-
1998	3.653 50	3786.5	3	30 052	6	54 ^a	-
	3.659 61	3792.8	3	30 068	6	54	-
2018	3.637 14	4610.8	4	30 180	5.6	110	30 180(110)

^a updated evaluation to include the use of an ionization chamber at the PTB for the measurement result submitted

^b An average value and average uncertainty between all submitted samples is used for the KCDB [10].

4.1. The key comparison reference value

In May 2013, the CCRI(II) decided to calculate the key comparison reference value (KCRV) by using the power-moderated weighted mean [11] rather than an unweighted mean, as had been the policy. This type of weighted mean is similar to a Mandel-Paule mean in that the NMIs' uncertainties may be increased until the reduced chisquared

value is one. In addition, it allows for a power α smaller than two in the weighting factor. As proposed in [11], α is taken as $2 - 3/N$ where N is the number of results selected for the KCRV. 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 may only use one result (normally the most recent result or the mean if more than one ampoule is submitted);
- (c) results more than 20 years old are included in the calculation of the KCRV but are not included in data shown in the KCDB or in the plots in this report, as they have expired;
- (d) 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;
- (e) results can also be excluded for technical reasons; and
- (f) 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, or by consensus through electronic means (e.g., email) as discussed at the CCRI(II) meeting in 2013.

Consequently, using the recent result produces an updated KCRV for ^{85}Sr in 2020 of **29 983(52) kBq** with the power $\alpha = 1.667$ that has been calculated using the previously published results, selected as shown in Table 4, for the BIPM (1975), NPL (1981), CMI-IIR (1982), NIST (1983), BKFH (1994), NMIJ (1994), LNE-LNHB (1995), POLATOM (2009), and the present PTB (2018) result. This can be compared with the previous KCRV values of 29 953(42) kBq published in 2004 [3] and 29 975(46) kBq published in 2015 [5].

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

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

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 B1 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 C1. 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.

5. Conclusion

The BIPM continuous key comparison for ^{85}Sr , BIPM.RI(II)-K1.Sr-85, currently comprises 4 results. The KCRV has been recalculated to include the result from the PTB (Germany). The results have been analyzed with respect to the updated KCRV, providing degrees of equivalence for 4 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 ^{85}Sr activity measurements to this comparison or take part in other linked comparisons.

6. References

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Appendix A. Introductory text for ^{85}Sr degrees of equivalence

Key comparison BIPM.RI(II)-K1.Sr-85

MEASURAND: Equivalent activity of ^{85}Sr

Key comparison reference value: the SIR reference value x_{R} for this radionuclide is 29983 kBq , with a standard uncertainty, u_{R} equal to 52 kBq (see Section 4.1 of the Final Report). The value x_i is taken as the equivalent activity for a laboratory i .

The degree of equivalence of each laboratory with respect to the reference value is given by a pair of terms: $D_i = (x_i - x_{\text{R}})$ and U_i , its expanded uncertainty ($k = 2$), both expressed in MBq, and $U_i = 2((1 - 2w_i)u_i^2 + u_{\text{R}}^2)^{1/2}$, where w_i is the weight of laboratory i contributing to the calculation of x_{R} .

Appendix B. Table of degrees of equivalence for BIPM.RI(II)-K1.Sr-85

Table B1: The table of degrees of equivalence for BIPM.RI(II)-K1.Sr-85

NMI i	D_i /MBq	U_i /MBq
NIST	0.10	0.21
NMIJ	0.15	0.32
POLATOM	0.15	0.33
PTB	0.20	0.22

Appendix C. Graph of degrees of equivalence with the KCRV for ^{85}Sr (as it appears in Appendix B of the MRA)

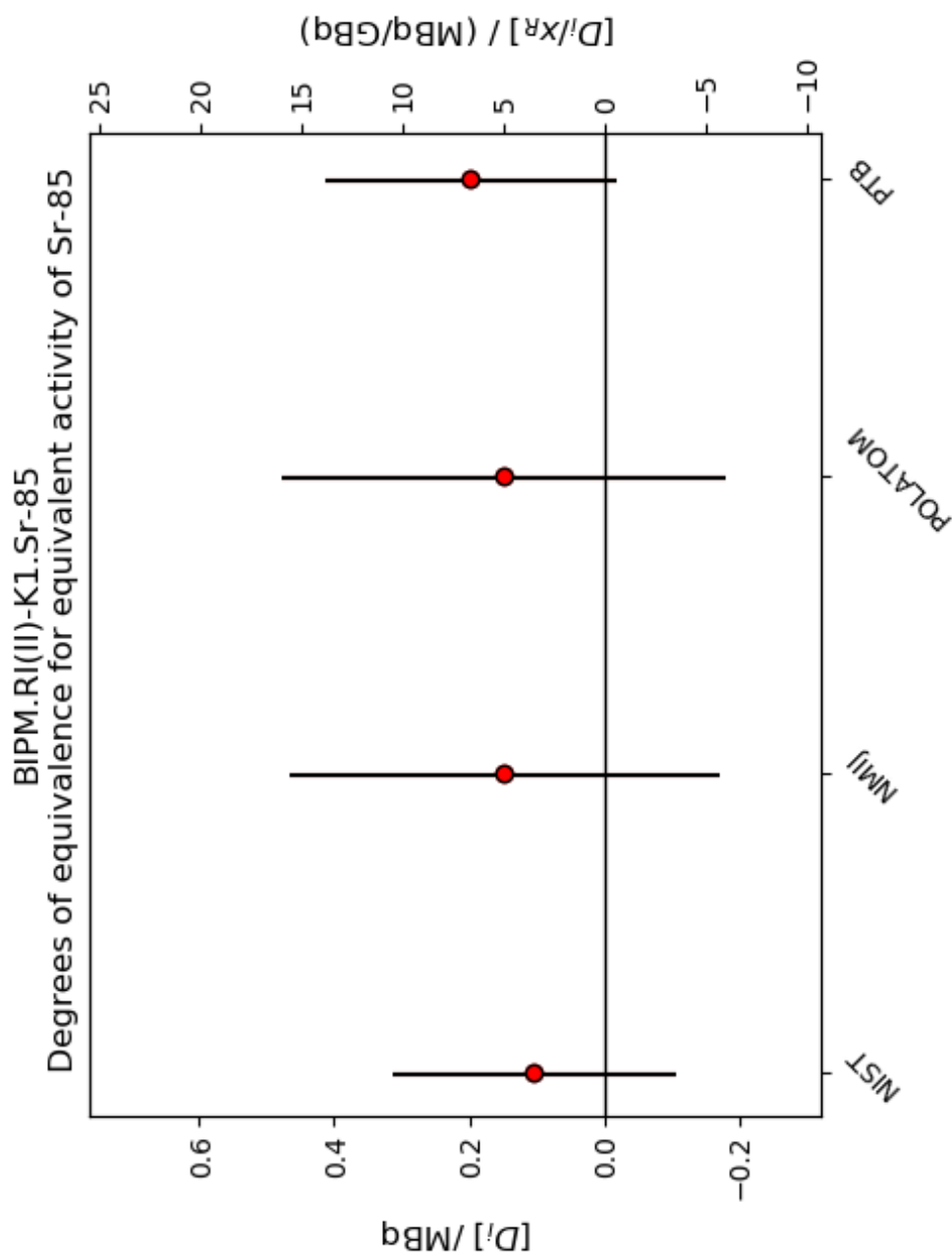


Figure C1. Degrees of equivalence for equivalent activity of ^{85}Sr .

Appendix D. Uncertainty budgets for the activity of ^{85}Sr submitted to the SIR

Detailed Uncertainty Budget

Laboratory: **PTB**

Radionuclide: **Sr-85** ; Ampoule number: **2018-1448**

*Uncertainty components**, in % of the activity concentration, due to

		Remarks	Evaluation type (A or B)	Relative sensitivity Factor
counting statistics	_ 0.15 _	-----	_ A _	-----
weighing	_ 0.006 _	-----	_ B _	-----
dead time	negligible	-----	_ B _	-----
background	_ 0.03 _	-----	_ A _	-----
pile-up	_ n.a. _	-----	_ B _	-----
counting time	_ 0.001 _	-----	_ B _	-----
adsorption	-----	-----	_ B _	-----
impurities	_ 0.10 _	-----	_ B _	-----
decay correction	_ 0.003 _	-----	_ B _	-----
fitting and extrapolation of efficiency curve	_ 0.30 _	-----	_ B _	-----
dilution	_ 0.01 _	-----	_ B _	-----
combined uncertainty (as quadratic sum of all uncertainty components)	_ 0.4 _	-----	-----	-----

* The uncertainty components are to be considered as approximations of the corresponding standard deviations (see also *Metrologia*, 1981, **17**, 73 and *Guide to expression of uncertainty in measurement*, <http://www.bipm.org/en/publications/guides/>)

Appendix E. 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
		solid plastic scintillator	SP
		PIPS detector	PS
		CeBr3	CB

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
photons + electrons	PE	selective sampling	SS
alpha particle	AP	high efficiency	HE
mixture of various radiation	MX	digital coincidence counting	DC

Examples of methods	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
$4\pi(\text{PPC})\text{AX-}\gamma(\text{GeHP})\text{-}$ anticoincidence counting	4P-PP-MX-GH-GR-AC
$4\pi\text{CsI-}\beta,\text{AX},\gamma$ counting	4P-CS-MX-00-00-HE
calibrated IC	4P-IC-GR-00-00-00
internal gas counting	4P-PC-BP-00-00-IG