

**Activity measurements of the radionuclide ^{186}Re
for the PTB, Germany in the BIPM.RI(II)-K1.Re-186 comparison**

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Abstract

In 2006, the Physikalisch-Technische Bundesanstalt (PTB), Germany submitted a sample of known activity of ^{186}Re to the International Reference System (SIR). The value of the activity submitted was about 166 MBq. This comparison result is the first submission in the BIPM.RI(II)-K1.Re-186 ongoing key comparison. The result agrees with that predicted from the efficiency curve for the SIR within a standard uncertainty.

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 (3.6 g) with the radionuclide in liquid form or a different standard ampoule for radioactive gases. The 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 reference 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 2007, the SIR has measured 905 ampoules to give 662 independent results for 63 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 realizations. These comparisons are described as BIPM ongoing comparisons and the results form the basis of the BIPM key comparison database (KCDB) that was set up under the CIPM Mutual Recognition Arrangement (CIPM MRA) [2]. The comparison described in this report is known as the BIPM.RI(II)-K1.Re-186 key comparison.

2. Participation

The PTB, by submitting one ampoule of a solution of Re-186 in 2006, became the first participant in this comparison. The PTB details are given in Table 1.

Table 1. Details of the participation in the comparison BIPM.RI(II)-K1.Re-186

NMI	Full name	Country	Regional metrology organization	Date of measurement at the BIPM YYYY-MM-DD
PTB	Physikalisch-Technische Bundesanstalt	Germany	EURAMET	2006-05-02

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 any correlations are taken into account.

A brief description of the standardization methods for the laboratory, the activities submitted and the relative standard uncertainties ($k = 1$) are given in Table 2. The uncertainty budget is given in Appendix 1. The acronyms used for the measurement methods are given in Appendix 2.

The half-life used by the BIPM is 3.7186 (17) d as published in *BIPM Monographie 5* [3]. The half-life given in Table 2 is the value (with its uncertainty) as used by the participant.

Table 2. Standardization methods of the participation for ^{186}Re

NMI	Method used and acronym (see Appendix 2)	Half-life / d	Activity A_i / kBq	Reference date YY-MM-DD	Relative standard uncertainty / 10^{-2} by method of evaluation	
					A	B
PTB	4P-LS-MX-00-00-CN	3.7183(11)	165 870	06-04-27 0 h UTC	0.03	0.25

Details regarding the solution submitted are shown in Table 3, including any impurities, when present, as identified by the laboratory. The BIPM has a standard method for evaluating the activity of impurities using a calibrated Ge(Li) spectrometer [4]. The CCRI(II) agreed in 1999 [5] that this method should be followed according to the protocol described in [6] when an NMI makes such a request or when there appear to be discrepancies. In addition to the Re-188 impurity reported by the laboratory, impurities of Re-184 and Ir-192 were detected at the BIPM. These latter impurities were not detectable initially at the PTB due to the high activity level of the ^{186}Re . Subsequent measurements at the PTB indicated a small amount of ^{184}Re and traces of ^{192}Ir as given in Table 3. These values have no effect on the PTB activity measurement of ^{186}Re .

Table 3. Details of the solution of ^{186}Re 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 [†]
PTB 2006	NH_4ReO_4 in NH_3	0.2	NH_4ReO_4 : 29	0.997	^{184}Re : 0.000 162(12)% ^{188}Re : 0.054(5)% ^{192}Ir : 0.000 058 7(10)%

[†] the ratio of the activity of the impurity to the activity of ^{186}Re at the reference date

4. Results

All the submissions to the SIR since its inception in 1976 are maintained in a database master-file. There are no previous activity measurements for ^{186}Re . The SIR equivalent activity, $A_{e,i}$, for this first submission is given in Table 4. The date of measurement in the SIR is given in Table 1 and is that used in the KCDB and all references in this report. The relative standard uncertainty arising from the measurements in the SIR is also shown. This uncertainty is additional to that declared by the NMI for the activity measurement shown in Table 2. Although activities submitted are compared with a given source of ^{226}Ra , all the SIR results are normalized to the radium source number 5 [1].

Table 4. Result of SIR measurements of ^{186}Re for the PTB

NMI / SIR year	Mass of solution / g	Activity submitted/ kBq	N° of Ra source used	SIR $A_{e,i}$ / MBq	Relative uncertainty from SIR	Total uncertainty $u_{c,i}$ / MBq
PTB 2006	3.632 81	165 870	2	1088.1	12×10^{-4}	3.1

The SIR measurements were repeated at the BIPM after 17 h, 3 d and 7 d respectively giving results in agreement well within one SIR combined uncertainty, which confirms the impurity analysis of the PTB.

4.1 The key comparison reference value

As there is only one result in the SIR for ^{186}Re , no KCRV can be identified. However, the SIRIC efficiency curve of the SIR [7] predicts a value of 1086.1 (5.9) MBq for ^{186}Re which agrees with the PTB result well within one standard uncertainty.

4.2 Degrees of equivalence

Every NMI that has submitted ampoules to the SIR is entitled to have one result included in the CIPM MRA KCDB as long as the NMI is a signatory or designated institute listed in the CIPM MRA. Normally, the most recent result is the one included. Any NMI may withdraw its result only if all the participants agree.

However, as the degree of equivalence of a given measurement standard is the degree to which this standard is consistent with the key comparison reference value [2] and there is no KCRV, it follows that no degrees of equivalence can be published for this PTB submission until another NMI submits an ampoule of ^{186}Re to the SIR..

Conclusion

The result for the PTB in this ongoing comparison agrees with the SIRIC predicted result well within one standard uncertainty.

As the BIPM ongoing key comparison for ^{186}Re , BIPM.RI(II)-K1.Re-186 currently comprises only one result, no degrees of equivalence can be established.

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Appendix 1. Uncertainty budget for the activity of ^{186}Re submitted to the SIR**Uncertainty budget for the PTB measurement**

Relative standard uncertainties	$u_i \times 10^4$ evaluated by method	
	A	B
Contributions due to		
Counting statistics	3	–
Tracer	–	4
Weighing	–	8
Dead time	–	10
Time measurement (time and duration)	–	< 1
Background	–	3
Impurities	–	5
Decay data and model	–	18
Quenching	–	5
Dilution factor by weighing	–	7
Half life	–	6
Quadratic summation	3	25.5
Relative combined standard uncertainty, u_c	26	

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	Nal(Tl)	NA
		Ge(HP)	GH
		Ge(Li)	GL
		Si(Li)	SL
		CsI(Tl)	CS
		ionization chamber	IC
		grid ionization chamber	GC
		bolometer	BO
		calorimeter	CA
		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
photons + electrons	PE	selective sampling	SS
alpha - particle	AP	high efficiency	HE
mixture of various radiations	MX	digital coincidence counting	DC

Examples	method	acronym
4π (PC) β - γ -coincidence counting		4P-PC-BP-NA-GR-CO
4π (PPC) β - γ -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
4π (PPC)AX- γ (Ge(HP))-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