BIPM comparison BIPM.RI(II)-K1.Lu-177 of activity measurements of the radionuclide ^{177}Lu for the NPL (UK) and the IRMM (EU), with linked results for the CCRI(II)-K2.Lu-177 comparison

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Abstract

Two new participations in the BIPM.RI(II)-K1.Lu-177 comparison have been added to the previous results and this has produced a revised value for the key comparison reference value (KCRV), calculated using the power-moderated weighted mean. A link has been made to the CCRI(II)-K2.Lu-177 comparison held in 2009 through the NPL and IRMM who participated in both comparisons. Two NMIs used the K2 comparison to update their degree of equivalence. The degrees of equivalence between each equivalent activity measured in the International Reference System (SIR) and the KCRV have been calculated and the results are given in the form of a table for the remaining two NMIs in the BIPM.RI(II)-K1.Lu-177 comparison and the nine other participants in the CCRI(II)-K2.Lu-177 comparison. 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, or a different standard ampoule for radioactive gases. 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 2012, the SIR has measured 966 ampoules to give 721 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 CIPM Mutual Recognition Arrangement (CIPM MRA) [2]. The comparison described in this report is known as the BIPM.RI(II)-K1.Lu-177 key comparison and includes results published previously [3].

In addition, an international comparison was held in 2009 for this radionuclide, CCRI(II)-K2.Lu-177 [4-5]. Eleven laboratories took part in this comparison including the NPL and IRMM who participated in the SIR at the same time, enabling to link the CCRI(II)-K2 comparison to the BIPM.RI(II)-K1 comparison. Two NMIs had previously submitted ampoules to the SIR and have updated their results through this CCRI(II) comparison.

2. Participants

Three NMIs and another laboratory have submitted four ampoules for the comparison of ^{177}Lu activity measurements since 2000. Since the key comparison reference value has been re-evaluated for this comparison all the participants' details are given in Table 1a.

Table 1a. Details of the participants in the BIPM.RI(II)-K1.Lu-177

NMI	Full name	Country	Regional metrology organization	Date of measurement at the BIPM
PTB	Physikalisch-Technische Bundesanstalt	Germany	EURAMET	2000-01-26
NIST	National Institute of Standards and Technology	United States	SIM	2000-02-15
NPL	National Physical Laboratory	United Kingdom	EURAMET	2009-04-28
IRMM	Institute for Reference Materials and Measurements	European Union	EURAMET	2009-04-30

The seven additional NMIs that took part in the CCRI(II) international comparison, CCRI(II)-K2.Lu-177 in 2009 [4-5] and are also eligible for the KCDB are shown in Table 1b together with the NIST and the PTB that used this comparison to update their results.

Table 1b. Details of the participants in the 2009 CCRI(II)-K2.Lu-177 to be linked to BIPM.RI(II)-K1.Lu-177

NMI	**Full name**	**Country**	**Regional metrology organization**
ANSTO	Australian Nuclear Science and Technology Organisation	Australia	APMP
ENEA-INMRI	Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile - Istituto Nazionale di Metrologia delle Radiazioni Ionizzanti	Italy	EURAMET
IFIN-HH	Institutul de Fizica si Inginerie Nucleara - "Horia Hulubei"	Romania	EURAMET
LNE-LNHB	Laboratoire national de métrologie et d'essais - Laboratoire national Henri Becquerel	France	EURAMET
LNMRI-IRD	Laboratorio Nacional de Metrologia das Radiaçoes Ionizantes/ Instituto de Radioproteção e Dosimetria	Brazil	SIM
NIST	National Institute of Standards and Technology	United States	SIM
NMISA	National Metrology Institute, South Africa	South Africa	SADCMET
POLATOM	National Centre for Nuclear Research, Radioisotope Centre	Poland	EURAMET
PTB	Physikalisch-Technische Bundesanstalt	Germany	EURAMET

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 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 two new submissions are given in the report of the CCRI(II)-K2.Lu-177 comparison [4], previous uncertainty budgets are given in the earlier K1 report [3]. The uncertainty budgets for all the participants in the CCRI(II)-K2.Lu-177 comparison were published in the final report [4]. The acronyms used for the measurement methods are given in Appendix 1.

The half-life used by the BIPM has been updated to 6.647 (4) d from the BIPM Monographie 5 [6] and all the results in Table 4a have been updated accordingly. The same half-life value was used in the CCRI(II)-K2 comparison.

Table 2. Standardization methods of the participants for ^{177}Lu

NMI	Method used and acronym (see Appendix 1)	Half-life / d	Activity A_i / kBq	Reference date	Relative standard uncertainty × 100 by method of evaluation	
				YYYY-MM-DD	A	B
PTB	LSC 4P-LS-MX-00-00-CN and 4πβ–γ coincidence 4P-PC-BP-NA-GR-CO	6.646 (5) [7]	138 790	2000-01-19 0 h UTC	0.20	0.40
NIST	4πβ LS [8] 4P-LS-MX-00-00-CN	6.60 (1)	133 850	2000-02-01 17 h UTC	0.19	0.28
NPL	4P-PC-BP-NA-GR-CO 4P-LS-MX-00-00-CN 4P-LS-BP-NA-GR-CO	6.647 (4) [6]	11 790#	2009-05-01 12 h UTC	0.03	0.30
IRMM	4P-LS-MX-00-00-CN 4P-PC-BP-NA-GR-CO	6.647 (4) [6]	2 462*	2009-05-01 12 h UTC	–	1.64

* Partially weighted mean (power = 1) of the rather discrepant results obtained with the two methods indicated.

corresponds to an activity concentration of 3 286 kBq g^{-1} (see Table 4b) evaluated as the arithmetic mean of the three results obtained with the three methods given in column 2.

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 has developed a standard method for evaluating the activity of impurities using a calibrated Ge(Li) spectrometer [9]. The CCRI(II) agreed in 1999 [10] that this method should be followed according to the protocol described in [11] when an NMI makes such a request or when there appear to be discrepancies. It was not necessary to use the results of the impurity measurements made at the BIPM to correct the results of NPL and IRMM in the present case.

Table 3. Details of the solution of ^{177}Lu submitted

NMI, year	Chemical composition	Solvent conc. / (mol dm^{-3})	Carrier: conc. /(μg g^{-1})	Density /(g cm^{-3})	Relative activity of ^{177}Lu^{m} impurity[a]
PTB, 2000	$LuCl_3$ in HCl	0.1	$LuCl_3$: 20	0.999	6.9 (6) × 10^{-3} %
NIST, 2000	Lu in HCl	0.01	-	1.00	27.1 (5) × 10^{-3} % [b]
NPL, 2009 [c]	$LuCl_3$ in HCl	1	$LuCl_3$: 20	1.0	33 (3) × 10^{-3} %
IRMM, 2009 [d]	$LuCl_3$ in HCl	1	$LuCl_3$: 20	1.037	40 (10) × 10^{-3} % 33.5 (7) × 10^{-3} % [e]

[a] the ratio of the activity of the impurity to the activity of ^{177}Lu at the reference date.
[b] measured at the BIPM [3, 12].
[c] same solution as for the CCRI(II)-K2.Lu-177 comparison.
[d] same solution as for the CCRI(II)-K2.Lu-177 comparison but diluted by a factor of 4.955 317.
[e] weighted mean value from the CCRI(II)-K2.Lu-177 comparison, used for the evaluation of the KCRV and for the link of the K2 comparison.

4. Results

All the submissions to the SIR since its inception in 1976 are maintained in a database known as the "master-file". The SIR equivalent activity, A_{ei}, for each ampoule for the previous and new results is given in Table 4a. The date of measurement in the SIR is also given and is 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 submitted activities are compared with a given source of ^{226}Ra, all the SIR results are normalized to the radium source number 5 [1].

All the results in Table 4a have been re-evaluated using updated values for the equivalent activities needed for the SIR impurity corrections: A_e(^{177}Lu) = 559 (3) MBq and A_e(^{177m}Lu) = 16.94 (22) MBq. Moreover, it should be noted that the influence of the daughter ^{177}Lu from the ^{177m}Lu decay has a relative influence of less than a few 10^{-4} on the SIR result (1 % in relative terms on the ^{177m}Lu impurity correction which amounts, at maximum, to 3.5×10^{-2} for the NIST ampoule). This re-evaluation gives slightly improved consistency in the repeated SIR results of the PTB and NIST ampoules compared to the results given in [12].

The NPL and IRMM SIR measurements were repeated after seven days and four days respectively giving a result in agreement within two standard uncertainties.

In view of the large uncertainty given by the IRMM for the activity measurement of the ^{177m}Lu impurity, it was agreed with this laboratory that for the evaluation of the KCRV and the link to the CCRI(II)-K2.Lu-177 comparison the weighted mean ^{177m}Lu activity value from the CCRI(II)-K2.Lu-177 comparison [4, 5] is used instead of the IRMM value. For the degrees of equivalence the IRMM result remains unchanged (see tables 3 and 4).

Table 4a. Results of SIR measurements of ^{177}Lu

NMI, year	Mass of solution /g	Activity submitted A_i / kBq	N° of Ra source used	SIR A_e / MBq	Relative uncertainty from SIR	Combined uncertainty u_i / MBq
PTB, 2000	3.675 5	138 790	3	559.0	11×10^{-4}	2.7
NIST, 2000	3.627 4	133 850	3	551.5	14×10^{-4}	2.0
NPL, 2009	3.589 37	11 790	2	559.5 [a]	13×10^{-4}	1.8
IRMM, 2009	3.674 99	2 462	1	566.3 565.2 [#, a]	33×10^{-4} * 13×10^{-4} #	9.5 9.3 [#]

* dominated by the uncertainty on the impurity correction in the SIR measurement because of the large uncertainty on the ^{177m}Lu activity quoted by the participant

[#] result when the weighted mean ^{177m}Lu activity value from the CCRI(II)-K2 comparison is used in the impurity correction of the SIR measurement

[a] results used to link the CCRI(II)-K2 comparison

No recent submission has been identified as a pilot study so the result of each NMI is normally eligible for the key comparison database (KCDB) of the CIPM MRA.

An international comparison for this radionuclide, CCRI(II)-K2.Lu-177 was held in 2009 [4, 5] and the results of that comparison have been linked to the BIPM.RI(II)-K1.Lu-177 comparison through the participations of the NPL and the IRMM in both comparisons.

The nine laboratories to be added to the matrix of degrees of equivalence from the CCRI(II)-K2.Lu-177 comparison are given in Table 4b. The results $(A/m)_i$ for these laboratories are linked to the SIR through the measurement in the SIR of two ampoules of the same solution standardized by the NPL and the IRMM. The link is made using a normalization ratio deduced from the weighted mean of the values in the rows indicated in Table 4a and taking into account the dilution factor for the IRMM:

$$A_{ei} = (A/m)_i \times \sum_{j=1}^{2} w_j \left(A_{e,\mathrm{Link}\,j} / (A/m)_{\mathrm{Link}\,j} \right) = (A/m)_i \times 170.25 \qquad \text{(a)}$$

The details of the links are given in Table 4b. The uncertainties for the CCRI(II) comparison results linked to the SIR are comprised of the original uncertainties together with the uncertainty in the link, 9×10^{-4}, given by the internal standard deviation of the linking values from the NPL and IRMM ampoules. Such a standard deviation lower than 10^{-3} is obtained when the impurity correction of the IRMM result is based on the weighted mean ^{177m}Lu activity value from the CCRI(II)-K2.Lu-177 comparison.

The PTB result in the CCRI(II)-K2.Lu-177 comparison is in close agreement with the earlier SIR result of the PTB. The NIST SIR and K2 results differ by 1.4 % and this is probably related to problems in the ^{177m}Lu impurity corrections in the now superseded SIR measurement in 2000 (see [12]). For this reason, the NIST SIR result is no more included in the KCRV. The NIST 2009 K2 result agrees with the KCRV to within one standard uncertainty.

Table 4b. Results of the 2009 CCRI(II) comparison of ^{177}Lu and links to the SIR

NMI	Measurement method and acronym (see Appendix 1 and [4, 5])	Activity* concentration measured $(A/m)_i$ / (MBq g^{-1})	Standard uncertainty u_i / (MBq·g^{-1})	Equivalent SIR activity A_{ei} / MBq	Combined standard uncertainty u_i / MBq
ANSTO	4P-PC-BP-NA-GR-CO	3.264	0.8×10^{-2}	555.8	1.4
ENEA-INMRI	4P-LS-MX-00-00-CN 4P-NA-MX-00-00-HE	3.314	2.2×10^{-2}	564.1	3.8
IFIN-HH	4P-LS-BP-NA-GR-CO	3.386	4.4×10^{-2}	576.5	7.5
LNE-LNHB	4P-LS-BP-NA-GR-AC 4P-LS-MX-00-00-TD	3.311	0.9×10^{-2}	563.7	1.6
LNMRI-IRD	4P-PC-BP-NA-GR-AC 4P-PC-BP-NA-GR-CO	3.276 [a]	2.0×10^{-2}	557.8	3.4
NIST	4P-LS-BP -NA-GR-AC	3.286	1.1×10^{-2}	559.4	1.9
NMISA	4P-LS-BP-NA-GR-CO	3.293	0.9×10^{-2}	560.6	1.5
POLATOM	4P-LS-BP-NA-GR-CO/AC	3.279	1.8×10^{-2}	558.2	3.1
PTB	4P-PC-BP-NA-GR-CO 4P-LS-MX-00-00-TD 4P-LS-MX-00-00-CN	3.281	0.6×10^{-2}	558.6	1.2
NPL	4P-PC-BP-NA-GR-CO 4P-LS-MX-00-00-CN 4P-LS-BP-NA-GR-CO	3.286	1.0×10^{-2}	see Table 4a	
IRMM	4P-LS-MX-00-00-CN 4P-PC-BP-NA-GR-CO	3.320	5.4×10^{-2}	see Table 4a	

*referenced to 12:00 UTC 1 May 2009
[a] Median of six values obtained from the LNMRI/IRD and IPEN/CNEN

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 [13]. 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.
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 ^{177}Lu in May 2013, or by consensus through electronic means (e.g., email) as discussed at the CCRI(II) meeting in 2013.

Consequently, the KCRV for ^{177}Lu has been calculated as 559.9 (1.8) MBq on the basis of the SIR results from the PTB, NPL and the IRMM. The NIST SIR result is not included as explained above. This KCRV can be compared with the value of 560.1 (3.1) MBq obtained using the SIRIC efficiency curve of the SIR [14].

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

$$D_i = A_{\mathrm{e}\,i} - \mathrm{KCRV} \tag{1}$$

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

$$U_i = 2u(D_i)\,. \tag{2}$$

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

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

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

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

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

$$D_{ij} = D_i - D_j = A_{\mathrm{e}\,i} - A_{\mathrm{e}\,j} \tag{5}$$

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

$$u(D_{ij})^2 = u_i^{\,2} + u_j^{\,2} - 2u(A_{\mathrm{e},i}, A_{\mathrm{e},j}) \tag{6}$$

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 $u(A_{\mathrm{e}i}, A_{\mathrm{e}j})$ (see [15] 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 ^{177}Lu, BIPM.RI(II)-K1.Lu-177 currently comprises two results. These have been analysed with respect to the updated KCRV determined for this radionuclide. The results of the CCRI(II)-K2.Lu-177 comparison held in 2009 have been linked to the BIPM comparison through the mutual participations of the NPL and the IRMM. This has enabled the table of degrees of equivalence to include eleven results in total.

The degrees of equivalence have been approved by the CCRI(II) and are published in the BIPM key comparison database. Further results may be added when other NMIs contribute ^{177}Lu activity measurements to the ongoing comparison or take part in other linked comparisons.

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Table 5. Table of degrees of equivalence and introductory text for ^{177}Lu

Key comparison BIPM.RI(II)-K1.Lu-177

MEASURAND : **Equivalent activity of ^{177}Lu**

Key comparison reference value: the SIR reference value x_R for this radionuclide is 559.9 MBq, with a standard uncertainty u_R of 1.8 MBq.
The value x_i is taken as 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
$U_i = 2((1 - 2w_i)u_i^2 + u_R^2)^{1/2}$ when each laboratory has contributed to the calculation of x_R.

When required, the degree of equivalence between two laboratories is given by a pair of numbers:
$D_{ij} = D_i - D_j = (x_i - x_j)$ and U_{ij}, its expanded uncertainty (k = 2), both expressed in MBq.
The approximation $U_{ij}^2 \sim 2^2(u_i^2 + u_j^2)$ may be used.

Linking CCRI(II)-K2.Lu-177 to BIPM.RI(II)-K1.Lu-177

The value x_i is the equivalent activity for laboratory *i* participant in CCRI(II)-K2.Lu-177 having been normalized to the value of the NPL and IRMM as the linking laboratories.

The degree of equivalence of laboratory *i* participant in CCRI(II)-K2.Lu-177 with respect to the key comparison 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.

The approximation $U_i = 2(u_i^2 + u_R^2)^{1/2}$ is used in the following table as none of these D_i contributed to the KCRV.

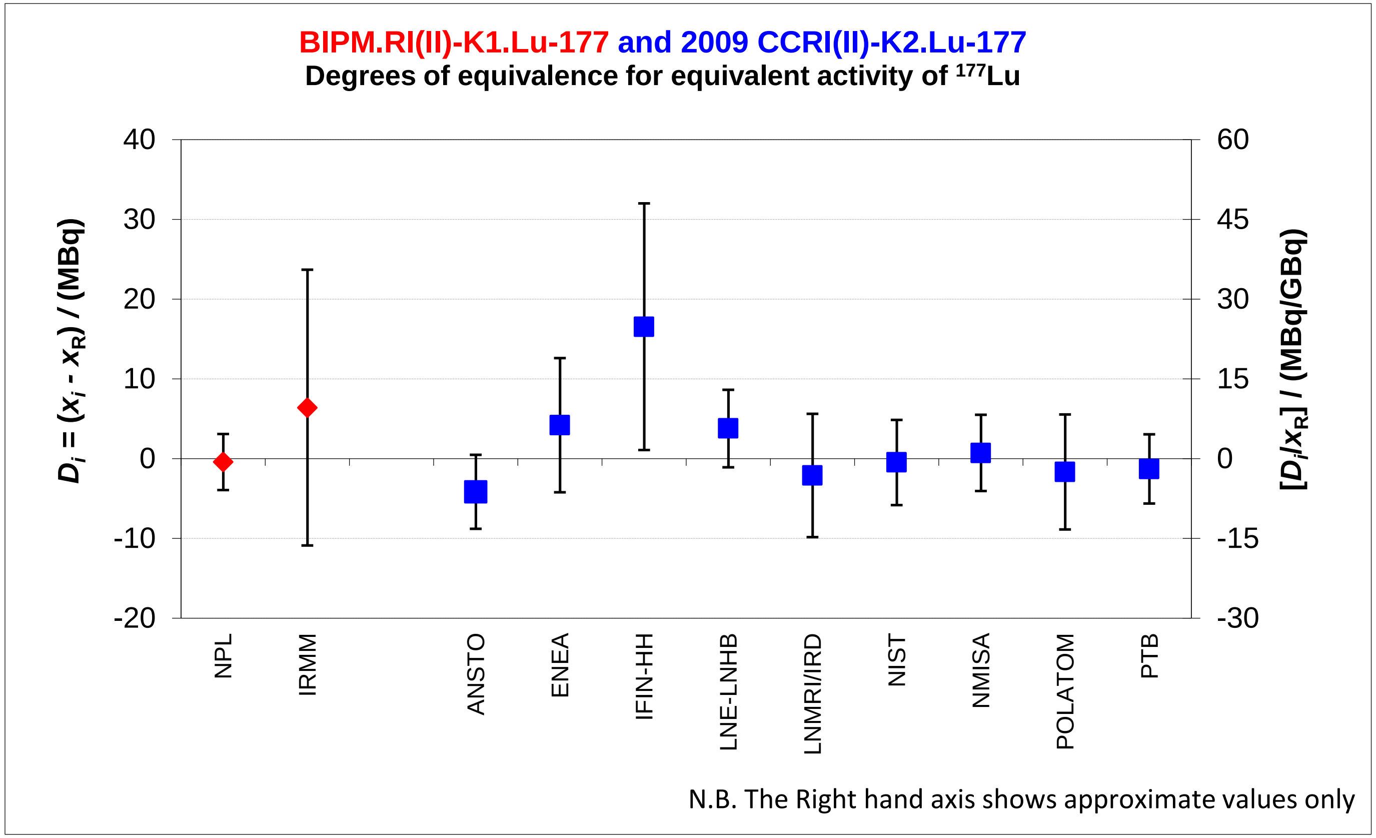
When required, the degree of equivalence between two laboratories *i* and *j*, one participant in BIPM.RI(II)-K1.Lu-177 and one in CCRI(II)-K2.Lu-177, or both participants in CCRI(II)-K2.Lu-177, is given by a pair of terms expressed in MBq: $D_{ij} = D_i - D_j$ and U_{ij}, its expanded uncertainty (k = 2), approximated by $U_{ij} \sim 2(u_i^2 + u_j^2 - 2fu_l^2)^{1/2}$ with *l* being the linking laboratory when each laboratory is from the CCRI(II)-K2 and *f* is the correlation coefficient.

These statements make it possible to extend the BIPM.RI(II)-K1.Lu-177 matrices of equivalence to the participants in CCRI(II)-K2.Lu-177.

Lab *i* ⇩

	D_i / MBq	U_i / MBq
NPL	0	4
IRMM	6	17
ANSTO	**-4**	**5**
ENEA	**4**	**8**
IFIN-HH	**17**	**15**
LNE-LNHB	**4**	**5**
LNMRI/IRD	**-2**	**8**
NIST	**0**	**5**
NMISA	**1**	**5**
POLATOM	**-2**	**7**
PTB	**-1**	**4**

Figure 1. Graph of degrees of equivalence with the KCRV for ^{177}Lu



Appendix 1. 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
		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 + γ)	PH	triple-to-double coincidence ratio counting	TD
alpha - particle	AP	selective sampling	SS
mixture of various radiations	MX	high efficiency	HE

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