European Commission

JRC REFERENCE MATERIALS

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2014

Report EUR 26520 EN

Joint Research Centre

European Commission
Joint Research Centre
Institute for Reference Materials and Measurements

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This publication is a Reference Materials Report by the Joint Research Centre of the European Commission.

JRC87429

EUR 26520 EN

ISBN 978-92-79-35502-8

ISSN 1831-9424

doi:10.2787/89614

Luxembourg: Publications Office of the European Union, 2014

Printed in Belgium

CERTIFICATION REPORT

Preparation and Certification of Large-Sized Dried (LSD) Spike - IRMM-1027p

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Summary

IRMM Large-Sized Dried (LSD) Spikes are widely used as a fundamental part of the fissile material control of irradiated nuclear fuel and have been provided on a regular basis to safeguards authorities and industry for more than 10 years. This report describes the preparation and certification of a new batch of LSD Spikes. IRMM-1027p is a dried nitrate material in cellulose acetate butyrate (CAB), certified for the mass of uranium and plutonium and isotope amount ratios per unit. The material was produced following ISO Guide 34:2009 [1].

The certified reference materials uranium metal EC NRM 101, enriched uranium metal NBL CRM-116 and plutonium metal CETAMA MP2 were used as starting materials to prepare the mother solution. This solution was dispensed by means of an automated robot system into individual units and dried down. A solution of an organic substance, cellulose acetate butyrate (CAB), was dried on the spike material as a stabiliser to retain the dried material at the bottom of the vial.

Between unit-homogeneity was quantified and stability during dispatch and storage were assessed in accordance with ISO Guide 35:2006 [2].

The certified values were obtained from the gravimetric preparation of the mother solution, taking into account the mass, purity and isotopic abundances of the starting materials, the mass of the mother solution, and the mass of an aliquot in each individual unit. The certified values were confirmed by isotope dilution thermal ionisation mass spectrometry (ID-TIMS) and thermal ionisation mass spectrometry (TIMS) as independent confirmation methods.

Uncertainties of the certified values were estimated in compliance with the Guide to the Expression of Uncertainty in Measurement (GUM) [3] and include uncertainties related to possible inhomogeneity and to characterisation.

This spike CRM is applied as a calibrant to measure the uranium and plutonium amount content of dissolved spent nuclear fuel solutions using isotope dilution mass spectrometry (IDMS). Each unit contains about 50 mg of uranium with a relative mass fraction $m(^{235}U)/m(U)$ of 17.4 % and 1.8 mg of plutonium with a relative mass fraction $m(^{239}Pu)/m(Pu)$ of 97.8 % as dried nitrates in CAB. The whole amount of sample per unit has to be used for analysis.

The following values were assigned:

	Isotope amount ratios	
	Certified value [1)] [mol/mol]	Uncertainty [2)] [mol/mol]
$n(^{234}U)/n(^{238}U)$	0.0022637	0.0000018
$n(^{235}U)/n(^{238}U)$	0.21390	0.00008
$n(^{240}Pu)/n(^{239}Pu)$	0.022421	0.000009
$n(^{241}Pu)/n(^{239}Pu)$	0.0001709	0.0000025
$n(^{242}Pu)/n(^{239}Pu)$	0.0000757	0.0000011
The certified masses and the uncertainties of ^{235}U, ^{238}U and ^{239}Pu per unit are listed on pages 3 to 26 of the certificate in Annex 1.		

[1)] The certified values are traceable to the values on the respective metal certificates and report of analysis (Annexes 2 - 7). The reference date for the plutonium and uranium isotope amount ratios is November 1, 2013.

[2)] The certified uncertainty is the expanded uncertainty with a coverage factor $k = 2$ corresponding to a level of confidence of about 95 % estimated in accordance with ISO/IEC Guide 98-3, Guide to the Expression of Uncertainty in Measurement (GUM:1995), ISO, 2008.

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Glossary

ANOVA	Analysis of variance
BIPM	Bureau International des Poids et Mesures (International Bureau of Weights and measures)
c	amount of substance concentration
CAB	Cellulose acetate butyrate
CETAMA	Commission D`Etablissement des Methodes D`Analyse
CRM	Certified reference material
EC	European Commission
ESARDA	European Safeguards Research and Development Association
GUM	Guide to the Expression of Uncertainty in Measurements [3]
IAEA	International Atomic Energy Agency
IDMS	Isotope dilution mass spectrometry
ID-TIMS	Isotope dilution thermal ionisation mass spectrometry
IRMM	Institute for Reference Materials and Measurements of the JRC
ITU	Institute for Transuranium Elements of the JRC
ITVs	International Target Values
JRC	Joint Research Centre of the European Commission
k	Coverage factor
LSD	Large-Sized Dried
m	mass
M	Molar mass
MS	Mass spectrometry
$MS_{between}$	Mean of squares between-unit from an ANOVA
MS_{within}	Mean of squares within-unit from an ANOVA
n	amount of substance
N	Number of replicates per unit
NBL	New Brunswick Laboratory
rel	Index denoting relative figures (uncertainties etc.)
RM	Reference material
s	Standard deviation
s_{bb}	Between-unit standard deviation; an additional index "rel" is added when appropriate
SI	International System of Units
SDS	Safety data sheet

s_{wb}	Within-unit standard deviation
TIMS	Thermal Ionisation Mass Spectrometry
u	Standard uncertainty
U	Expanded uncertainty
u^*_{bb}	Standard uncertainty related to a maximum between-unit inhomogeneity that could be hidden by method repeatability; an additional index "rel" is added as appropriate
u_{bb}	Standard uncertainty related to a possible between-unit inhomogeneity; an additional index "rel" is added as appropriate
u_{char}	Standard uncertainty of the material characterisation; an additional index "rel" is added as appropriate
u_{CRM}	Combined standard uncertainty of the certified value; an additional index "rel" is added as appropriate
U_{CRM}	Expanded uncertainty of the certified value; an additional index "rel" is added as appropriate
u_{lts}	Standard uncertainty of the long-term stability; an additional index "rel" is added as appropriate
u_{sts}	Standard uncertainty of the short-term stability; an additional index "rel" is added as appropriate
$\bar{y}$	Arithmetic mean
α	Significance level
$\nu_{MSwithin}$	Degrees of freedom of MS_{within}

1 Introduction

1.1 Background

The International Target Values for Measurement Uncertainties in Safeguarding Nuclear Materials (ITVs) are uncertainties to be considered in judging the reliability of analytical techniques applied to industrial nuclear and fissile material, which are subject to safeguards verification. ITVs should be achievable under the conditions normally encountered in typical industrial laboratories or during actual safeguards inspections. In 2010, the International Atomic Energy Agency (IAEA) together with the European Safeguards Research and Development Association (ESARDA), international standardisation organisations and regional safeguards authorities published a revised version of the ITVs [4]. The ITVs-2010 are intended to be used by nuclear plant operators and safeguards organisations as a reference of the quality of measurements necessary for nuclear material accountancy. The series of IRMM-1027 Large-Sized Dried (LSD) spikes are prepared by IRMM to meet the existing requirement for reliable isotope reference materials for the accountancy measurements of uranium and plutonium by IDMS in compliance with the ITVs-2010 in spent nuclear fuel. These spikes contain relatively large amounts of uranium and plutonium (50 mg U and 1.8 mg Pu), isotopically different to the uranium and plutonium in the test sample and are in dried nitrate form. About 1200 units of IRMM-1027 LSD spikes are prepared annually to fulfil the demands for fissile material control from European Safeguards Authorities and industry [5].

1.2 Choice of the material

The IRMM-1027p batch of LSD spikes was prepared from certified reference metals (EC NRM 101, NBL CRM-116 and CETAMA MP2). Each unit contains about 50 mg of uranium with a relative mass fraction $m(^{235}U)/m(U)$ of 17.4 % and 1.8 mg of plutonium with a relative mass fraction $m(^{239}Pu)/m(Pu)$ of 97.8 %. The relative mass fraction $m(^{235}U)/m(U)$ is below 20 %, so that for accountability purposes the uranium is classified as "low enriched". Individual units are certified for the mass of plutonium and uranium and for the isotope amount ratios. The uranium and plutonium amount content in a single IRMM-1027 LSD spike is such that no dilution of a typical sample of dissolved fuel is needed before measurement by IDMS. As the dried nitrates could flake off the vial surface over time or during transport, an organic polymer in the form of cellulose acetate butyrate (CAB) is added to retain the material at the bottom of the vial.

1.3 Design of the project

The individual units of IRMM-1027p LSD spikes were prepared by dispensing aliquots of the mother solution into vials and dried down. This solution was prepared gravimetrically by dissolving uranium and plutonium certified reference metals in nitric acid. Finally, the dried nitrate was treated with CAB for preservation during storage and transport. The certified masses and the isotope amount ratios are based on the data given by the weighing certificates and the certificate of the starting materials. Confirmation measurements, homogeneity and stability assessment were combined using IDMS analysis on selected vials.

2 Participants

Project management and evaluation, processing, homogeneity study, stability study and characterisation have been performed at the European Commission, Joint Research Centre, Institute for Reference Materials and Measurements (IRMM), Geel, Belgium.

3 Material processing and process control

3.1 Origin and purity of the starting materials

CRMs of high purity uranium (EC NRM 101, Geel, Belgium and NBL CRM-116, Argonne, USA) and plutonium (CETAMA MP2, Marcoule, France) metals were used as starting materials for the preparation of the IRMM-1027p LSD spikes. The isotopic composition and the purity of the metals are given in Annexes 2 - 7.

3.2 Processing

The respective units of plutonium MP2 metal for the preparation of the IRMM-1027p mother solution were weighed and transferred into a pre-cleaned 3 L borosilicate flask. The metal was dissolved by addition of a solution prepared from concentrated nitric acid (*p.a.*, Merck, Darmstadt, Germany), a few drops of concentrated hydrofluoric acid (*p.a.*, Merck, Darmstadt, Germany) and deionised water. After heating on a hot plate at 90 °C for several days, the addition of the solution and the heating step were repeated until the plutonium metal dissolved completely. The dissolution of plutonium metal was controlled by visual inspection. Subsequently the respective units of enriched uranium metal (NBL CRM-116) and of natural uranium metal (EC NRM 101) were weighed and added into the above solution. Prior to weighing, the units of NBL CRM-116 metal were etched with 1 M HNO_3 to remove surface oxides, and subsequently rinsed with deionised water and acetone (*p.a.*, Merck, Darmstadt, Germany) and dried down. Finally, a solution prepared from concentrated nitric acid and deionised water was added to adjust the concentration of the solution to 5 M HNO_3. The solution was left to homogenise for a few days with occasionally swirling by hand, and weighed to determine the final concentrations of the uranium and plutonium in the solution, taking into account the necessary corrections for air buoyancy effects.

Prior to dispensing the mother solution into individual vials four aliquots were analysed by ID-TIMS to confirm the concentration of plutonium and uranium from gravimetric preparation (see Section 3.3).

Dispensing and weighing of the solution into individual vials were performed by a validated automated system, which was installed at IRMM in collaboration with Nucomat (Lokeren, Belgium) [6]. The major components of the system are a robot, two balances and a dispenser. The robot is software driven and designed to control all movements inside the glove box, such as identifying the vial with a barcode reader, dispensing and weighing of an aliquot of the solution (2.5 g) into the vials. The weighing component is equipped with an analytical balance (Sartorius TE124S, Göttingen, Germany) and a 5 kg balance (Sartorius TE6101, Göttingen, Germany) to monitor the mass of the mother solution during dispensing. The whole solution (about 3 kg) was dispensed into 1186 units in five consecutive working days.

The drying of the dispensed solution contained in the units was carried out on a hot plate equipped with a sensor for controlling the surface temperature. This temperature was increased to a maximum of 60 °C and the units were kept at this temperature for several

days (typically 4-5 days continuous heating) to evaporate the solution completely. After the solution had dried, about 0.7 mL of 10 wt% CAB solution in acetone (35-39 wt% butyryl content, Acros, New Jersey, USA) was added. This solution was evaporated at room temperature and then heated to about 45 °C to dry completely. CAB was added to retain the dried material at the bottom of the vial so that it can resist physical shocks that might be encountered during transport and to avoid flaking of the material during long-term storage. This cellulose matrix dissolves readily in warm nitric acid solution and has no significant effect on the subsequent IDMS analysis. This has been demonstrated by measurements performed both on the vials (containing CAB) and on the mother solution (without CAB). Two separate glove boxes were used for drying and CAB application, allowing the preparation of up to 48 units per week. The vials were closed with an iso-versilic stopper and an aluminium cap, sealed in PVC package and labelled. The processing steps are shown in Figure 1.

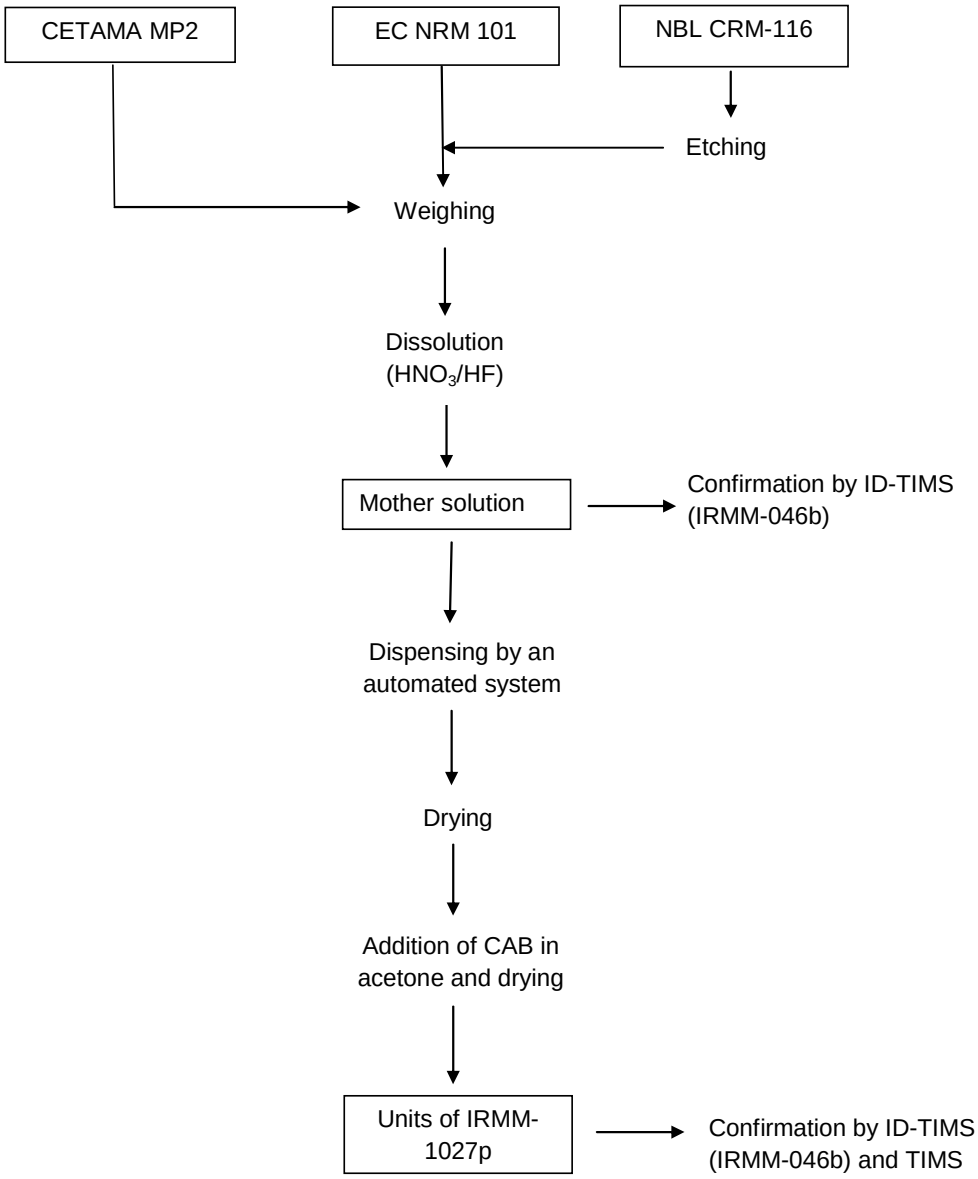

Fig. 1 Preparation of IRMM-1027p LSD spikes

3.3 Process control

This section describes the confirmation measurements performed on the mother solution prior to dispensing into individual vials.

Four aliquots (about 2.5 g each) were individually spiked with a mixed U/Pu spike CRM (IRMM-046b) for ID-TIMS analysis to confirm the concentration of uranium and plutonium in the solution from gravimetric preparation. The IRMM-046b certificate can be found in Annex 8. One unspiked aliquot was analysed to determine the isotopic composition (e.g. uranium and plutonium amount ratios) by thermal ionisation mass spectrometry (TIMS).

The spiked and unspiked solutions were evaporated to dryness and dissolved in 200 µL nitric acid (c = 2 mol L^{-1}, *p.a.*, Merck, Darmstadt, Germany). To achieve isotopic equilibrium between the spike and the sample, first 50 µL iron(II) chloride solution (c = 1.25 mol L^{-1}, *p.a.*, Merck, Darmstadt, Germany) was added to reduce plutonium to Pu(III) and then 100 µL hydroxyl ammonium chloride solution (c = 1 mol L^{-1}, *p.a.*, Merck, Darmstadt, Germany) and 100 µL sodium nitrite (c = 1 mol L^{-1}, *p.a.*, Merck, Darmstadt, Germany) to oxidise Pu(III) to Pu(IV). Finally 430 µL concentrated nitric acid were added to obtain Pu(IV) in nitric acid with an amount of substance concentration of 8 mol L^{-1}. The U/Pu separation was performed using anion-exchange columns (Bio-Rad AG1-X4, 100-200 mesh, Bio-Rad, Hercules, USA). Uranium was eluted with nitric acid (c = 8 mol L^{-1}) and plutonium with nitric acid (c = 0.35 mol L^{-1}). The separation was repeated once for uranium and twice for plutonium to avoid isobaric interference in the TIMS measurement. Both purified fractions were evaporated and re-dissolved in nitric acid (c = 1 mol L^{-1}) to give concentrations of 1 mg Pu mL^{-1} and 5 mg U mL^{-1} for loading the rhenium filaments. The isotopic measurements of the uranium and plutonium were performed on a Triton TIMS (Thermo Fischer Scientific, Bremen, Germany) [7].

The results of the confirmation measurements for ^{239}Pu and ^{235}U amount contents in the mother solution of IRMM-1027p agreed within the uncertainties with the values from the gravimetrical preparation and are shown in Annex 9.

A unit of IRMM-1027p LSD spike can be seen in Figure 2.

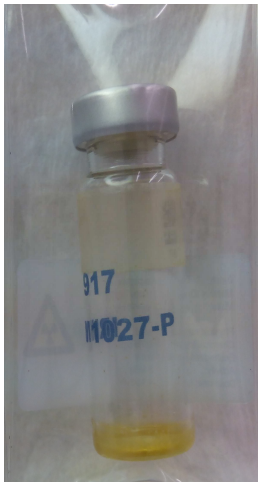

Fig. 2 Unit of IRMM-1027p LSD spike

4 Homogeneity

A key requirement for any reference material is the equivalence between the various units. In this respect, it is relevant whether the variation between units is significant compared to the uncertainty of the certified value. In contrast to that it is not relevant if this variation between units is significant compared to the analytical variation. Consequently, ISO Guide 34 [1] requires RM producers to quantify the between unit variation. This aspect is covered in

between-unit homogeneity studies. The homogeneity study was combined together with the measurements to confirm the gravimetric preparation of the IRMM-1027p LSD spikes.

4.1 Between-unit homogeneity

The between-unit homogeneity was evaluated to ensure that the certified values of the CRM are valid for all 1186 units of the material, within the stated uncertainty.

The number of selected units corresponds to approximately the cubic root of the total number of the produced units (1186). Ten units were selected to assess the homogeneity for the amount content and ten units for the isotope amount ratios using a random stratified sampling scheme covering the whole batch for the between-unit homogeneity test. The batch was divided into ten groups (with a similar number of units) and one unit was selected randomly from each group. The whole amount of sample per unit (equals minimum sample intake) was taken, chemically separated and the isotopic measurements were performed on a fraction of the purified sample. Each sample was measured in three replicates together with the isotopic standards to correct for instrumental mass fractionation. This enabled five independent samples to be measured on the same TIMS sample carrousel on the same day. Therefore, the measurements for all twenty units of IRMM-1027p were performed under intermediate precision conditions rather than repeatability conditions. The respective fractions of the samples were measured in a randomised manner to be able to separate a potential analytical drift from a trend in the filling sequence. Some of the measured data had to be excluded from the evaluation due to technical reasons, such as e.g. loss of sample prior to total evaporation measurement, high background from the filament due to unusually high filament temperatures, very low signal intensity. The results of the homogeneity study are shown in Annex 10 and Annex 11.

Regression analyses were performed to evaluate potential trends in the analytical sequence as well as trends in the filling sequence. No trends in the filling sequence or the analytical sequence were visible.

Quantification of between-unit inhomogeneity was accomplished by analysis of variance (ANOVA), which can separate the between-unit variation (s_{bb}) from the within-unit variation (s_{wb}). The latter is equivalent to the method repeatability if the individual samples are representative for the whole unit.

Evaluation by ANOVA requires unit means that follow at least a unimodal distribution and results for each unit that follow unimodal distributions with approximately the same standard deviations. Distribution of the unit means was visually tested using histograms and normal probability plots. Minor deviations from unimodality of the individual values do not significantly affect the estimate of between-unit standard deviations. The results of all statistical evaluations are given in Table 1 and Table 2.

Table 1: Results of the statistical evaluation of the homogeneity studies of the amount content at 99 % confidence level

Amount content (ID-TIMS)	Trends		Outliers		Distribution	
	Analytical sequence	Filling sequence	Individual results	Unit means	Individual results	Unit means
^{235}U	no	no	none	none	unimodal	unimodal
^{238}U	no	no	none	none	unimodal	unimodal
^{239}Pu	no	no	none	none	unimodal	unimodal

Table 2: Results of the statistical evaluation of the homogeneity studies of the isotope amount ratios at 99 % confidence level

Amount ratios (TIMS)	Trends		Outliers		Distribution	
	Analytical sequence	Filling sequence	Individual results	Unit means	Individual results	Unit means
$n(^{234}U)/n(^{238}U)$	no	no	none	none	unimodal	unimodal
$n(^{235}U)/n(^{238}U)$	no	no	none	none	unimodal	unimodal
$n(^{240}Pu)/n(^{239}Pu)$	no	no	one	none	unimodal	unimodal
$n(^{241}Pu)/n(^{239}Pu)$	no	no	none	none	unimodal	unimodal
$n(^{242}Pu)/n(^{239}Pu)$	no	no	none	none	unimodal	unimodal

One outlying individual result was found for the $n(^{240}Pu)/n(^{239}Pu)$ amount ratio (Grubbs single and double test at $\alpha = 0.01$). Since no technical reason was identified for the outlying results, the data was retained for statistical analysis.

One has to bear in mind that $s_{bb,rel}$ and $s_{wb,rel}$ are estimates of the true standard deviations and therefore subject to random fluctuations. Therefore, the mean square between groups ($MS_{between}$) can be smaller than the mean squares within groups (MS_{within}), resulting in negative arguments under the square root used for the estimation of the between-unit variation, whereas the true variation cannot be lower than zero. In this case, u^*_{bb}, the maximum inhomogeneity that could be hidden by method repeatability, was calculated as described by Linsinger *et al.* [8]. u^*_{bb} is comparable to the limit of detection of an analytical method, yielding the maximum inhomogeneity that might be undetected by the given study setup.

Method repeatability ($s_{wb,rel}$), between–unit standard deviation ($s_{bb,rel}$) and $u^*_{bb,rel}$ were calculated as:

$$s_{wb,rel} = \frac{\sqrt{MS_{within}}}{\bar{y}} \qquad \textbf{Equation 1}$$

$$s_{bb,rel} = \frac{\sqrt{\frac{MS_{between} - MS_{within}}{N}}}{\bar{y}} \qquad \textbf{Equation 2}$$

$$u^*_{bb,rel} = \frac{\sqrt{\frac{MS_{within}}{N}}\sqrt[4]{\frac{2}{v_{MSwithin}}}}{\bar{y}} \qquad \textbf{Equation 3}$$

MS_{within} mean square within a unit from an ANOVA

$MS_{between}$ mean squares between-unit from an ANOVA

$\bar{y}$ mean of all results of the homogeneity study

N mean number of replicates per unit

$v_{MSwithin}$ degrees of freedom of MS_{within}

The uncertainty contribution for homogeneity was determined under intermediate precision conditions because the isotopic measurements for all selected units of IRMM-1027p could not be carried out on the same day. Consequently, day-to-day effects can occur that could mask the between-unit variation. Therefore, the data were first checked using one way-ANOVA for any significant difference in between-day means. A significant day-to-day difference was observed for the ^{235}U and ^{238}U amount contents, and for $n(^{235}U)/n(^{238}U)$ and $n(^{240}Pu)/n(^{239}Pu)$ amount ratios. For that reason, the data were first normalised by the respective day mean and the resulting data were evaluated using one way-ANOVA. The results of the evaluation of the between-unit variation are summarised in Table 3 and Table 4. The resulting values from the above equations were converted into relative uncertainties.

Table 3: Results of the homogeneity studies of the amount content

	$s_{wb,rel}$ [1)] [%]	$s_{bb,rel}$ [1)] [%]	$u^*_{bb,rel}$ [1)] [%]
^{235}U content	0.01844	0.01864	0.00599
^{238}U content	0.04425	0.01559	0.01437
^{239}Pu content	0.02021	0.02227	0.00698

[1)] Rounding rules not applicable to the intermediate results

Table 4: Results of the homogeneity studies of the isotope amount ratios

	$s_{wb,rel}$ [1)] [%]	$s_{bb,rel}$ [1)] [%]	$u^*_{bb,rel}$ [1)] [%]
$n(^{234}U)/n(^{238}U)$	0.10841	n.c.	0.03628
$n(^{235}U)/n(^{238}U)$	0.02879	n.c.	0.00964
$n(^{240}Pu)/n(^{239}Pu)$	0.02155	0.00218	0.00744
$n(^{241}Pu)/n(^{239}Pu)$	0.94821	0.11914	0.32754
$n(^{242}Pu)/n(^{239}Pu)$	3.31707	n.c.	1.14580

[1)] Rounding rules not applicable to the intermediate results

n.c. cannot be calculated, $MS_{between} < MS_{within}$

The homogeneity study showed no outlying unit means and no trends in the filling sequence. Therefore, the between-unit standard deviation can be used as estimate of u_{bb}. As u^*_{bb} sets the limits of the study to detect inhomogeneity, the larger value of s_{bb} and u^*_{bb} is adopted as uncertainty contribution to account for potential inhomogeneity.

4.2 Within-unit homogeneity and minimum sample intake

The within-unit inhomogeneity does not influence the uncertainty of the certified value when the minimum sample intake is respected, but determines the minimum size of an aliquot that is representative for the whole unit. Sample sizes equal to or above the minimum sample intake guarantee the certified value within its stated uncertainty. The uranium and plutonium amount content in a single IRMM-1027 LSD spike is such that no dilution of a typical sample of dissolved fuel is needed. The only quantitative step needed at the reprocessing plant laboratory is to weigh as accurately as possible an aliquot of the dissolved fuel solution onto

the spike and ensure complete mixing of spike and sample. The whole amount of sample per unit has to be used for analysis and thus equals the minimum sample intake. Quantification of within-unit inhomogeneity to determine the minimum sample intake for IRMM-1027p is therefore not necessary.

5 Stability

Stability testing is necessary to establish conditions for storage (long-term stability) as well as conditions for dispatch to the customers (short-term stability). The IRMM-1027p is a mixed U/Pu reference material, consisting of U and Pu radionuclides. Therefore, the certified isotope amount ratios and amount contents of this reference material are unstable by nature following the law of radioactive decay, depending on the respective half-lives [9, 10].

Temperatures up to 40 °C could be reached for regular shipment of reference materials. Therefore, stability under these conditions had to be demonstrated. The shipment of nuclear material follows the legal requirements related to radioprotection measures for transport of radioactive materials. The packing of radioactive material is divided into two parts, the packing of the inner package and the packing of the container according to regulations and respective procedures [11]. Units of IRMM-1027p LSD spikes are sealed in plastic bags, put in a plastic Type A container for radioactive materials and are transported finally in large sealed containers. From the package material specification and the fact that the transport of radioactive material does not take longer than one week, the IRMM-1027p units packed as described above are never exposed to temperatures outside the range of 4 to 40 °C.

Taking into account that

1) Certified values of IRMM-1027p are valid for a specific reference date given on the certificate only;
2) The dried uranyl and plutonium nitrates are embedded in an organic substance providing a stable layer at the bottom of the vial to preserve the integrity during transport;
3) Preparation time of a batch of the IRMM-1027 series from dispensing of the mother solution until confirmation measurements on the completed LSD spikes in CAB takes about 6-10 months;
4) The packing of IRMM-1027p is such that the units are never exposed to temperatures outside the range of 4 to 40 °C;
5) Transport of IRMM-1027p does not exceed one week;
6) IRMM has provided IRMM-1027 series of LSD spikes for more than 10 years to customers

the short-term and long-term stability for the IRMM-1027 series are demonstrated in combination with confirmation measurements of the gravimetrically certified values and from experience in preparing the same kind of reference material over years, as described in detail in the certification report of IRMM-1027o by Jakopič et *al*. [7].

5.1 Short-term stability study

In the scope of the certification and preparation of IRMM-1027o a thorough short-term stability study of the CAB applied was demonstrated using a modified isochronous design [12]. To assess the short-term stability of the CAB with 35-39 wt% butyryl content used in the preparation of IRMM-1027o, samples were stored at 4 °C and 40 °C for one week at each temperature. The reference temperature was set to 18 °C. The test samples contained only CAB with 35-39 wt% butyryl content without plutonium and uranyl nitrate. This short-term

stability study demonstrated that IRMM-1027o LSD spikes show no sign of deterioration during transport period [7]. The same vials and the same CAB preparation procedure were used for IRMM-1027p. Therefore the IRMM-1027p LSD spikes can be shipped to customers under normal temperature conditions.

5.2 Long-term stability study

The long-term stability for IRMM-1027p is demonstrated in combination with confirmation measurements of the gravimetrically certified values and in addition underpinned by measurement results carried out using IRMM-1027m LSD spikes over a period of 4 years [13]. The applied approach for IRMM-1027p of combining confirmation and homogeneity IDMS measurements already demonstrated the stability for the IRMM-1027 LSD series from the time of starting the dispensing until the time of performing confirmation measurements on randomly selected units. This time span is for each of the LSD batches about 6-10 months. Furthermore, long-term stability of the certified properties of IRMM-1027p is underpinned by confirmation measurements from previous IRMM-1027 batches, which have the same characteristics as IRMM-1027p. Particularly, the compatibility study carried out using IRMM-1027m proves the long-term stability of the IRMM-1027 series LSD spikes [14, 15].

Furthermore, IRMM, ITU and the IAEA are engaged in mutual verification measurements of mixed uranium plutonium spike reference materials via an EC support task to the IAEA. In the frame of this support task verification measurements of randomly selected IRMM-1027 LSD spikes from different batches are performed sometimes up to two years after the certificate was issued, which is not only an external verification of the certified values but also a demonstration of the long-term stability of the IRMM-1027 series of LSD spikes. As a further proof of the long-term stability of the IRMM-1027 series, selected units of IRMM-1027m were set aside and stored under room temperature conditions for already almost five years. Regular visual inspection confirmed that the CAB in these units is still intact and does not show any sign of deterioration.

5.3 Estimation of uncertainties

Due to the chosen approach of demonstrating the stability by combining confirmation and homogeneity assessment and taking into account points 1) – 6) as listed in section 5, no additional contribution from the stability study to the expanded uncertainty of the certified values of IRMM-1027p is taken into account.

Underpinned by internal confirmation, external verification and long-term monitoring of the IRMM-1027 series of LSD spikes in CAB, short- and long-term stability have been demonstrated. The IRMM-1027p certificate is valid for three years from the date of signature. The validity may be extended after further tests on the stability of the spike material are carried out. The material has to be transported according to the legal requirements related to radioprotection measures for the transport of radioactive materials. It is recommended to store the units of IRMM-1027p at + 18 °C ± 5 °C in an upright position.

After the certification campaign, the material will be subjected to IRMM's regular stability monitoring programme to control its stability. At least two units per year will be analysed in the IRMM nuclear laboratories to confirm the certified values.

6 Characterisation

The material characterisation is the process of determining the property values of a reference material.

The material characterisation was based on gravimetric preparation confirmed by independent analysis. The IRMM-1027p series of LSD spikes was prepared by dispensing an aliquot (about 2.5 g) of the mother solution into individual units by an automated robot system and subsequent drying. The masses of dispensed aliquots per unit before drying are given in Annex 14. The mother solution was prepared by gravimetric mixing of uranium and plutonium metals (see Section 3.2 and Annexes 15 - 17). Each individual unit of IRMM-1027p LSD spike is certified for the mass of ^{239}Pu, ^{235}U and ^{238}U and the $n(^{234}U)/n(^{238}U)$, $n(^{235}U)/n(^{238}U)$, $n(^{240}Pu)/n(^{239}Pu)$, $n(^{241}Pu)/n(^{239}Pu)$, and $n(^{242}Pu)/n(^{239}Pu)$ amount ratios.

6.1 Purity of the starting materials

The purity of the starting materials (metals) was taken from the corresponding certificates (see Annexes 2 - 4). The purity of Pu MP2 metal was calculated for November 1, 2013 from the original purity of the CETAMA certificate (see Annex 16).

6.2 Masses of ^{239}Pu, ^{235}U and ^{238}U, Pu and U amount ratios and their uncertainties

The mass of ^{239}Pu, ^{235}U and ^{238}U and the Pu and U isotope amount ratios in each individual unit of IRMM-1027p are calculated from the mass fraction of uranium and plutonium in the mother solution, taking into account the mass of the metals and the solution, their purity and isotopic composition (e.g. isotope amount ratios), and the mass of an aliquot dispensed into each vial.

In Table 5 the data supporting the calculation of the masses of ^{239}Pu, ^{235}U and ^{238}U and Pu and U amount ratios per unit of IRMM-1027p are summarised.

Table 5: Gravimetric mixing to prepare the mother solution of IRMM-1027p

	MP2	EC NRM 101	NBL CRM-116	Mother solution
Mass [1] [g]	2.2443	53.324	11.747	3070.76
Purity [2] [g/g]	0.9990	0.99985	0.999672	
Isotope amount ratios [3] [mol/mol]	$n(^{238}Pu)/n(^{239}Pu)$ 0.00003083 $n(^{240}Pu)/n(^{239}Pu)$ 0.0224324 $n(^{241}Pu)/n(^{239}Pu)$ 0.0002378 $n(^{242}Pu)/n(^{239}Pu)$ 0.00007570	$n(^{234}U)/n(^{238}U)$ 0.00005548 $n(^{235}U)/n(^{238}U)$ 0.0072593 $n(^{236}U)/n(^{238}U)$ 0.000000151	$n(^{234}U)/n(^{235}U)$ 0.0106853 $n(^{238}U)/n(^{235}U)$ 0.057975 $n(^{236}U)/n(^{235}U)$ 0.00448811	

[1] The masses of the metals are obtained from the weighing certificate, see Annex 15.

[2] The purity of the metals is obtained from the certificates, see Annexes 2 - 4.

[3] Amount ratios are obtained from the certificates, see Annexes 5 - 6, and the report of analysis, see Annex 7.

The uncertainties on the certified mass (u_{char}) of ^{239}Pu, ^{235}U and ^{238}U in the vial are composed of several contributions (Table 6), i.e. the uncertainty on the mass determination ($u_{char,1}$, $u_{char,2}$ and $u_{char,3}$), the uncertainty on the purity of the metals ($u_{char,4}$), and the uncertainties on the

amount ratios ($u_{char,5}$). The complete and detailed calculations of the mass fractions, amount ratios and their uncertainty budgets are given in Annex 16 and Annex 17.

Table 6: Uncertainty budgets for the masses of ^{239}Pu, ^{235}U and ^{238}U in the vials of IRMM-1027p

	Standard uncertainty contribution					Combined relative uncertainty
	$u_{char,1}$ [1)] [g]	$u_{char,2}$ [2)] [g]	$u_{char,3}$ [3)] [g]	$u_{char,4}$ [4)] [g/g]	$u_{char,5}$ [5)] [mol/mol]	$u_{char,rel}$ [6)] [%]
^{239}Pu	0.0001	0.045	0.0003	0.00020	0.00000255	0.02372
^{235}U	0.001	0.045	0.0003	0.0000345	0.0000085	0.01488
^{238}U	0.003	0.045	0.0003	0.000025	0.0000018	0.01338

[1)] Standard uncertainty of the mass determination of the metals, see Annex 15.

[2)] Standard uncertainty of the mass determination of the mother solution, see Annex 15.

[3)] Standard uncertainty of the mass determination of an aliquot, see Annex 14.

[4)] Standard uncertainty of the purity of the metals, see Annexes 2 - 4.

[5)] Standard uncertainty of the largest amount ratio, for other amount ratios see Annexes 5 - 7.

[6)] Rounding rules not applicable to the intermediate results

6.3 Weighing and associated uncertainties

Masses of dispensed aliquots of the mother solution per unit used for the calculation of the certified values can be found in Annex 14. The dispensed masses were corrected for air buoyancy, taking into account the density of the air and the sample, the ambient humidity, temperature and pressure inside the glove box, and for the evaporation losses. Traceability to the SI is ensured by weighing a reference weight before and after dispensing a series of 96 units. The uncertainties on the dispensed mass are composed of several contributions, i.e. the uncertainty on the mass determination by an automated system, the uncertainty on the buoyancy correction, the uncertainty due to evaporation correction, and the uncertainty associated with the variability of the balance [6].

For the determination of the mass of the starting materials (metals) and the mother solution substitution weighing was used. In the substitution weighing, the mass of a sample is determined through a series of mass determinations of an unknown (U) and a reference weight (S). The so called "SUUS" method was applied. The uncertainty contributions in substitution weighing of the metals are the uncertainties associated with the calibrated weights (certificate), air buoyancy correction and the variability of the balance used in "SUUS" method.

6.4 Confirmation measurements

Ten units of IRMM-1027p were randomly selected from the whole batch and analysed by ID-TIMS to confirm the uranium and plutonium amount contents and from gravimetric preparation. To each of these vials, about 5 g of IRMM-046b mixed U/Pu spike in 5 M HNO_3 was weighed in and evaporated to dryness. In addition, ten units of IRMM-1027p were randomly selected for the confirmation of the uranium and plutonium isotope amount ratios. To each of these vials about, 5 mL of nitric acid (c = 8 mol L^{-1}) was added and evaporated to dryness. Subsequently, the isotopic equilibrium, chemical separation and isotopic measurements on Triton TIMS were carried out [7].

The results of the confirmation measurements of the uranium and plutonium amount contents and isotope amount ratios agreed well with the values from the gravimetrical preparation except for the $n(^{238}Pu)/n(^{239}Pu)$ and $n(^{236}U)/n(^{238}U)$ amount ratios. These two amount ratios were therefore not certified and are given only as additional information in the certification report. All the results are shown as graphs in Annex 12 and Annex 13

7 Value Assignment

Certified values are values that fulfil the highest standards of accuracy. Certified values for IRMM-1027p were assigned on the basis of gravimetric preparation as a primary method of measurement. Full uncertainty budgets in accordance with the 'Guide to the Expression of Uncertainty in Measurement' [4] were established.

7.1 Certified values and their uncertainties

The certified values (masses of ^{239}Pu, ^{235}U and ^{238}U and Pu and U isotope amount ratios) are based on the masses of the metals, their purity and isotopic composition, the mass of the mother solution and the mass of an aliquot dispensed into the vials. All weighings were carried out with a set of calibrated weights, directly traceable to the kg prototype at BIPM, Paris, with the necessary corrections for air buoyancy effects.

The assigned uncertainty consists of uncertainties related to characterisation, u_{char} (Section 6), potential between-unit inhomogeneity, s_{bb} (Section 4.1) and potential degradation during transport (u_{sts}) and long-term storage, u_{lts} (Section 5). As described in Section 5 the uncertainty related to degradation during transport and long-term storage was found to be negligible. These different contributions were combined to estimate the expanded, relative uncertainty of the certified value ($U_{CRM,\,rel}$) with a coverage factor k as:

$$U_{CRM,rel} = k \cdot \sqrt{u_{char,rel}^2 + s_{bb,rel}^2} \qquad \textbf{Equation 4}$$

- u_{char} was estimated as described in Section 6
- s_{bb} was estimated as described in Section 4.1.

Because of sufficient degrees of freedom of the different uncertainty contributions**,** a coverage factor k of 2 was applied to obtain the expanded uncertainties. The certified masses and their uncertainties for unit No. 1 are summarised in Table 7. The certified values of all 1186 units are given in Annex 1.

Table 7: Certified masses and their uncertainties for unit No.1 of IRMM-1027p

Mass	Certified value [mg]	$u_{char,\,rel}$ [1)] [%]	$s_{bb,\,rel}$ [1)] [%]	$U_{CRM,\,rel}$ [2)] [%]	U_{CRM} [2)] [mg]
^{239}Pu	1.8088	0.02372	0.02227	0.065	0.0012
^{235}U	9.341	0.01488	0.01864	0.047	0.005
^{238}U	44.230	0.01338	0.01559	0.041	0.018

[1)] Rounding rules not applicable to the intermediate results

[2)] Expanded (k = 2) and rounded uncertainty.

The certified plutonium and uranium isotope amount ratios are summarised in Table 8.

Table 8: Certified isotope amount ratios and their uncertainties for IRMM-1027p LSD spikes

Isotope amount ratios	Certified value [1] [mol/mol]	$u_{char, rel}$ [2] [%]	$u^*_{bb, rel}$ [2] [%]	$U_{CRM, rel}$ [%]	U_{CRM} [3] [mol/mol]
$n(^{234}U)/n(^{238}U)$	0.0022637	0.01748	0.03628	0.08054	0.0000018
$n(^{235}U)/n(^{238}U)$	0.21390	0.01605	0.00964	0.03744	0.00008
$n(^{240}Pu)/n(^{239}Pu)$	0.022421	0.01653	0.00744	0.03625	0.000009
$n(^{241}Pu)/n(^{239}Pu)$	0.0001709	0.6613	0.32754	1.4760	0.0000025
$n(^{242}Pu)/n(^{239}Pu)$	0.0000757	0.5153	1.14580	2.5127	0.0000011

[1] The reference date for the plutonium and uranium isotope amount ratios is November 1, 2013.

[2] Rounding rules not applicable to the intermediate results

[3] Expanded (k = 2) and rounded uncertainty.

7.2 Additional material information

As additional information, the values for the plutonium and uranium amount contents, mass fractions and isotopic composition of the mother solution from gravimetric preparation are summarised in Table 9 and Table 10.

Table 9: Plutonium and uranium isotopic mass fractions (expressed as $^{xxx}U/^{tot}U$ and $^{xxx}Pu/^{tot}Pu$) in the mother solution used for IRMM-1027p.

	Isotopic mass fraction	
	Value [1] [%]	Uncertainty [2] [%]
$m(^{234}U)/m(U)\times100$	0.18328	0.00005
$m(^{235}U)/m(U)\times100$	17.392	0.003
$m(^{236}U)/m(U)\times100$	0.075772	0.000021
$m(^{238}U)/m(U)\times100$	82.349	0.004
$m(^{238}Pu)/m(Pu)\times100$	0.002844	0.000027
$m(^{239}Pu)/m(Pu)\times100$	97.7715	0.0006
$m(^{240}Pu)/m(Pu)\times100$	2.2013	0.0005
$m(^{241}Pu)/m(Pu)\times100$	0.01685	0.00022
$m(^{242}Pu)/m(Pu)\times100$	0.00750	0.00008
	Isotope amount ratios	
	Value [1] [mol/mol]	Uncertainty [2] [mol/mol]
$n(^{238}Pu)/n(^{239}Pu)$	0.00002922	0.00000028
$n(^{236}U)/n(^{238}U)$	0.00092794	0.00000028

[1] The reference date for the plutonium and uranium isotopic mass fractions and amount ratios is November 1, 2013.

[2] Expanded (k = 2) and rounded uncertainty.

Table 10: Plutonium and uranium amount contents and mass fractions in the mother solution (sol) used for IRMM-1027p.

IRMM-1027p	Amount content		Mass fraction	
	Value [µmol/g sol]	Uncertainty [1)] [µmol/g sol]	Value [mg/g sol]	Uncertainty [1)] [mg/g sol]
^{235}U	15.6767	0.0028	3.6847	0.0007
^{238}U	73.291	0.010	17.4471	0.0022
U	89.202	0.010	21.1867	0.0023
^{239}Pu	2.9846	0.0012	0.71348	0.00029
Pu	3.0524	0.0013	0.72974	0.00030

[1)] Expanded (k = 2) and rounded uncertainty.

8 Metrological traceability and commutability

8.1 Metrological traceability

Quantity value

The certified values are traceable to the values on the respective metal certificate (EC NRM 101, CETAMA MP2 and NBL CRM-116).

8.2 Commutability

Many measurement procedures include one or more steps, which are selecting specific (or specific groups) of analytes from the sample for the subsequent steps of the whole measurement process. Often the complete identity of these 'intermediate analytes' is not fully known or taken into account. Therefore, it is difficult to mimic all the analytically relevant properties of real samples within a CRM. The degree of equivalence in the analytical behaviour of real samples and a CRM with respect to various measurement procedures (methods) is summarised in a concept called 'commutability of a reference material'. There are various definitions expressing this concept. For instance, the CSLI Guideline C-53A [16] recommends the use of the following definition for the term *commutability*:

> "The equivalence of the mathematical relationships among the results of different measurement procedures for an RM and for representative samples of the type intended to be measured."

The commutability of a CRM defines its fitness for use and, thus, is a crucial characteristic in case of the application of different measurement methods. When commutability of a CRM is not established in such cases, the results from routinely used methods cannot be legitimately compared with the certified value to determine whether a bias does not exist in calibration, nor can the CRM be used as a calibrant.

The IRMM-1027p is a dried nitrate in CAB certified for uranium and plutonium isotope amount ratios and masses of ^{235}U, ^{238}U and ^{239}Pu per unit. This CRM is tailor-made by IRMM for its intended use and serves as calibrant for uranium and plutonium IDMS measurements of samples from input solutions at reprocessing plants and is not intended to be used for other measurement methods.

9 Instructions for use

9.1 Safety information

The IRMM-1027p series contains radioactive material. The vials should be handled with great care and by experienced personnel in a laboratory suitably equipped for the safe handling of radioactive materials.

9.2 Storage conditions

The vials should be stored at + 18 °C ± 5 °C in an upright position.

Please note that the European Commission cannot be held responsible for changes that happen during storage of the material at the customer's premises, especially of opened vials.

9.3 Preparation and use of the material

The spike CRM has to be dissolved in the appropriate amount of acid (e.g. nitric acid with an amount of substance concentration c = 5 mol L^{-1}) or sample solution to ensure the isotopic equilibrium between the spike and the sample.

9.4 Minimum sample intake

The whole amount of sample per unit has to be used for analysis.

9.5 Use of the certified value

This spike CRM is applied as a calibrant to measure the uranium and plutonium amount content in an unknown sample of dissolved nuclear fuel solution using isotope dilution mass spectrometry (IDMS). The amount of plutonium or uranium can be calculated using the following IDMS equation:

$$C_x = C_y \frac{m_y}{m_x} \frac{R_y - R_b}{R_b - R_x} \frac{\Sigma(R_i)_x}{\Sigma(R_i)_y} \quad , \qquad \textbf{Equation 5}$$

where C_y is the element content of the spike, m_x and m_y are the masses of sample and spike, respectively, R_x, R_y and R_b are the isotope amount ratios of the sample, the spike and the blend, respectively, $\Sigma(R_i)_x$ and $\Sigma(R_i)_y$ are the sums of all isotope amount ratios in sample and in spike, respectively.

10 Acknowledgments

The authors would like to thank A. Bernreuther and D. Vanleeuw (IRMM) for the reviewing of the certification report, as well as the experts of the Certification Advisory Panel "Elements and Inorganic Ions", S. D. Balsley (International Atomic Energy Agency, Vienna, Austria), P. Vermaercke (Belgium Nuclear Research Centre, Mol, Belgium) and T. Prohaska (University of Natural Resources and Life Sciences, Vienna, Austria).

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Annex 1: The certificate of analysis of IRMM-1027p

EUROPEAN COMMISSION
JOINT RESEARCH CENTRE

Institute for Reference Materials and Measurements (Geel)

CERTIFIED REFERENCE MATERIAL
IRMM – 1027p

CERTIFICATE OF ANALYSIS

Uranium and Plutonium in Cellulose Acetate Butyrate (CAB)		
	Isotope amount ratio	
	Certified value [1] [mol/mol]	Uncertainty [2] [mol/mol]
$n(^{234}U)/n(^{238}U)$	0.0022637	0.0000018
$n(^{235}U)/n(^{238}U)$	0.21390	0.00008
$n(^{240}Pu)/n(^{239}Pu)$	0.022421	0.000009
$n(^{241}Pu)/n(^{239}Pu)$	0.0001709	0.0000025
$n(^{242}Pu)/n(^{239}Pu)$	0.0000757	0.0000011
The certified masses and uncertainties of ^{235}U, ^{238}U and ^{239}Pu per unit are listed in Annex 1 on pages 3 to 26 of this certificate.		
1) The certified values are traceable to the values on the respective metal certificates (EC NRM 101, NBL CRM-116 and CETAMA MP2). The reference date for the plutonium and uranium isotope amount ratios is November 1, 2013. 2) The certified uncertainty is the expanded uncertainty with a coverage factor k = 2 corresponding to a level of confidence of about 95 % estimated in accordance with ISO/IEC Guide 98-3, Guide to the Expression of Uncertainty in Measurement (GUM:1995), ISO, 2008.		

The certificate is valid for 3 years; the validity may be extended after further tests on the stability of the spike material are carried out.

Geel, January 2014

Signed: _____

Prof. Dr. Hendrik Emons
European Commission
Joint Research Centre
Institute for Reference Materials and Measurements
Retieseweg 111
B-2440 Geel, Belgium

DESCRIPTION OF THE MATERIAL

The IRMM-1027p series of Large-Sized Dried (LSD) spikes consists of 1186 units, each containing approximately 50 mg of uranium and 1.8 mg of Pu in dried form. Units were prepared by aliquoting of about 2.5 g of a gravimetrically prepared nitrate solution of uranium (EC NRM 101 and NBL CRM-116) and plutonium (CETAMA MP2) into individual vials. The solution in each vial was dried down, re-dissolved in cellulose acetate butyrate (CAB) and dried again to produce a stable layer at the bottom of the vial. Each unit contains a unique quantity of uranium and plutonium and is assigned a serial number for identification and reference.

ANALYTICAL METHODS USED FOR CERTIFICATION

The certified values are based on the gravimetric preparation of the mother solution taking into account the isotopic composition and the purity of the starting materials, their masses and the mass of the solution. The confirmatory measurements were performed by isotope dilution thermal ionisation mass spectrometry (ID-TIMS) and thermal ionisation mass spectrometry (TIMS).

All the work related to the preparation and certification of this CRM has been performed at the European Commission, Joint Research Centre, Institute for Reference Materials and Measurement (IRMM) in Geel, Belgium.

SAFETY INFORMATION

The IRMM-1027p series contains radioactive material. The vials should be handled with great care and by experienced personnel in a laboratory suitably equipped for the safe handling of radioactive materials.

INSTRUCTIONS FOR USE AND INTENDED USE

This Certified Reference Material (CRM) is used as a calibrant in the analysis of plutonium and uranium materials by isotope dilution mass spectrometry. The spike has to be dissolved in the approprioate amount of acid (e.g. nitric acid with an amount of substance concentration c = 5 mol L^{-1}) or sample solution to ensure the isotopic equilibrium between the spike and the sample. The whole amount of sample per unit has to be used for analysis.

STORAGE

The vials should be stored at + 18 °C ± 5 °C in an upright position.
However, the European Commission cannot be held responsible for changes that happen during storage of the material at the customer's premises, especially of opened samples.

LEGAL NOTICE

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NOTE

A technical report on the production of IRMM-1027p is available on the internet (www.irmm.jrc.be).
A paper copy can be obtained from IRMM on request.

Annex 1: The certified masses of ^{238}U, ^{235}U and ^{239}Pu per unit of IRMM-1027p.

Vial No	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0001	44.230	0.018	9.341	0.005	1.8088	0.0012
0002	44.941	0.018	9.491	0.005	1.8378	0.0012
0003	44.721	0.018	9.445	0.005	1.8288	0.0012
0004	44.581	0.018	9.415	0.005	1.8231	0.0012
0005	44.613	0.018	9.422	0.005	1.8244	0.0012
0006	44.600	0.018	9.419	0.005	1.8239	0.0012
0007	44.609	0.018	9.421	0.005	1.8243	0.0012
0008	44.614	0.018	9.422	0.005	1.8245	0.0012
0009	44.609	0.018	9.421	0.005	1.8243	0.0012
0010	44.618	0.018	9.423	0.005	1.8246	0.0012
0011	44.613	0.018	9.422	0.005	1.8244	0.0012
0012	44.616	0.018	9.423	0.005	1.8245	0.0012
0013	44.611	0.018	9.422	0.005	1.8243	0.0012
0014	44.613	0.018	9.422	0.005	1.8244	0.0012
0015	44.613	0.018	9.422	0.005	1.8244	0.0012
0016	44.618	0.018	9.423	0.005	1.8246	0.0012
0017	44.611	0.018	9.422	0.005	1.8243	0.0012
0018	44.613	0.018	9.422	0.005	1.8244	0.0012
0019	44.613	0.018	9.422	0.005	1.8244	0.0012
0020	44.595	0.018	9.418	0.005	1.8237	0.0012
0021	44.616	0.018	9.423	0.005	1.8245	0.0012
0022	44.602	0.018	9.420	0.005	1.8240	0.0012
0023	44.600	0.018	9.419	0.005	1.8239	0.0012
0024	44.604	0.018	9.420	0.005	1.8240	0.0012
0025	44.585	0.018	9.416	0.005	1.8233	0.0012
0026	44.597	0.018	9.419	0.005	1.8238	0.0012
0027	44.567	0.018	9.412	0.005	1.8225	0.0012
0028	44.611	0.018	9.422	0.005	1.8243	0.0012
0029	44.576	0.018	9.414	0.005	1.8229	0.0012
0030	44.576	0.018	9.414	0.005	1.8229	0.0012
0031	44.590	0.018	9.417	0.005	1.8235	0.0012
0032	44.571	0.018	9.413	0.005	1.8227	0.0012
0033	44.576	0.018	9.414	0.005	1.8229	0.0012
0034	44.580	0.018	9.415	0.005	1.8230	0.0012
0035	44.560	0.018	9.411	0.005	1.8223	0.0012
0036	44.611	0.018	9.422	0.005	1.8243	0.0012
0037	44.545	0.018	9.408	0.005	1.8216	0.0012
0038	44.580	0.018	9.415	0.005	1.8230	0.0012
0039	44.562	0.018	9.411	0.005	1.8223	0.0012
0040	44.567	0.018	9.412	0.005	1.8225	0.0012
0041	44.555	0.018	9.410	0.005	1.8220	0.0012
0042	44.578	0.018	9.415	0.005	1.8230	0.0012
0043	44.541	0.018	9.407	0.005	1.8215	0.0012
0044	44.569	0.018	9.413	0.005	1.8226	0.0012
0045	44.536	0.018	9.406	0.005	1.8213	0.0012
0046	44.567	0.018	9.412	0.005	1.8225	0.0012
0047	44.543	0.018	9.407	0.005	1.8215	0.0012
0048	44.555	0.018	9.410	0.005	1.8220	0.0012
0049	44.548	0.018	9.408	0.005	1.8218	0.0012
0050	44.548	0.018	9.408	0.005	1.8218	0.0012

Annex 1: The certified masses of ^{238}U, ^{235}U and ^{239}Pu per unit of IRMM-1027p.

Vial No	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0051	44.513	0.018	9.401	0.005	1.8203	0.0012
0052	44.576	0.018	9.414	0.005	1.8229	0.0012
0053	44.524	0.018	9.403	0.005	1.8208	0.0012
0054	44.559	0.018	9.410	0.005	1.8222	0.0012
0055	44.524	0.018	9.403	0.005	1.8208	0.0012
0056	44.553	0.018	9.409	0.005	1.8220	0.0012
0057	44.525	0.018	9.403	0.005	1.8208	0.0012
0058	44.548	0.018	9.408	0.005	1.8218	0.0012
0059	44.515	0.018	9.401	0.005	1.8204	0.0012
0060	44.548	0.018	9.408	0.005	1.8218	0.0012
0061	44.531	0.018	9.405	0.005	1.8210	0.0012
0062	44.517	0.018	9.402	0.005	1.8205	0.0012
0063	44.545	0.018	9.408	0.005	1.8216	0.0012
0064	44.525	0.018	9.403	0.005	1.8208	0.0012
0065	44.520	0.018	9.402	0.005	1.8206	0.0012
0066	44.541	0.018	9.407	0.005	1.8215	0.0012
0067	44.536	0.018	9.406	0.005	1.8213	0.0012
0068	44.508	0.018	9.400	0.005	1.8201	0.0012
0069	44.517	0.018	9.402	0.005	1.8205	0.0012
0070	44.536	0.018	9.406	0.005	1.8213	0.0012
0071	44.511	0.018	9.400	0.005	1.8203	0.0012
0072	44.529	0.018	9.404	0.005	1.8210	0.0012
0073	44.534	0.018	9.405	0.005	1.8212	0.0012
0074	44.515	0.018	9.401	0.005	1.8204	0.0012
0075	44.524	0.018	9.403	0.005	1.8208	0.0012
0076	44.094	0.018	9.312	0.005	1.8032	0.0012
0077	44.826	0.018	9.467	0.005	1.8331	0.0012
0078	44.660	0.018	9.432	0.005	1.8263	0.0012
0079	44.098	0.018	9.313	0.005	1.8033	0.0012
0080	44.805	0.018	9.462	0.005	1.8322	0.0012
0081	44.655	0.018	9.431	0.005	1.8261	0.0012
0082	44.096	0.018	9.313	0.005	1.8033	0.0012
0083	44.765	0.018	9.454	0.005	1.8306	0.0012
0084	44.735	0.018	9.448	0.005	1.8294	0.0012
0085	44.112	0.018	9.316	0.005	1.8039	0.0012
0086	44.827	0.018	9.467	0.005	1.8332	0.0012
0087	44.623	0.018	9.424	0.005	1.8248	0.0012
0088	44.085	0.018	9.311	0.005	1.8028	0.0012
0089	44.801	0.018	9.462	0.005	1.8321	0.0012
0090	44.716	0.018	9.444	0.005	1.8286	0.0012
0091	44.073	0.018	9.308	0.005	1.8023	0.0012
0092	44.805	0.018	9.462	0.005	1.8322	0.0012
0093	44.686	0.018	9.437	0.005	1.8274	0.0012
0094	44.105	0.018	9.315	0.005	1.8036	0.0012
0095	44.803	0.018	9.462	0.005	1.8322	0.0012
0096	44.618	0.018	9.423	0.005	1.8246	0.0012
0097	44.159	0.018	9.326	0.005	1.8058	0.0012
0098	44.826	0.018	9.467	0.005	1.8331	0.0012
0099	44.593	0.018	9.418	0.005	1.8236	0.0012
0100	44.160	0.018	9.326	0.005	1.8059	0.0012

Annex 1: The certified masses of ^{238}U, ^{235}U and ^{239}Pu per unit of IRMM-1027p.

Vial No	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0101	44.854	0.018	9.473	0.005	1.8342	0.0012
0102	44.171	0.018	9.329	0.005	1.8063	0.0012
0103	44.848	0.018	9.472	0.005	1.8340	0.0012
0104	44.157	0.018	9.326	0.005	1.8058	0.0012
0105	44.866	0.018	9.475	0.005	1.8347	0.0012
0106	44.160	0.018	9.326	0.005	1.8059	0.0012
0107	44.848	0.018	9.472	0.005	1.8340	0.0012
0108	44.201	0.018	9.335	0.005	1.8075	0.0012
0109	44.174	0.018	9.329	0.005	1.8065	0.0012
0110	44.665	0.018	9.433	0.005	1.8265	0.0012
0111	44.576	0.018	9.414	0.005	1.8229	0.0012
0112	44.574	0.018	9.414	0.005	1.8228	0.0012
0113	44.545	0.018	9.407	0.005	1.8216	0.0012
0114	44.300	0.018	9.356	0.005	1.8116	0.0012
0115	44.756	0.018	9.452	0.005	1.8302	0.0012
0116	44.249	0.018	9.345	0.005	1.8095	0.0012
0117	44.782	0.018	9.458	0.005	1.8313	0.0012
0118	44.288	0.018	9.353	0.005	1.8111	0.0012
0119	44.698	0.018	9.440	0.005	1.8279	0.0012
0120	44.279	0.018	9.351	0.005	1.8108	0.0012
0121	44.770	0.018	9.455	0.005	1.8308	0.0012
0122	44.270	0.018	9.350	0.005	1.8104	0.0012
0123	44.744	0.018	9.450	0.005	1.8297	0.0012
0124	44.262	0.018	9.348	0.005	1.8100	0.0012
0125	44.752	0.018	9.451	0.005	1.8301	0.0012
0126	44.260	0.018	9.347	0.005	1.8100	0.0012
0127	44.761	0.018	9.453	0.005	1.8305	0.0012
0128	44.260	0.018	9.347	0.005	1.8100	0.0012
0129	44.752	0.018	9.451	0.005	1.8301	0.0012
0130	44.260	0.018	9.347	0.005	1.8100	0.0012
0131	44.766	0.018	9.454	0.005	1.8307	0.0012
0132	44.263	0.018	9.348	0.005	1.8101	0.0012
0133	44.745	0.018	9.450	0.005	1.8298	0.0012
0134	44.270	0.018	9.350	0.005	1.8104	0.0012
0135	44.765	0.018	9.454	0.005	1.8306	0.0012
0136	44.248	0.018	9.345	0.005	1.8095	0.0012
0137	44.810	0.018	9.464	0.005	1.8325	0.0012
0138	44.244	0.018	9.344	0.005	1.8093	0.0012
0139	44.789	0.018	9.459	0.005	1.8316	0.0012
0140	44.256	0.018	9.347	0.005	1.8098	0.0012
0141	44.787	0.018	9.459	0.005	1.8315	0.0012
0142	44.274	0.018	9.350	0.005	1.8105	0.0012
0143	44.779	0.018	9.457	0.005	1.8312	0.0012
0144	44.244	0.018	9.344	0.005	1.8093	0.0012
0145	44.826	0.018	9.467	0.005	1.8331	0.0012
0146	44.262	0.018	9.348	0.005	1.8100	0.0012
0147	44.772	0.018	9.455	0.005	1.8309	0.0012
0148	44.267	0.018	9.349	0.005	1.8103	0.0012
0149	44.813	0.018	9.464	0.005	1.8326	0.0012
0150	44.263	0.018	9.348	0.005	1.8101	0.0012

Annex 1: The certified masses of ^{238}U, ^{235}U and ^{239}Pu per unit of IRMM-1027p.

Vial No	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0151	44.780	0.018	9.457	0.005	1.8312	0.0012
0152	44.300	0.018	9.356	0.005	1.8116	0.0012
0153	44.731	0.018	9.447	0.005	1.8292	0.0012
0154	44.276	0.018	9.351	0.005	1.8106	0.0012
0155	44.805	0.018	9.462	0.005	1.8322	0.0012
0156	44.290	0.018	9.354	0.005	1.8112	0.0012
0157	44.747	0.018	9.450	0.005	1.8299	0.0012
0158	44.267	0.018	9.349	0.005	1.8103	0.0012
0159	44.815	0.018	9.465	0.005	1.8327	0.0012
0160	44.272	0.018	9.350	0.005	1.8105	0.0012
0161	44.761	0.018	9.453	0.005	1.8305	0.0012
0162	44.290	0.018	9.354	0.005	1.8112	0.0012
0163	44.724	0.018	9.445	0.005	1.8290	0.0012
0164	44.316	0.018	9.359	0.005	1.8123	0.0012
0165	44.786	0.018	9.458	0.005	1.8315	0.0012
0166	44.346	0.018	9.365	0.005	1.8135	0.0012
0167	44.276	0.018	9.351	0.005	1.8106	0.0012
0168	44.995	0.018	9.503	0.005	1.8400	0.0012
0169	44.366	0.018	9.370	0.005	1.8143	0.0012
0170	44.351	0.018	9.367	0.005	1.8137	0.0012
0171	44.817	0.018	9.465	0.005	1.8327	0.0012
0172	44.347	0.018	9.366	0.005	1.8135	0.0012
0173	44.318	0.018	9.360	0.005	1.8123	0.0012
0174	44.951	0.018	9.493	0.005	1.8382	0.0012
0175	44.349	0.018	9.366	0.005	1.8136	0.0012
0176	44.387	0.018	9.374	0.005	1.8152	0.0012
0177	44.623	0.018	9.424	0.005	1.8248	0.0012
0178	44.674	0.018	9.435	0.005	1.8269	0.0012
0179	44.627	0.018	9.425	0.005	1.8250	0.0012
0180	44.503	0.018	9.399	0.005	1.8199	0.0012
0181	44.541	0.018	9.407	0.005	1.8215	0.0012
0182	44.517	0.018	9.402	0.005	1.8205	0.0012
0183	44.536	0.018	9.406	0.005	1.8213	0.0012
0184	44.529	0.018	9.404	0.005	1.8210	0.0012
0185	44.539	0.018	9.406	0.005	1.8214	0.0012
0186	44.527	0.018	9.404	0.005	1.8209	0.0012
0187	44.527	0.018	9.404	0.005	1.8209	0.0012
0188	44.525	0.018	9.403	0.005	1.8208	0.0012
0189	44.525	0.018	9.403	0.005	1.8208	0.0012
0190	44.531	0.018	9.405	0.005	1.8210	0.0012
0191	44.518	0.018	9.402	0.005	1.8205	0.0012
0192	44.531	0.018	9.405	0.005	1.8210	0.0012
0193	44.566	0.018	9.412	0.005	1.8225	0.0012
0194	44.518	0.018	9.402	0.005	1.8205	0.0012
0195	44.515	0.018	9.401	0.005	1.8204	0.0012
0196	44.532	0.018	9.405	0.005	1.8211	0.0012
0197	44.520	0.018	9.402	0.005	1.8206	0.0012
0198	44.525	0.018	9.403	0.005	1.8208	0.0012
0199	44.518	0.018	9.402	0.005	1.8205	0.0012
0200	44.531	0.018	9.405	0.005	1.8210	0.0012

Annex 1: The certified masses of ^{238}U, ^{235}U and ^{239}Pu per unit of IRMM-1027p.

Vial No	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0201	44.522	0.018	9.403	0.005	1.8207	0.0012
0202	44.525	0.018	9.403	0.005	1.8208	0.0012
0203	44.525	0.018	9.403	0.005	1.8208	0.0012
0204	44.524	0.018	9.403	0.005	1.8208	0.0012
0205	44.517	0.018	9.402	0.005	1.8205	0.0012
0206	44.529	0.018	9.404	0.005	1.8210	0.0012
0207	44.532	0.018	9.405	0.005	1.8211	0.0012
0208	44.518	0.018	9.402	0.005	1.8205	0.0012
0209	44.529	0.018	9.404	0.005	1.8210	0.0012
0210	44.515	0.018	9.401	0.005	1.8204	0.0012
0211	44.525	0.018	9.403	0.005	1.8208	0.0012
0212	44.524	0.018	9.403	0.005	1.8208	0.0012
0213	44.525	0.018	9.403	0.005	1.8208	0.0012
0214	44.531	0.018	9.405	0.005	1.8210	0.0012
0215	44.527	0.018	9.404	0.005	1.8209	0.0012
0216	44.529	0.018	9.404	0.005	1.8210	0.0012
0217	44.517	0.018	9.402	0.005	1.8205	0.0012
0218	44.529	0.018	9.404	0.005	1.8210	0.0012
0219	44.524	0.018	9.403	0.005	1.8208	0.0012
0220	44.522	0.018	9.403	0.005	1.8207	0.0012
0221	44.531	0.018	9.405	0.005	1.8210	0.0012
0222	44.524	0.018	9.403	0.005	1.8208	0.0012
0223	44.525	0.018	9.403	0.005	1.8208	0.0012
0224	44.562	0.018	9.411	0.005	1.8223	0.0012
0225	44.518	0.018	9.402	0.005	1.8205	0.0012
0226	44.522	0.018	9.403	0.005	1.8207	0.0012
0227	44.531	0.018	9.405	0.005	1.8210	0.0012
0228	44.539	0.018	9.406	0.005	1.8214	0.0012
0229	44.524	0.018	9.403	0.005	1.8208	0.0012
0230	44.541	0.018	9.407	0.005	1.8215	0.0012
0231	44.525	0.018	9.403	0.005	1.8208	0.0012
0232	44.527	0.018	9.404	0.005	1.8209	0.0012
0233	44.532	0.018	9.405	0.005	1.8211	0.0012
0234	44.525	0.018	9.403	0.005	1.8208	0.0012
0235	44.518	0.018	9.402	0.005	1.8205	0.0012
0236	44.541	0.018	9.407	0.005	1.8215	0.0012
0237	44.520	0.018	9.402	0.005	1.8206	0.0012
0238	44.576	0.018	9.414	0.005	1.8229	0.0012
0239	44.518	0.018	9.402	0.005	1.8205	0.0012
0240	44.517	0.018	9.402	0.005	1.8205	0.0012
0241	44.525	0.018	9.403	0.005	1.8208	0.0012
0242	44.511	0.018	9.400	0.005	1.8203	0.0012
0243	44.538	0.018	9.406	0.005	1.8213	0.0012
0244	44.532	0.018	9.405	0.005	1.8211	0.0012
0245	44.527	0.018	9.404	0.005	1.8209	0.0012
0246	44.524	0.018	9.403	0.005	1.8208	0.0012
0247	44.532	0.018	9.405	0.005	1.8211	0.0012
0248	44.527	0.018	9.404	0.005	1.8209	0.0012
0249	44.538	0.018	9.406	0.005	1.8213	0.0012
0250	44.525	0.018	9.403	0.005	1.8208	0.0012

Annex 1: The certified masses of ^{238}U, ^{235}U and ^{239}Pu per unit of IRMM-1027p.

Vial No	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0251	44.522	0.018	9.403	0.005	1.8207	0.0012
0252	44.539	0.018	9.406	0.005	1.8214	0.0012
0253	44.522	0.018	9.403	0.005	1.8207	0.0012
0254	44.534	0.018	9.405	0.005	1.8212	0.0012
0255	44.517	0.018	9.402	0.005	1.8205	0.0012
0256	44.529	0.018	9.404	0.005	1.8210	0.0012
0257	44.532	0.018	9.405	0.005	1.8211	0.0012
0258	44.515	0.018	9.401	0.005	1.8204	0.0012
0259	44.525	0.018	9.403	0.005	1.8208	0.0012
0260	44.499	0.018	9.398	0.005	1.8198	0.0012
0261	44.573	0.018	9.413	0.005	1.8228	0.0012
0262	44.099	0.018	9.313	0.005	1.8034	0.0012
0263	44.841	0.018	9.470	0.005	1.8337	0.0012
0264	N/A	N/A	N/A	N/A	N/A	N/A
0265	44.145	0.018	9.323	0.005	1.8053	0.0012
0266	44.847	0.018	9.471	0.005	1.8340	0.0012
0267	44.346	0.018	9.365	0.005	1.8135	0.0012
0268	44.241	0.018	9.343	0.005	1.8092	0.0012
0269	44.885	0.018	9.479	0.005	1.8355	0.0012
0270	44.202	0.018	9.335	0.005	1.8076	0.0012
0271	44.854	0.018	9.473	0.005	1.8342	0.0012
0272	44.195	0.018	9.334	0.005	1.8073	0.0012
0273	44.861	0.018	9.474	0.005	1.8345	0.0012
0274	44.194	0.018	9.333	0.005	1.8073	0.0012
0275	44.864	0.018	9.475	0.005	1.8347	0.0012
0276	44.242	0.018	9.344	0.005	1.8093	0.0012
0277	44.784	0.018	9.458	0.005	1.8314	0.0012
0278	44.253	0.018	9.346	0.005	1.8097	0.0012
0279	44.812	0.018	9.464	0.005	1.8325	0.0012
0280	44.248	0.018	9.345	0.005	1.8095	0.0012
0281	44.819	0.018	9.465	0.005	1.8328	0.0012
0282	44.276	0.018	9.351	0.005	1.8106	0.0012
0283	44.751	0.018	9.451	0.005	1.8300	0.0012
0284	44.255	0.018	9.346	0.005	1.8098	0.0012
0285	44.833	0.018	9.468	0.005	1.8334	0.0012
0286	44.267	0.018	9.349	0.005	1.8103	0.0012
0287	44.063	0.018	9.306	0.005	1.8019	0.0012
0288	44.943	0.018	9.492	0.005	1.8379	0.0012
0289	44.314	0.018	9.359	0.005	1.8122	0.0012
0290	44.308	0.018	9.358	0.005	1.8120	0.0012
0291	44.965	0.018	9.496	0.005	1.8388	0.0012
0292	44.282	0.018	9.352	0.005	1.8109	0.0012
0293	44.322	0.018	9.361	0.005	1.8125	0.0012
0294	44.970	0.018	9.497	0.005	1.8390	0.0012
0295	44.291	0.018	9.354	0.005	1.8112	0.0012
0296	44.312	0.018	9.358	0.005	1.8121	0.0012
0297	44.981	0.018	9.500	0.005	1.8394	0.0012
0298	44.291	0.018	9.354	0.005	1.8112	0.0012
0299	44.315	0.018	9.359	0.005	1.8122	0.0012
0300	44.969	0.018	9.497	0.005	1.8389	0.0012

Annex 1: The certified masses of ^{238}U, ^{235}U and ^{239}Pu per unit of IRMM-1027p.

Vial No	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0301	44.298	0.018	9.355	0.005	1.8115	0.0012
0302	44.329	0.018	9.362	0.005	1.8128	0.0012
0303	44.951	0.018	9.493	0.005	1.8382	0.0012
0304	44.272	0.018	9.350	0.005	1.8105	0.0012
0305	44.729	0.018	9.447	0.005	1.8292	0.0012
0306	44.310	0.018	9.358	0.005	1.8120	0.0012
0307	44.745	0.018	9.450	0.005	1.8298	0.0012
0308	44.293	0.018	9.354	0.005	1.8113	0.0012
0309	44.771	0.018	9.455	0.005	1.8309	0.0012
0310	44.289	0.018	9.354	0.005	1.8112	0.0012
0311	44.785	0.018	9.458	0.005	1.8314	0.0012
0312	44.302	0.018	9.356	0.005	1.8117	0.0012
0313	44.736	0.018	9.448	0.005	1.8294	0.0012
0314	44.322	0.018	9.361	0.005	1.8125	0.0012
0315	44.899	0.018	9.482	0.005	1.8361	0.0012
0316	44.031	0.018	9.299	0.005	1.8006	0.0012
0317	44.714	0.018	9.443	0.005	1.8285	0.0012
0318	44.626	0.018	9.425	0.005	1.8250	0.0012
0319	44.354	0.018	9.367	0.005	1.8138	0.0012
0320	44.602	0.018	9.420	0.005	1.8240	0.0012
0321	44.570	0.018	9.413	0.005	1.8227	0.0012
0322	44.544	0.018	9.407	0.005	1.8216	0.0012
0323	44.534	0.018	9.405	0.005	1.8212	0.0012
0324	44.546	0.018	9.408	0.005	1.8217	0.0012
0325	44.537	0.018	9.406	0.005	1.8213	0.0012
0326	44.542	0.018	9.407	0.005	1.8215	0.0012
0327	44.537	0.018	9.406	0.005	1.8213	0.0012
0328	44.527	0.018	9.404	0.005	1.8209	0.0012
0329	44.522	0.018	9.403	0.005	1.8207	0.0012
0330	44.525	0.018	9.403	0.005	1.8208	0.0012
0331	44.513	0.018	9.401	0.005	1.8203	0.0012
0332	44.488	0.018	9.396	0.005	1.8193	0.0012
0333	44.473	0.018	9.392	0.005	1.8187	0.0012
0334	44.483	0.018	9.395	0.005	1.8191	0.0012
0335	44.448	0.018	9.387	0.005	1.8177	0.0012
0336	44.427	0.018	9.383	0.005	1.8168	0.0012
0337	44.960	0.018	9.495	0.005	1.8386	0.0012
0338	44.438	0.018	9.385	0.005	1.8172	0.0012
0339	44.405	0.018	9.378	0.005	1.8159	0.0012
0340	44.757	0.018	9.452	0.005	1.8303	0.0012
0341	44.212	0.018	9.337	0.005	1.8080	0.0012
0342	44.897	0.018	9.482	0.005	1.8360	0.0012
0343	44.192	0.018	9.333	0.005	1.8072	0.0012
0344	44.885	0.018	9.479	0.005	1.8355	0.0012
0345	44.193	0.018	9.333	0.005	1.8072	0.0012
0346	44.883	0.018	9.479	0.005	1.8354	0.0012
0347	44.202	0.018	9.335	0.005	1.8076	0.0012
0348	44.885	0.018	9.479	0.005	1.8355	0.0012
0349	44.207	0.018	9.336	0.005	1.8078	0.0012
0350	44.853	0.018	9.473	0.005	1.8342	0.0012

Annex 1: The certified masses of ^{238}U, ^{235}U and ^{239}Pu per unit of IRMM-1027p.

Vial No	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0351	44.192	0.018	9.333	0.005	1.8072	0.0012
0352	44.881	0.018	9.479	0.005	1.8354	0.0012
0353	44.169	0.018	9.328	0.005	1.8062	0.0012
0354	N/A	N/A	N/A	N/A	N/A	N/A
0355	44.900	0.018	9.483	0.005	1.8362	0.0012
0356	44.169	0.018	9.328	0.005	1.8062	0.0012
0357	44.879	0.018	9.478	0.005	1.8353	0.0012
0358	44.167	0.018	9.328	0.005	1.8062	0.0012
0359	44.879	0.018	9.478	0.005	1.8353	0.0012
0360	44.136	0.018	9.321	0.005	1.8049	0.0012
0361	44.867	0.018	9.476	0.005	1.8348	0.0012
0362	44.642	0.018	9.428	0.005	1.8256	0.0012
0363	44.123	0.018	9.319	0.005	1.8044	0.0012
0364	44.862	0.018	9.475	0.005	1.8346	0.0012
0365	44.637	0.018	9.427	0.005	1.8254	0.0012
0366	44.104	0.018	9.314	0.005	1.8036	0.0012
0367	44.907	0.018	9.484	0.005	1.8364	0.0012
0368	44.586	0.018	9.416	0.005	1.8233	0.0012
0369	44.123	0.018	9.319	0.005	1.8044	0.0012
0370	44.852	0.018	9.472	0.005	1.8342	0.0012
0371	44.696	0.018	9.440	0.005	1.8278	0.0012
0372	44.102	0.018	9.314	0.005	1.8035	0.0012
0373	44.824	0.018	9.466	0.005	1.8330	0.0012
0374	44.693	0.018	9.439	0.005	1.8277	0.0012
0375	44.102	0.018	9.314	0.005	1.8035	0.0012
0376	44.817	0.018	9.465	0.005	1.8327	0.0012
0377	44.700	0.018	9.440	0.005	1.8279	0.0012
0378	44.108	0.018	9.315	0.005	1.8037	0.0012
0379	44.813	0.018	9.464	0.005	1.8326	0.0012
0380	44.698	0.018	9.440	0.005	1.8279	0.0012
0381	44.071	0.018	9.307	0.005	1.8022	0.0012
0382	44.850	0.018	9.472	0.005	1.8341	0.0012
0383	44.689	0.018	9.438	0.005	1.8275	0.0012
0384	44.088	0.018	9.311	0.005	1.8030	0.0012
0385	44.896	0.018	9.482	0.005	1.8360	0.0012
0386	44.621	0.018	9.424	0.005	1.8248	0.0012
0387	44.146	0.018	9.323	0.005	1.8053	0.0012
0388	44.833	0.018	9.468	0.005	1.8334	0.0012
0389	44.637	0.018	9.427	0.005	1.8254	0.0012
0390	44.105	0.018	9.315	0.005	1.8036	0.0012
0391	44.850	0.018	9.472	0.005	1.8341	0.0012
0392	44.703	0.018	9.441	0.005	1.8281	0.0012
0393	44.126	0.018	9.319	0.005	1.8045	0.0012
0394	44.920	0.018	9.487	0.005	1.8370	0.0012
0395	44.150	0.018	9.324	0.005	1.8055	0.0012
0396	44.880	0.018	9.478	0.005	1.8353	0.0012
0397	44.173	0.018	9.329	0.005	1.8064	0.0012
0398	44.903	0.018	9.483	0.005	1.8362	0.0012
0399	44.579	0.018	9.415	0.005	1.8230	0.0012
0400	44.171	0.018	9.329	0.005	1.8063	0.0012

Annex 1: The certified masses of ^{238}U, ^{235}U and ^{239}Pu per unit of IRMM-1027p.

Vial No	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0401	44.897	0.018	9.482	0.005	1.8360	0.0012
0402	44.581	0.018	9.415	0.005	1.8231	0.0012
0403	44.181	0.018	9.331	0.005	1.8068	0.0012
0404	44.941	0.018	9.491	0.005	1.8378	0.0012
0405	44.173	0.018	9.329	0.005	1.8064	0.0012
0406	44.916	0.018	9.486	0.005	1.8368	0.0012
0407	44.197	0.018	9.334	0.005	1.8074	0.0012
0408	44.911	0.018	9.485	0.005	1.8366	0.0012
0409	44.201	0.018	9.335	0.005	1.8075	0.0012
0410	44.887	0.018	9.480	0.005	1.8356	0.0012
0411	44.300	0.018	9.356	0.005	1.8116	0.0012
0412	44.373	0.018	9.371	0.005	1.8146	0.0012
0413	44.976	0.018	9.499	0.005	1.8392	0.0012
0414	44.265	0.018	9.348	0.005	1.8102	0.0012
0415	44.803	0.018	9.462	0.005	1.8322	0.0012
0416	44.199	0.018	9.334	0.005	1.8075	0.0012
0417	44.906	0.018	9.484	0.005	1.8364	0.0012
0418	44.211	0.018	9.337	0.005	1.8080	0.0012
0419	44.889	0.018	9.480	0.005	1.8357	0.0012
0420	44.249	0.018	9.345	0.005	1.8095	0.0012
0421	44.768	0.018	9.455	0.005	1.8307	0.0012
0422	44.258	0.018	9.347	0.005	1.8099	0.0012
0423	44.883	0.018	9.479	0.005	1.8355	0.0012
0424	44.527	0.018	9.404	0.005	1.8209	0.0012
0425	44.559	0.018	9.410	0.005	1.8222	0.0012
0426	44.552	0.018	9.409	0.005	1.8219	0.0012
0427	44.506	0.018	9.399	0.005	1.8200	0.0012
0428	44.564	0.018	9.412	0.005	1.8224	0.0012
0429	44.564	0.018	9.412	0.005	1.8224	0.0012
0430	44.541	0.018	9.407	0.005	1.8215	0.0012
0431	44.543	0.018	9.407	0.005	1.8215	0.0012
0432	44.555	0.018	9.410	0.005	1.8220	0.0012
0433	44.525	0.018	9.403	0.005	1.8208	0.0012
0434	44.531	0.018	9.405	0.005	1.8210	0.0012
0435	44.569	0.018	9.413	0.005	1.8226	0.0012
0436	44.510	0.018	9.400	0.005	1.8202	0.0012
0437	44.593	0.018	9.418	0.005	1.8236	0.0012
0438	44.511	0.018	9.400	0.005	1.8203	0.0012
0439	44.579	0.018	9.415	0.005	1.8230	0.0012
0440	44.499	0.018	9.398	0.005	1.8198	0.0012
0441	44.599	0.018	9.419	0.005	1.8238	0.0012
0442	44.501	0.018	9.398	0.005	1.8198	0.0012
0443	44.590	0.018	9.417	0.005	1.8235	0.0012
0444	44.510	0.018	9.400	0.005	1.8202	0.0012
0445	44.586	0.018	9.416	0.005	1.8233	0.0012
0446	44.520	0.018	9.402	0.005	1.8206	0.0012
0447	44.578	0.018	9.415	0.005	1.8230	0.0012
0448	44.494	0.018	9.397	0.005	1.8195	0.0012
0449	44.590	0.018	9.417	0.005	1.8235	0.0012
0450	44.510	0.018	9.400	0.005	1.8202	0.0012

Annex 1: The certified masses of ^{238}U, ^{235}U and ^{239}Pu per unit of IRMM-1027p.

Vial No	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0451	44.578	0.018	9.415	0.005	1.8230	0.0012
0452	44.508	0.018	9.400	0.005	1.8201	0.0012
0453	44.581	0.018	9.415	0.005	1.8231	0.0012
0454	44.524	0.018	9.403	0.005	1.8208	0.0012
0455	44.578	0.018	9.415	0.005	1.8230	0.0012
0456	44.511	0.018	9.400	0.005	1.8203	0.0012
0457	44.583	0.018	9.416	0.005	1.8232	0.0012
0458	44.504	0.018	9.399	0.005	1.8200	0.0012
0459	44.566	0.018	9.412	0.005	1.8225	0.0012
0460	44.557	0.018	9.410	0.005	1.8221	0.0012
0461	44.522	0.018	9.403	0.005	1.8207	0.0012
0462	44.574	0.018	9.414	0.005	1.8228	0.0012
0463	44.510	0.018	9.400	0.005	1.8202	0.0012
0464	44.573	0.018	9.413	0.005	1.8228	0.0012
0465	44.499	0.018	9.398	0.005	1.8198	0.0012
0466	44.576	0.018	9.414	0.005	1.8229	0.0012
0467	44.504	0.018	9.399	0.005	1.8200	0.0012
0468	44.578	0.018	9.415	0.005	1.8230	0.0012
0469	44.529	0.018	9.404	0.005	1.8210	0.0012
0470	44.553	0.018	9.409	0.005	1.8220	0.0012
0471	44.506	0.018	9.399	0.005	1.8200	0.0012
0472	44.557	0.018	9.410	0.005	1.8221	0.0012
0473	44.506	0.018	9.399	0.005	1.8200	0.0012
0474	44.595	0.018	9.418	0.005	1.8237	0.0012
0475	44.497	0.018	9.398	0.005	1.8197	0.0012
0476	44.597	0.018	9.419	0.005	1.8238	0.0012
0477	44.503	0.018	9.399	0.005	1.8199	0.0012
0478	44.592	0.018	9.417	0.005	1.8235	0.0012
0479	44.497	0.018	9.398	0.005	1.8197	0.0012
0480	44.583	0.018	9.416	0.005	1.8232	0.0012
0481	44.511	0.018	9.400	0.005	1.8202	0.0012
0482	44.562	0.018	9.411	0.005	1.8223	0.0012
0483	44.506	0.018	9.399	0.005	1.8200	0.0012
0484	44.562	0.018	9.411	0.005	1.8223	0.0012
0485	44.541	0.018	9.407	0.005	1.8215	0.0012
0486	44.550	0.018	9.409	0.005	1.8218	0.0012
0487	44.545	0.018	9.407	0.005	1.8216	0.0012
0488	44.543	0.018	9.407	0.005	1.8215	0.0012
0489	44.536	0.018	9.406	0.005	1.8212	0.0012
0490	44.524	0.018	9.403	0.005	1.8207	0.0012
0491	44.534	0.018	9.405	0.005	1.8212	0.0012
0492	44.578	0.018	9.414	0.005	1.8230	0.0012
0493	44.532	0.018	9.405	0.005	1.8211	0.0012
0494	44.567	0.018	9.412	0.005	1.8225	0.0012
0495	44.529	0.018	9.404	0.005	1.8210	0.0012
0496	44.550	0.018	9.409	0.005	1.8218	0.0012
0497	44.513	0.018	9.401	0.005	1.8203	0.0012
0498	44.548	0.018	9.408	0.005	1.8217	0.0012
0499	44.550	0.018	9.409	0.005	1.8218	0.0012
0500	44.148	0.018	9.324	0.005	1.8054	0.0012

Annex 1: The certified masses of ^{238}U, ^{235}U and ^{239}Pu per unit of IRMM-1027p.

Vial No	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0501	44.868	0.018	9.476	0.005	1.8348	0.0012
0502	44.244	0.018	9.344	0.005	1.8093	0.0012
0503	44.920	0.018	9.487	0.005	1.8370	0.0012
0504	44.213	0.018	9.337	0.005	1.8080	0.0012
0505	44.943	0.018	9.492	0.005	1.8379	0.0012
0506	44.218	0.018	9.339	0.005	1.8083	0.0012
0507	44.871	0.018	9.476	0.005	1.8350	0.0012
0508	44.220	0.018	9.339	0.005	1.8083	0.0012
0509	44.882	0.018	9.479	0.005	1.8354	0.0012
0510	44.194	0.018	9.333	0.005	1.8073	0.0012
0511	44.888	0.018	9.480	0.005	1.8357	0.0012
0512	44.146	0.018	9.323	0.005	1.8053	0.0012
0513	44.883	0.018	9.479	0.005	1.8355	0.0012
0514	44.136	0.018	9.321	0.005	1.8049	0.0012
0515	44.876	0.018	9.478	0.005	1.8352	0.0012
0516	44.239	0.018	9.343	0.005	1.8091	0.0012
0517	44.911	0.018	9.485	0.005	1.8366	0.0012
0518	44.274	0.018	9.350	0.005	1.8105	0.0012
0519	44.490	0.018	9.396	0.005	1.8194	0.0012
0520	44.576	0.018	9.414	0.005	1.8229	0.0012
0521	44.534	0.018	9.405	0.005	1.8212	0.0012
0522	44.548	0.018	9.408	0.005	1.8217	0.0012
0523	44.550	0.018	9.409	0.005	1.8218	0.0012
0524	44.546	0.018	9.408	0.005	1.8217	0.0012
0525	44.541	0.018	9.407	0.005	1.8215	0.0012
0526	44.541	0.018	9.407	0.005	1.8215	0.0012
0527	44.522	0.018	9.403	0.005	1.8207	0.0012
0528	44.510	0.018	9.400	0.005	1.8202	0.0012
0529	44.503	0.018	9.399	0.005	1.8199	0.0012
0530	44.971	0.018	9.497	0.005	1.8390	0.0012
0531	44.497	0.018	9.398	0.005	1.8197	0.0012
0532	44.504	0.018	9.399	0.005	1.8200	0.0012
0533	44.497	0.018	9.398	0.005	1.8197	0.0012
0534	44.478	0.018	9.393	0.005	1.8189	0.0012
0535	44.497	0.018	9.398	0.005	1.8197	0.0012
0536	44.419	0.018	9.381	0.005	1.8165	0.0012
0537	44.916	0.018	9.486	0.005	1.8368	0.0012
0538	44.452	0.018	9.388	0.005	1.8178	0.0012
0539	44.441	0.018	9.386	0.005	1.8174	0.0012
0540	44.438	0.018	9.385	0.005	1.8173	0.0012
0541	44.820	0.018	9.466	0.005	1.8329	0.0012
0542	44.176	0.018	9.330	0.005	1.8065	0.0012
0543	44.576	0.018	9.414	0.005	1.8229	0.0012
0544	44.545	0.018	9.407	0.005	1.8216	0.0012
0545	44.548	0.018	9.408	0.005	1.8217	0.0012
0546	44.569	0.018	9.413	0.005	1.8226	0.0012
0547	44.543	0.018	9.407	0.005	1.8215	0.0012
0548	44.480	0.018	9.394	0.005	1.8190	0.0012
0549	44.487	0.018	9.395	0.005	1.8192	0.0012
0550	44.462	0.018	9.390	0.005	1.8182	0.0012

Annex 1: The certified masses of ^{238}U, ^{235}U and ^{239}Pu per unit of IRMM-1027p.

Vial No	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0551	44.433	0.018	9.384	0.005	1.8170	0.0012
0552	44.852	0.018	9.472	0.005	1.8342	0.0012
0553	44.408	0.018	9.379	0.005	1.8160	0.0012
0554	44.386	0.018	9.374	0.005	1.8151	0.0012
0555	44.822	0.018	9.466	0.005	1.8330	0.0012
0556	44.377	0.018	9.372	0.005	1.8148	0.0012
0557	44.412	0.018	9.379	0.005	1.8162	0.0012
0558	44.845	0.018	9.471	0.005	1.8339	0.0012
0559	44.438	0.018	9.385	0.005	1.8173	0.0012
0560	44.503	0.018	9.399	0.005	1.8199	0.0012
0561	44.494	0.018	9.397	0.005	1.8195	0.0012
0562	44.443	0.018	9.386	0.005	1.8175	0.0012
0563	44.478	0.018	9.393	0.005	1.8189	0.0012
0564	44.469	0.018	9.392	0.005	1.8185	0.0012
0565	44.985	0.018	9.500	0.005	1.8396	0.0012
0566	44.445	0.018	9.386	0.005	1.8175	0.0012
0567	44.478	0.018	9.393	0.005	1.8189	0.0012
0568	44.414	0.018	9.380	0.005	1.8163	0.0012
0569	44.483	0.018	9.395	0.005	1.8191	0.0012
0570	44.462	0.018	9.390	0.005	1.8182	0.0012
0571	44.901	0.018	9.483	0.005	1.8362	0.0012
0572	44.485	0.018	9.395	0.005	1.8192	0.0012
0573	44.504	0.018	9.399	0.005	1.8200	0.0012
0574	44.536	0.018	9.406	0.005	1.8212	0.0012
0575	44.551	0.018	9.409	0.005	1.8219	0.0012
0576	44.286	0.018	9.353	0.005	1.8110	0.0012
0577	44.585	0.018	9.416	0.005	1.8233	0.0012
0578	44.562	0.018	9.411	0.005	1.8223	0.0012
0579	44.513	0.018	9.401	0.005	1.8203	0.0012
0580	44.423	0.018	9.382	0.005	1.8166	0.0012
0581	44.599	0.018	9.419	0.005	1.8238	0.0012
0582	44.545	0.018	9.408	0.005	1.8216	0.0012
0583	44.548	0.018	9.408	0.005	1.8218	0.0012
0584	44.541	0.018	9.407	0.005	1.8215	0.0012
0585	44.543	0.018	9.407	0.005	1.8215	0.0012
0586	44.541	0.018	9.407	0.005	1.8215	0.0012
0587	44.548	0.018	9.408	0.005	1.8218	0.0012
0588	44.533	0.018	9.405	0.005	1.8211	0.0012
0589	44.524	0.018	9.403	0.005	1.8208	0.0012
0590	44.526	0.018	9.403	0.005	1.8208	0.0012
0591	44.534	0.018	9.405	0.005	1.8212	0.0012
0592	44.524	0.018	9.403	0.005	1.8208	0.0012
0593	44.520	0.018	9.402	0.005	1.8206	0.0012
0594	44.526	0.018	9.403	0.005	1.8208	0.0012
0595	44.522	0.018	9.403	0.005	1.8207	0.0012
0596	44.512	0.018	9.401	0.005	1.8203	0.0012
0597	44.498	0.018	9.398	0.005	1.8197	0.0012
0598	44.505	0.018	9.399	0.005	1.8200	0.0012
0599	44.491	0.018	9.396	0.005	1.8194	0.0012
0600	44.464	0.018	9.391	0.005	1.8183	0.0012

Annex 1: The certified masses of ^{238}U, ^{235}U and ^{239}Pu per unit of IRMM-1027p.

Vial No	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0601	44.875	0.018	9.477	0.005	1.8351	0.0012
0602	44.410	0.018	9.379	0.005	1.8161	0.0012
0603	44.431	0.018	9.384	0.005	1.8170	0.0012
0604	44.421	0.018	9.381	0.005	1.8165	0.0012
0605	44.931	0.018	9.489	0.005	1.8374	0.0012
0606	44.386	0.018	9.374	0.005	1.8151	0.0012
0607	44.426	0.018	9.382	0.005	1.8168	0.0012
0608	44.430	0.018	9.383	0.005	1.8169	0.0012
0609	44.553	0.018	9.409	0.005	1.8220	0.0012
0610	44.492	0.018	9.396	0.005	1.8195	0.0012
0611	44.478	0.018	9.394	0.005	1.8189	0.0012
0612	44.938	0.018	9.491	0.005	1.8377	0.0012
0613	44.381	0.018	9.373	0.005	1.8149	0.0012
0614	44.400	0.018	9.377	0.005	1.8157	0.0012
0615	44.388	0.018	9.374	0.005	1.8152	0.0012
0616	45.046	0.018	9.513	0.005	1.8421	0.0012
0617	44.344	0.018	9.365	0.005	1.8134	0.0012
0618	44.367	0.018	9.370	0.005	1.8143	0.0012
0619	44.910	0.018	9.485	0.005	1.8365	0.0012
0620	44.318	0.018	9.360	0.005	1.8123	0.0012
0621	44.368	0.018	9.370	0.005	1.8144	0.0012
0622	44.966	0.018	9.496	0.005	1.8388	0.0012
0623	44.300	0.018	9.356	0.005	1.8116	0.0012
0624	44.351	0.018	9.367	0.005	1.8137	0.0012
0625	44.987	0.018	9.501	0.005	1.8397	0.0012
0626	44.285	0.018	9.353	0.005	1.8110	0.0012
0627	44.323	0.018	9.361	0.005	1.8125	0.0012
0628	45.020	0.018	9.508	0.005	1.8410	0.0012
0629	44.265	0.018	9.349	0.005	1.8102	0.0012
0630	44.786	0.018	9.458	0.005	1.8315	0.0012
0631	44.239	0.018	9.343	0.005	1.8091	0.0012
0632	44.903	0.018	9.483	0.005	1.8363	0.0012
0633	44.255	0.018	9.346	0.005	1.8098	0.0012
0634	44.793	0.018	9.460	0.005	1.8318	0.0012
0635	44.243	0.018	9.344	0.005	1.8093	0.0012
0636	44.885	0.018	9.479	0.005	1.8355	0.0012
0637	44.230	0.018	9.341	0.005	1.8088	0.0012
0638	44.852	0.018	9.472	0.005	1.8342	0.0012
0639	44.215	0.018	9.338	0.005	1.8081	0.0012
0640	44.884	0.018	9.479	0.005	1.8355	0.0012
0641	44.363	0.018	9.369	0.005	1.8142	0.0012
0642	44.765	0.018	9.454	0.005	1.8306	0.0012
0643	44.203	0.018	9.335	0.005	1.8076	0.0012
0644	44.924	0.018	9.488	0.005	1.8371	0.0012
0645	44.169	0.018	9.328	0.005	1.8063	0.0012
0646	44.920	0.018	9.487	0.005	1.8370	0.0012
0647	44.161	0.018	9.326	0.005	1.8059	0.0012
0648	44.906	0.018	9.484	0.005	1.8364	0.0012
0649	44.164	0.018	9.327	0.005	1.8061	0.0012
0650	44.892	0.018	9.481	0.005	1.8358	0.0012

Annex 1: The certified masses of ^{238}U, ^{235}U and ^{239}Pu per unit of IRMM-1027p.

Vial No	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0651	44.140	0.018	9.322	0.005	1.8051	0.0012
0652	44.904	0.018	9.484	0.005	1.8363	0.0012
0653	44.159	0.018	9.326	0.005	1.8058	0.0012
0654	44.910	0.018	9.485	0.005	1.8365	0.0012
0655	44.573	0.018	9.413	0.005	1.8228	0.0012
0656	44.150	0.018	9.324	0.005	1.8055	0.0012
0657	44.890	0.018	9.481	0.005	1.8358	0.0012
0658	44.613	0.018	9.422	0.005	1.8244	0.0012
0659	44.117	0.018	9.317	0.005	1.8041	0.0012
0660	44.878	0.018	9.478	0.005	1.8353	0.0012
0661	44.655	0.018	9.431	0.005	1.8261	0.0012
0662	44.093	0.018	9.312	0.005	1.8031	0.0012
0663	44.866	0.018	9.475	0.005	1.8348	0.0012
0664	44.679	0.018	9.436	0.005	1.8271	0.0012
0665	44.089	0.018	9.311	0.005	1.8030	0.0012
0666	44.850	0.018	9.472	0.005	1.8341	0.0012
0667	44.698	0.018	9.440	0.005	1.8279	0.0012
0668	44.079	0.018	9.309	0.005	1.8026	0.0012
0669	44.843	0.018	9.471	0.005	1.8338	0.0012
0670	44.709	0.018	9.442	0.005	1.8283	0.0012
0671	44.489	0.018	9.396	0.005	1.8193	0.0012
0672	44.536	0.018	9.406	0.005	1.8213	0.0012
0673	44.594	0.018	9.418	0.005	1.8236	0.0012
0674	44.517	0.018	9.402	0.005	1.8205	0.0012
0675	44.538	0.018	9.406	0.005	1.8213	0.0012
0676	44.519	0.018	9.402	0.005	1.8205	0.0012
0677	44.567	0.018	9.412	0.005	1.8225	0.0012
0678	44.520	0.018	9.402	0.005	1.8206	0.0012
0679	44.540	0.018	9.406	0.005	1.8214	0.0012
0680	44.524	0.018	9.403	0.005	1.8208	0.0012
0681	44.554	0.018	9.409	0.005	1.8220	0.0012
0682	44.541	0.018	9.407	0.005	1.8215	0.0012
0683	44.547	0.018	9.408	0.005	1.8217	0.0012
0684	44.550	0.018	9.409	0.005	1.8218	0.0012
0685	44.375	0.018	9.372	0.005	1.8147	0.0012
0686	44.576	0.018	9.414	0.005	1.8229	0.0012
0687	44.513	0.018	9.401	0.005	1.8203	0.0012
0688	44.587	0.018	9.416	0.005	1.8233	0.0012
0689	44.533	0.018	9.405	0.005	1.8211	0.0012
0690	44.550	0.018	9.409	0.005	1.8218	0.0012
0691	44.540	0.018	9.406	0.005	1.8214	0.0012
0692	44.541	0.018	9.407	0.005	1.8215	0.0012
0693	44.545	0.018	9.408	0.005	1.8216	0.0012
0694	44.541	0.018	9.407	0.005	1.8215	0.0012
0695	44.531	0.018	9.405	0.005	1.8210	0.0012
0696	44.540	0.018	9.406	0.005	1.8214	0.0012
0697	44.543	0.018	9.407	0.005	1.8215	0.0012
0698	44.547	0.018	9.408	0.005	1.8217	0.0012
0699	44.547	0.018	9.408	0.005	1.8217	0.0012
0700	44.540	0.018	9.406	0.005	1.8214	0.0012

Annex 1: The certified masses of ^{238}U, ^{235}U and ^{239}Pu per unit of IRMM-1027p.

Vial No	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0701	44.540	0.018	9.406	0.005	1.8214	0.0012
0702	44.547	0.018	9.408	0.005	1.8217	0.0012
0703	44.540	0.018	9.406	0.005	1.8214	0.0012
0704	44.547	0.018	9.408	0.005	1.8217	0.0012
0705	44.543	0.018	9.407	0.005	1.8215	0.0012
0706	44.548	0.018	9.408	0.005	1.8218	0.0012
0707	44.543	0.018	9.407	0.005	1.8215	0.0012
0708	44.538	0.018	9.406	0.005	1.8213	0.0012
0709	44.547	0.018	9.408	0.005	1.8217	0.0012
0710	44.547	0.018	9.408	0.005	1.8217	0.0012
0711	44.540	0.018	9.406	0.005	1.8214	0.0012
0712	44.547	0.018	9.408	0.005	1.8217	0.0012
0713	44.536	0.018	9.406	0.005	1.8213	0.0012
0714	44.555	0.018	9.410	0.005	1.8220	0.0012
0715	44.543	0.018	9.407	0.005	1.8215	0.0012
0716	44.543	0.018	9.407	0.005	1.8215	0.0012
0717	44.547	0.018	9.408	0.005	1.8217	0.0012
0718	44.547	0.018	9.408	0.005	1.8217	0.0012
0719	44.550	0.018	9.409	0.005	1.8218	0.0012
0720	44.543	0.018	9.407	0.005	1.8215	0.0012
0721	44.541	0.018	9.407	0.005	1.8215	0.0012
0722	44.555	0.018	9.410	0.005	1.8220	0.0012
0723	44.538	0.018	9.406	0.005	1.8213	0.0012
0724	44.548	0.018	9.408	0.005	1.8218	0.0012
0725	44.547	0.018	9.408	0.005	1.8217	0.0012
0726	44.550	0.018	9.409	0.005	1.8218	0.0012
0727	44.547	0.018	9.408	0.005	1.8217	0.0012
0728	44.543	0.018	9.407	0.005	1.8215	0.0012
0729	44.543	0.018	9.407	0.005	1.8215	0.0012
0730	44.541	0.018	9.407	0.005	1.8215	0.0012
0731	44.548	0.018	9.408	0.005	1.8218	0.0012
0732	44.554	0.018	9.409	0.005	1.8220	0.0012
0733	44.548	0.018	9.408	0.005	1.8218	0.0012
0734	44.550	0.018	9.409	0.005	1.8218	0.0012
0735	44.557	0.018	9.410	0.005	1.8221	0.0012
0736	44.541	0.018	9.407	0.005	1.8215	0.0012
0737	44.466	0.018	9.391	0.005	1.8184	0.0012
0738	44.557	0.018	9.410	0.005	1.8221	0.0012
0739	44.531	0.018	9.405	0.005	1.8210	0.0012
0740	44.569	0.018	9.413	0.005	1.8226	0.0012
0741	44.543	0.018	9.407	0.005	1.8215	0.0012
0742	44.548	0.018	9.408	0.005	1.8218	0.0012
0743	44.379	0.018	9.373	0.005	1.8148	0.0012
0744	44.615	0.018	9.422	0.005	1.8245	0.0012
0745	44.527	0.018	9.404	0.005	1.8209	0.0012
0746	44.559	0.018	9.410	0.005	1.8222	0.0012
0747	44.547	0.018	9.408	0.005	1.8217	0.0012
0748	44.548	0.018	9.408	0.005	1.8218	0.0012
0749	44.559	0.018	9.410	0.005	1.8222	0.0012
0750	44.550	0.018	9.409	0.005	1.8218	0.0012

Annex 1: The certified masses of ^{238}U, ^{235}U and ^{239}Pu per unit of IRMM-1027p.

Vial No	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0751	44.547	0.018	9.408	0.005	1.8217	0.0012
0752	44.550	0.018	9.409	0.005	1.8218	0.0012
0753	44.554	0.018	9.409	0.005	1.8220	0.0012
0754	44.552	0.018	9.409	0.005	1.8219	0.0012
0755	44.545	0.018	9.408	0.005	1.8216	0.0012
0756	44.550	0.018	9.409	0.005	1.8218	0.0012
0757	44.548	0.018	9.408	0.005	1.8218	0.0012
0758	44.548	0.018	9.408	0.005	1.8218	0.0012
0759	44.552	0.018	9.409	0.005	1.8219	0.0012
0760	44.550	0.018	9.409	0.005	1.8218	0.0012
0761	44.552	0.018	9.409	0.005	1.8219	0.0012
0762	44.555	0.018	9.410	0.005	1.8220	0.0012
0763	44.545	0.018	9.408	0.005	1.8216	0.0012
0764	44.554	0.018	9.409	0.005	1.8220	0.0012
0765	44.545	0.018	9.408	0.005	1.8216	0.0012
0766	44.554	0.018	9.409	0.005	1.8220	0.0012
0767	44.555	0.018	9.410	0.005	1.8220	0.0012
0768	44.552	0.018	9.409	0.005	1.8219	0.0012
0769	44.567	0.018	9.412	0.005	1.8225	0.0012
0770	44.540	0.018	9.406	0.005	1.8214	0.0012
0771	44.545	0.018	9.408	0.005	1.8216	0.0012
0772	44.545	0.018	9.408	0.005	1.8216	0.0012
0773	44.548	0.018	9.408	0.005	1.8218	0.0012
0774	44.546	0.018	9.408	0.005	1.8217	0.0012
0775	44.559	0.018	9.410	0.005	1.8222	0.0012
0776	44.540	0.018	9.406	0.005	1.8214	0.0012
0777	44.566	0.018	9.412	0.005	1.8225	0.0012
0778	44.545	0.018	9.408	0.005	1.8216	0.0012
0779	44.555	0.018	9.410	0.005	1.8220	0.0012
0780	44.555	0.018	9.410	0.005	1.8220	0.0012
0781	44.557	0.018	9.410	0.005	1.8221	0.0012
0782	44.552	0.018	9.409	0.005	1.8219	0.0012
0783	44.517	0.018	9.402	0.005	1.8205	0.0012
0784	44.567	0.018	9.412	0.005	1.8225	0.0012
0785	44.541	0.018	9.407	0.005	1.8215	0.0012
0786	44.559	0.018	9.410	0.005	1.8222	0.0012
0787	44.546	0.018	9.408	0.005	1.8217	0.0012
0788	44.562	0.018	9.411	0.005	1.8223	0.0012
0789	44.550	0.018	9.409	0.005	1.8218	0.0012
0790	44.552	0.018	9.409	0.005	1.8219	0.0012
0791	44.548	0.018	9.408	0.005	1.8218	0.0012
0792	44.559	0.018	9.410	0.005	1.8222	0.0012
0793	44.546	0.018	9.408	0.005	1.8217	0.0012
0794	44.559	0.018	9.410	0.005	1.8222	0.0012
0795	44.557	0.018	9.410	0.005	1.8221	0.0012
0796	44.548	0.018	9.408	0.005	1.8218	0.0012
0797	44.550	0.018	9.409	0.005	1.8218	0.0012
0798	44.526	0.018	9.403	0.005	1.8208	0.0012
0799	44.567	0.018	9.412	0.005	1.8225	0.0012
0800	44.526	0.018	9.403	0.005	1.8208	0.0012

Annex 1: The certified masses of ^{238}U, ^{235}U and ^{239}Pu per unit of IRMM-1027p.

Vial No	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0801	44.522	0.018	9.403	0.005	1.8207	0.0012
0802	44.492	0.018	9.396	0.005	1.8195	0.0012
0803	44.501	0.018	9.398	0.005	1.8198	0.0012
0804	44.508	0.018	9.400	0.005	1.8201	0.0012
0805	44.526	0.018	9.403	0.005	1.8208	0.0012
0806	44.531	0.018	9.405	0.005	1.8210	0.0012
0807	44.513	0.018	9.401	0.005	1.8203	0.0012
0808	44.492	0.018	9.396	0.005	1.8195	0.0012
0809	44.445	0.018	9.387	0.005	1.8175	0.0012
0810	44.913	0.018	9.485	0.005	1.8367	0.0012
0811	44.456	0.018	9.389	0.005	1.8180	0.0012
0812	44.470	0.018	9.392	0.005	1.8185	0.0012
0813	44.485	0.018	9.395	0.005	1.8192	0.0012
0814	44.449	0.018	9.387	0.005	1.8177	0.0012
0815	44.885	0.018	9.479	0.005	1.8355	0.0012
0816	44.450	0.018	9.388	0.005	1.8178	0.0012
0817	44.475	0.018	9.393	0.005	1.8188	0.0012
0818	44.295	0.018	9.355	0.005	1.8114	0.0012
0819	44.494	0.018	9.397	0.005	1.8195	0.0012
0820	44.456	0.018	9.389	0.005	1.8180	0.0012
0821	44.471	0.018	9.392	0.005	1.8186	0.0012
0822	44.464	0.018	9.391	0.005	1.8183	0.0012
0823	44.887	0.018	9.480	0.005	1.8356	0.0012
0824	44.430	0.018	9.383	0.005	1.8169	0.0012
0825	44.463	0.018	9.390	0.005	1.8183	0.0012
0826	44.463	0.018	9.390	0.005	1.8183	0.0012
0827	44.897	0.018	9.482	0.005	1.8360	0.0012
0828	44.445	0.018	9.387	0.005	1.8175	0.0012
0829	44.438	0.018	9.385	0.005	1.8173	0.0012
0830	44.445	0.018	9.387	0.005	1.8175	0.0012
0831	44.859	0.018	9.474	0.005	1.8345	0.0012
0832	44.405	0.018	9.378	0.005	1.8159	0.0012
0833	44.454	0.018	9.388	0.005	1.8179	0.0012
0834	44.438	0.018	9.385	0.005	1.8173	0.0012
0835	44.932	0.018	9.489	0.005	1.8375	0.0012
0836	44.431	0.018	9.384	0.005	1.8170	0.0012
0837	44.452	0.018	9.388	0.005	1.8178	0.0012
0838	44.457	0.018	9.389	0.005	1.8180	0.0012
0839	44.377	0.018	9.372	0.005	1.8148	0.0012
0840	44.880	0.018	9.478	0.005	1.8353	0.0012
0841	44.423	0.018	9.382	0.005	1.8166	0.0012
0842	44.438	0.018	9.385	0.005	1.8173	0.0012
0843	44.461	0.018	9.390	0.005	1.8182	0.0012
0844	44.890	0.018	9.481	0.005	1.8358	0.0012
0845	44.452	0.018	9.388	0.005	1.8178	0.0012
0846	44.447	0.018	9.387	0.005	1.8176	0.0012
0847	44.456	0.018	9.389	0.005	1.8180	0.0012
0848	44.440	0.018	9.385	0.005	1.8173	0.0012
0849	45.016	0.018	9.507	0.005	1.8409	0.0012
0850	44.454	0.018	9.388	0.005	1.8179	0.0012

Annex 1: The certified masses of ^{238}U, ^{235}U and ^{239}Pu per unit of IRMM-1027p.

Vial No	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0851	44.450	0.018	9.388	0.005	1.8178	0.0012
0852	44.463	0.018	9.390	0.005	1.8183	0.0012
0853	44.457	0.018	9.389	0.005	1.8180	0.0012
0854	44.885	0.018	9.479	0.005	1.8355	0.0012
0855	44.421	0.018	9.381	0.005	1.8165	0.0012
0856	44.443	0.018	9.386	0.005	1.8175	0.0012
0857	44.442	0.018	9.386	0.005	1.8174	0.0012
0858	44.941	0.018	9.491	0.005	1.8378	0.0012
0859	44.445	0.018	9.387	0.005	1.8175	0.0012
0860	44.436	0.018	9.385	0.005	1.8172	0.0012
0861	44.445	0.018	9.387	0.005	1.8175	0.0012
0862	44.910	0.018	9.485	0.005	1.8365	0.0012
0863	44.452	0.018	9.388	0.005	1.8178	0.0012
0864	44.471	0.018	9.392	0.005	1.8186	0.0012
0865	44.487	0.018	9.395	0.005	1.8193	0.0012
0866	44.475	0.018	9.393	0.005	1.8188	0.0012
0867	44.436	0.018	9.385	0.005	1.8172	0.0012
0868	44.955	0.018	9.494	0.005	1.8384	0.0012
0869	44.447	0.018	9.387	0.005	1.8176	0.0012
0870	44.461	0.018	9.390	0.005	1.8182	0.0012
0871	44.487	0.018	9.395	0.005	1.8193	0.0012
0872	44.482	0.018	9.394	0.005	1.8190	0.0012
0873	44.431	0.018	9.384	0.005	1.8170	0.0012
0874	44.983	0.018	9.500	0.005	1.8395	0.0012
0875	44.464	0.018	9.391	0.005	1.8183	0.0012
0876	44.457	0.018	9.389	0.005	1.8180	0.0012
0877	44.436	0.018	9.385	0.005	1.8172	0.0012
0878	44.440	0.018	9.385	0.005	1.8173	0.0012
0879	44.920	0.018	9.487	0.005	1.8370	0.0012
0880	44.424	0.018	9.382	0.005	1.8167	0.0012
0881	44.459	0.018	9.389	0.005	1.8181	0.0012
0882	44.491	0.018	9.396	0.005	1.8194	0.0012
0883	44.464	0.018	9.391	0.005	1.8183	0.0012
0884	44.915	0.018	9.486	0.005	1.8368	0.0012
0885	44.436	0.018	9.385	0.005	1.8172	0.0012
0886	44.463	0.018	9.390	0.005	1.8183	0.0012
0887	44.409	0.018	9.379	0.005	1.8160	0.0012
0888	44.906	0.018	9.484	0.005	1.8364	0.0012
0889	44.379	0.018	9.372	0.005	1.8148	0.0012
0890	44.501	0.018	9.398	0.005	1.8198	0.0012
0891	44.365	0.018	9.370	0.005	1.8143	0.0012
0892	44.992	0.018	9.502	0.005	1.8399	0.0012
0893	44.428	0.018	9.383	0.005	1.8168	0.0012
0894	44.670	0.018	9.434	0.005	1.8268	0.0012
0895	44.532	0.018	9.405	0.005	1.8211	0.0012
0896	44.559	0.018	9.410	0.005	1.8222	0.0012
0897	44.532	0.018	9.405	0.005	1.8211	0.0012
0898	44.571	0.018	9.413	0.005	1.8227	0.0012
0899	44.513	0.018	9.401	0.005	1.8203	0.0012
0900	44.602	0.018	9.420	0.005	1.8240	0.0012

Annex 1: The certified masses of ^{238}U, ^{235}U and ^{239}Pu per unit of IRMM-1027p.

Vial No	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0901	44.538	0.018	9.406	0.005	1.8213	0.0012
0902	44.557	0.018	9.410	0.005	1.8221	0.0012
0903	44.548	0.018	9.408	0.005	1.8218	0.0012
0904	44.557	0.018	9.410	0.005	1.8221	0.0012
0905	44.553	0.018	9.409	0.005	1.8220	0.0012
0906	44.557	0.018	9.410	0.005	1.8221	0.0012
0907	44.550	0.018	9.409	0.005	1.8218	0.0012
0908	44.550	0.018	9.409	0.005	1.8218	0.0012
0909	44.552	0.018	9.409	0.005	1.8219	0.0012
0910	44.562	0.018	9.411	0.005	1.8223	0.0012
0911	44.546	0.018	9.408	0.005	1.8217	0.0012
0912	44.560	0.018	9.411	0.005	1.8223	0.0012
0913	44.552	0.018	9.409	0.005	1.8219	0.0012
0914	44.555	0.018	9.410	0.005	1.8220	0.0012
0915	44.555	0.018	9.410	0.005	1.8220	0.0012
0916	44.557	0.018	9.410	0.005	1.8221	0.0012
0917	44.550	0.018	9.409	0.005	1.8218	0.0012
0918	44.154	0.018	9.325	0.005	1.8056	0.0012
0919	44.461	0.018	9.390	0.005	1.8182	0.0012
0920	44.883	0.018	9.479	0.005	1.8355	0.0012
0921	44.583	0.018	9.416	0.005	1.8232	0.0012
0922	44.539	0.018	9.406	0.005	1.8214	0.0012
0923	44.553	0.018	9.409	0.005	1.8220	0.0012
0924	44.562	0.018	9.411	0.005	1.8223	0.0012
0925	44.550	0.018	9.409	0.005	1.8218	0.0012
0926	44.541	0.018	9.407	0.005	1.8215	0.0012
0927	44.562	0.018	9.411	0.005	1.8223	0.0012
0928	44.555	0.018	9.410	0.005	1.8220	0.0012
0929	44.557	0.018	9.410	0.005	1.8221	0.0012
0930	44.550	0.018	9.409	0.005	1.8218	0.0012
0931	44.552	0.018	9.409	0.005	1.8219	0.0012
0932	44.562	0.018	9.411	0.005	1.8223	0.0012
0933	44.553	0.018	9.409	0.005	1.8220	0.0012
0934	44.560	0.018	9.411	0.005	1.8223	0.0012
0935	44.546	0.018	9.408	0.005	1.8217	0.0012
0936	44.651	0.018	9.430	0.005	1.8260	0.0012
0937	44.555	0.018	9.410	0.005	1.8220	0.0012
0938	44.510	0.018	9.400	0.005	1.8202	0.0012
0939	44.581	0.018	9.415	0.005	1.8231	0.0012
0940	44.559	0.018	9.410	0.005	1.8222	0.0012
0941	44.567	0.018	9.412	0.005	1.8225	0.0012
0942	44.559	0.018	9.410	0.005	1.8222	0.0012
0943	44.541	0.018	9.407	0.005	1.8215	0.0012
0944	44.562	0.018	9.411	0.005	1.8223	0.0012
0945	44.552	0.018	9.409	0.005	1.8219	0.0012
0946	44.550	0.018	9.409	0.005	1.8218	0.0012
0947	44.557	0.018	9.410	0.005	1.8221	0.0012
0948	44.534	0.018	9.405	0.005	1.8212	0.0012
0949	44.550	0.018	9.409	0.005	1.8218	0.0012
0950	44.541	0.018	9.407	0.005	1.8215	0.0012

Annex 1: The certified masses of ^{238}U, ^{235}U and ^{239}Pu per unit of IRMM-1027p.

Vial No	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0951	44.543	0.018	9.407	0.005	1.8215	0.0012
0952	44.536	0.018	9.406	0.005	1.8213	0.0012
0953	44.520	0.018	9.402	0.005	1.8206	0.0012
0954	44.532	0.018	9.405	0.005	1.8211	0.0012
0955	44.541	0.018	9.407	0.005	1.8215	0.0012
0956	44.529	0.018	9.404	0.005	1.8210	0.0012
0957	44.538	0.018	9.406	0.005	1.8213	0.0012
0958	44.534	0.018	9.405	0.005	1.8212	0.0012
0959	44.449	0.018	9.387	0.005	1.8177	0.0012
0960	44.510	0.018	9.400	0.005	1.8202	0.0012
0961	44.543	0.018	9.407	0.005	1.8215	0.0012
0962	44.508	0.018	9.400	0.005	1.8201	0.0012
0963	44.496	0.018	9.397	0.005	1.8196	0.0012
0964	44.512	0.018	9.401	0.005	1.8203	0.0012
0965	44.503	0.018	9.399	0.005	1.8199	0.0012
0966	44.494	0.018	9.397	0.005	1.8195	0.0012
0967	44.484	0.018	9.395	0.005	1.8191	0.0012
0968	44.484	0.018	9.395	0.005	1.8191	0.0012
0969	44.946	0.018	9.492	0.005	1.8380	0.0012
0970	44.499	0.018	9.398	0.005	1.8198	0.0012
0971	44.519	0.018	9.402	0.005	1.8205	0.0012
0972	44.475	0.018	9.393	0.005	1.8188	0.0012
0973	44.375	0.018	9.372	0.005	1.8147	0.0012
0974	44.946	0.018	9.492	0.005	1.8380	0.0012
0975	44.403	0.018	9.378	0.005	1.8158	0.0012
0976	44.405	0.018	9.378	0.005	1.8159	0.0012
0977	44.856	0.018	9.473	0.005	1.8343	0.0012
0978	44.393	0.018	9.375	0.005	1.8154	0.0012
0979	44.384	0.018	9.374	0.005	1.8150	0.0012
0980	44.840	0.018	9.470	0.005	1.8337	0.0012
0981	44.391	0.018	9.375	0.005	1.8153	0.0012
0982	44.374	0.018	9.371	0.005	1.8146	0.0012
0983	44.887	0.018	9.480	0.005	1.8356	0.0012
0984	44.382	0.018	9.373	0.005	1.8150	0.0012
0985	44.370	0.018	9.371	0.005	1.8145	0.0012
0986	44.901	0.018	9.483	0.005	1.8362	0.0012
0987	44.396	0.018	9.376	0.005	1.8155	0.0012
0988	44.368	0.018	9.370	0.005	1.8144	0.0012
0989	44.890	0.018	9.481	0.005	1.8358	0.0012
0990	44.379	0.018	9.372	0.005	1.8148	0.0012
0991	44.374	0.018	9.371	0.005	1.8146	0.0012
0992	44.904	0.018	9.483	0.005	1.8363	0.0012
0993	44.365	0.018	9.370	0.005	1.8143	0.0012
0994	44.344	0.018	9.365	0.005	1.8134	0.0012
0995	44.966	0.018	9.496	0.005	1.8388	0.0012
0996	44.326	0.018	9.361	0.005	1.8127	0.0012
0997	44.353	0.018	9.367	0.005	1.8138	0.0012
0998	44.967	0.018	9.497	0.005	1.8389	0.0012
0999	44.358	0.018	9.368	0.005	1.8140	0.0012
1000	44.361	0.018	9.369	0.005	1.8141	0.0012

Annex 1: The certified masses of ^{238}U, ^{235}U and ^{239}Pu per unit of IRMM-1027p.

Vial No	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
1001	44.918	0.018	9.486	0.005	1.8369	0.0012
1002	44.356	0.018	9.368	0.005	1.8139	0.0012
1003	44.339	0.018	9.364	0.005	1.8132	0.0012
1004	44.967	0.018	9.497	0.005	1.8389	0.0012
1005	44.354	0.018	9.367	0.005	1.8138	0.0012
1006	44.330	0.018	9.362	0.005	1.8128	0.0012
1007	44.971	0.018	9.498	0.005	1.8390	0.0012
1008	44.326	0.018	9.361	0.005	1.8127	0.0012
1009	44.328	0.018	9.362	0.005	1.8128	0.0012
1010	45.007	0.018	9.505	0.005	1.8405	0.0012
1011	44.328	0.018	9.362	0.005	1.8128	0.0012
1012	44.330	0.018	9.362	0.005	1.8128	0.0012
1013	44.993	0.018	9.502	0.005	1.8400	0.0012
1014	44.312	0.018	9.358	0.005	1.8121	0.0012
1015	44.440	0.018	9.385	0.005	1.8173	0.0012
1016	44.386	0.018	9.374	0.005	1.8151	0.0012
1017	44.742	0.018	9.449	0.005	1.8297	0.0012
1018	44.316	0.018	9.359	0.005	1.8123	0.0012
1019	44.829	0.018	9.468	0.005	1.8333	0.0012
1020	44.286	0.018	9.353	0.005	1.8110	0.0012
1021	44.821	0.018	9.466	0.005	1.8329	0.0012
1022	44.281	0.018	9.352	0.005	1.8108	0.0012
1023	44.843	0.018	9.471	0.005	1.8338	0.0012
1024	44.295	0.018	9.355	0.005	1.8114	0.0012
1025	44.793	0.018	9.460	0.005	1.8318	0.0012
1026	44.271	0.018	9.350	0.005	1.8104	0.0012
1027	44.866	0.018	9.475	0.005	1.8348	0.0012
1028	44.290	0.018	9.354	0.005	1.8112	0.0012
1029	44.815	0.018	9.465	0.005	1.8327	0.0012
1030	44.281	0.018	9.352	0.005	1.8108	0.0012
1031	44.843	0.018	9.471	0.005	1.8338	0.0012
1032	44.265	0.018	9.349	0.005	1.8102	0.0012
1033	44.843	0.018	9.471	0.005	1.8338	0.0012
1034	44.293	0.018	9.354	0.005	1.8113	0.0012
1035	44.803	0.018	9.462	0.005	1.8322	0.0012
1036	44.269	0.018	9.349	0.005	1.8103	0.0012
1037	44.842	0.018	9.470	0.005	1.8338	0.0012
1038	44.269	0.018	9.349	0.005	1.8103	0.0012
1039	44.833	0.018	9.468	0.005	1.8334	0.0012
1040	44.248	0.018	9.345	0.005	1.8095	0.0012
1041	44.856	0.018	9.473	0.005	1.8343	0.0012
1042	44.246	0.018	9.344	0.005	1.8094	0.0012
1043	44.857	0.018	9.474	0.005	1.8344	0.0012
1044	44.269	0.018	9.349	0.005	1.8103	0.0012
1045	44.829	0.018	9.468	0.005	1.8333	0.0012
1046	44.271	0.018	9.350	0.005	1.8104	0.0012
1047	44.850	0.018	9.472	0.005	1.8341	0.0012
1048	44.264	0.018	9.348	0.005	1.8101	0.0012
1049	44.850	0.018	9.472	0.005	1.8341	0.0012
1050	44.246	0.018	9.344	0.005	1.8094	0.0012

Annex 1: The certified masses of ^{238}U, ^{235}U and ^{239}Pu per unit of IRMM-1027p.

Vial No	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
1051	44.850	0.018	9.472	0.005	1.8341	0.0012
1052	44.251	0.018	9.346	0.005	1.8096	0.0012
1053	44.667	0.018	9.433	0.005	1.8266	0.0012
1054	44.229	0.018	9.341	0.005	1.8087	0.0012
1055	44.925	0.018	9.488	0.005	1.8372	0.0012
1056	44.248	0.018	9.345	0.005	1.8095	0.0012
1057	44.859	0.018	9.474	0.005	1.8345	0.0012
1058	44.213	0.018	9.337	0.005	1.8080	0.0012
1059	44.873	0.018	9.477	0.005	1.8350	0.0012
1060	44.246	0.018	9.344	0.005	1.8094	0.0012
1061	44.824	0.018	9.467	0.005	1.8330	0.0012
1062	44.243	0.018	9.344	0.005	1.8093	0.0012
1063	44.855	0.018	9.473	0.005	1.8343	0.0012
1064	44.222	0.018	9.339	0.005	1.8084	0.0012
1065	44.880	0.018	9.478	0.005	1.8353	0.0012
1066	44.236	0.018	9.342	0.005	1.8090	0.0012
1067	44.875	0.018	9.477	0.005	1.8351	0.0012
1068	44.236	0.018	9.342	0.005	1.8090	0.0012
1069	44.878	0.018	9.478	0.005	1.8352	0.0012
1070	44.234	0.018	9.342	0.005	1.8089	0.0012
1071	44.876	0.018	9.478	0.005	1.8352	0.0012
1072	44.232	0.018	9.342	0.005	1.8088	0.0012
1073	44.878	0.018	9.478	0.005	1.8352	0.0012
1074	44.227	0.018	9.340	0.005	1.8086	0.0012
1075	44.876	0.018	9.478	0.005	1.8352	0.0012
1076	44.236	0.018	9.342	0.005	1.8090	0.0012
1077	44.887	0.018	9.480	0.005	1.8356	0.0012
1078	44.236	0.018	9.342	0.005	1.8090	0.0012
1079	44.871	0.018	9.476	0.005	1.8350	0.0012
1080	44.241	0.018	9.343	0.005	1.8092	0.0012
1081	44.880	0.018	9.478	0.005	1.8353	0.0012
1082	44.215	0.018	9.338	0.005	1.8081	0.0012
1083	44.897	0.018	9.482	0.005	1.8360	0.0012
1084	44.215	0.018	9.338	0.005	1.8081	0.0012
1085	44.903	0.018	9.483	0.005	1.8362	0.0012
1086	44.201	0.018	9.335	0.005	1.8075	0.0012
1087	44.913	0.018	9.485	0.005	1.8367	0.0012
1088	44.192	0.018	9.333	0.005	1.8072	0.0012
1089	44.920	0.018	9.487	0.005	1.8370	0.0012
1090	44.178	0.018	9.330	0.005	1.8066	0.0012
1091	44.925	0.018	9.488	0.005	1.8372	0.0012
1092	44.192	0.018	9.333	0.005	1.8072	0.0012
1093	44.918	0.018	9.486	0.005	1.8369	0.0012
1094	44.204	0.018	9.336	0.005	1.8077	0.0012
1095	44.843	0.018	9.471	0.005	1.8338	0.0012
1096	44.211	0.018	9.337	0.005	1.8080	0.0012
1097	44.904	0.018	9.483	0.005	1.8363	0.0012
1098	44.208	0.018	9.336	0.005	1.8078	0.0012
1099	44.904	0.018	9.483	0.005	1.8363	0.0012
1100	44.204	0.018	9.336	0.005	1.8077	0.0012

Annex 1: The certified masses of ^{238}U, ^{235}U and ^{239}Pu per unit of IRMM-1027p.

Vial No	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
1101	44.901	0.018	9.483	0.005	1.8362	0.0012
1102	44.215	0.018	9.338	0.005	1.8081	0.0012
1103	44.887	0.018	9.480	0.005	1.8356	0.0012
1104	44.208	0.018	9.336	0.005	1.8078	0.0012
1105	44.890	0.018	9.481	0.005	1.8357	0.0012
1106	44.190	0.018	9.333	0.005	1.8071	0.0012
1107	44.908	0.018	9.484	0.005	1.8365	0.0012
1108	44.201	0.018	9.335	0.005	1.8075	0.0012
1109	44.920	0.018	9.487	0.005	1.8370	0.0012
1110	44.199	0.018	9.334	0.005	1.8075	0.0012
1111	44.897	0.018	9.482	0.005	1.8360	0.0012
1112	44.181	0.018	9.331	0.005	1.8068	0.0012
1113	44.786	0.018	9.458	0.005	1.8315	0.0012
1114	44.202	0.018	9.335	0.005	1.8076	0.0012
1115	44.890	0.018	9.481	0.005	1.8357	0.0012
1116	44.183	0.018	9.331	0.005	1.8068	0.0012
1117	44.894	0.018	9.481	0.005	1.8359	0.0012
1118	44.183	0.018	9.331	0.005	1.8068	0.0012
1119	44.897	0.018	9.482	0.005	1.8360	0.0012
1120	44.601	0.018	9.419	0.005	1.8239	0.0012
1121	44.171	0.018	9.329	0.005	1.8063	0.0012
1122	44.889	0.018	9.480	0.005	1.8357	0.0012
1123	44.601	0.018	9.419	0.005	1.8239	0.0012
1124	44.155	0.018	9.325	0.005	1.8057	0.0012
1125	44.897	0.018	9.482	0.005	1.8360	0.0012
1126	44.637	0.018	9.427	0.005	1.8254	0.0012
1127	44.159	0.018	9.326	0.005	1.8058	0.0012
1128	44.885	0.018	9.479	0.005	1.8355	0.0012
1129	44.639	0.018	9.427	0.005	1.8255	0.0012
1130	44.173	0.018	9.329	0.005	1.8064	0.0012
1131	44.880	0.018	9.478	0.005	1.8353	0.0012
1132	44.632	0.018	9.426	0.005	1.8252	0.0012
1133	44.148	0.018	9.324	0.005	1.8054	0.0012
1134	44.859	0.018	9.474	0.005	1.8345	0.0012
1135	44.667	0.018	9.433	0.005	1.8266	0.0012
1136	44.126	0.018	9.319	0.005	1.8045	0.0012
1137	44.873	0.018	9.477	0.005	1.8350	0.0012
1138	44.674	0.018	9.435	0.005	1.8269	0.0012
1139	44.150	0.018	9.324	0.005	1.8055	0.0012
1140	44.861	0.018	9.474	0.005	1.8345	0.0012
1141	44.676	0.018	9.435	0.005	1.8270	0.0012
1142	44.120	0.018	9.318	0.005	1.8043	0.0012
1143	44.868	0.018	9.476	0.005	1.8348	0.0012
1144	44.697	0.018	9.440	0.005	1.8278	0.0012
1145	44.113	0.018	9.316	0.005	1.8040	0.0012
1146	44.861	0.018	9.474	0.005	1.8345	0.0012
1147	44.711	0.018	9.443	0.005	1.8284	0.0012
1148	44.115	0.018	9.317	0.005	1.8040	0.0012
1149	44.869	0.018	9.476	0.005	1.8349	0.0012
1150	44.691	0.018	9.438	0.005	1.8276	0.0012

Annex 1: The certified masses of ^{238}U, ^{235}U and ^{239}Pu per unit of IRMM-1027p.

Vial No	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
1151	44.571	0.018	9.413	0.005	1.8227	0.0012
1152	44.119	0.018	9.318	0.005	1.8042	0.0012
1153	44.855	0.018	9.473	0.005	1.8343	0.0012
1154	44.555	0.018	9.410	0.005	1.8220	0.0012
1155	44.567	0.018	9.412	0.005	1.8225	0.0012
1156	44.572	0.018	9.413	0.005	1.8227	0.0012
1157	44.572	0.018	9.413	0.005	1.8227	0.0012
1158	44.560	0.018	9.411	0.005	1.8222	0.0012
1159	44.570	0.018	9.413	0.005	1.8227	0.0012
1160	44.574	0.018	9.414	0.005	1.8228	0.0012
1161	44.579	0.018	9.415	0.005	1.8230	0.0012
1162	44.542	0.018	9.407	0.005	1.8215	0.0012
1163	44.567	0.018	9.412	0.005	1.8225	0.0012
1164	44.569	0.018	9.413	0.005	1.8226	0.0012
1165	44.567	0.018	9.412	0.005	1.8225	0.0012
1166	44.562	0.018	9.411	0.005	1.8223	0.0012
1167	44.572	0.018	9.413	0.005	1.8227	0.0012
1168	44.560	0.018	9.411	0.005	1.8222	0.0012
1169	44.560	0.018	9.411	0.005	1.8222	0.0012
1170	44.565	0.018	9.412	0.005	1.8224	0.0012
1171	44.565	0.018	9.412	0.005	1.8224	0.0012
1172	44.558	0.018	9.410	0.005	1.8222	0.0012
1173	44.563	0.018	9.411	0.005	1.8224	0.0012
1174	44.556	0.018	9.410	0.005	1.8221	0.0012
1175	44.558	0.018	9.410	0.005	1.8222	0.0012
1176	44.555	0.018	9.410	0.005	1.8220	0.0012
1177	44.553	0.018	9.409	0.005	1.8219	0.0012
1178	44.551	0.018	9.409	0.005	1.8219	0.0012
1179	44.551	0.018	9.409	0.005	1.8219	0.0012
1180	44.551	0.018	9.409	0.005	1.8219	0.0012
1181	44.551	0.018	9.409	0.005	1.8219	0.0012
1182	44.551	0.018	9.409	0.005	1.8219	0.0012
1183	44.551	0.018	9.409	0.005	1.8219	0.0012
1184	44.560	0.018	9.411	0.005	1.8222	0.0012
1185	44.612	0.018	9.422	0.005	1.8244	0.0012
1186	43.720	0.018	9.233	0.005	1.7879	0.0012

[1] The certified values are traceable to the values on the respective metal certificates (EC NRM 101, NBL CRM-116 and CETAMA MP2).
[2] The certified uncertainty is the expanded uncertainty with a coverage factor $k = 2$ corresponding to a level of confidence of about 95 % estimated in accordance with ISO/IEC Guide 98-3, Guide to the Expression of Uncertainty in Measurement (GUM:1995), ISO, 2008.

European Commission – Joint Research Centre
Institute for Reference Materials and Measurements (IRMM)
Retieseweg 111, B - 2440 Geel (Belgium)
Telephone: +32-(0)14-571.722 - Telefax: +32-(0)14-590.406

Annex 2: The certificate of EC NRM 101 uranium metal

Certified Nuclear Reference Material

Certificate of Analysis

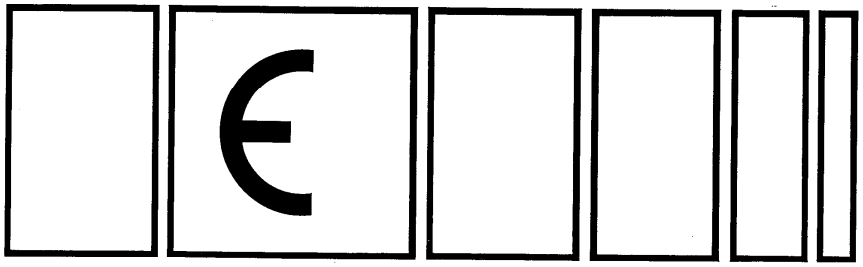
EC NUCLEAR REFERENCE MATERIAL NO. 101

MATERIAL : URANIUM METAL

URANIUM MASS FRACTION : (999.85 ± 0.05) g·kg^{-1}

The uncertainty has been calculated by multiplying the estimated overall standard deviation by a factor of two. This corresponds to a confidence level of about 95 percent.

Commission of the European Communities
Joint Research Centre
Geel Establishment (CBNM)



Annex 3: The certificate of NBL CRM-116 uranium metal

U. S. Department of Energy
New Brunswick Laboratory

New Brunswick Laboratory
Certified Reference Materials
Certificate of Analysis

CRM 116

Uranium (Enriched) Metal
(Uranium and Uranium-235 Standard)

Uranium (etched metal basis) ..... $99.967_2 \pm 0.006_9$ Wt.%
($\alpha = 0.05$, n = 6)

Uranium-235 ..... $93.121_5 \pm 0.004_7$ Wt.%
($\alpha = 0.05$, n = 6)
$93.183_7 \pm 0.004_7$ At.%

Relative atomic weight 235.201

Metal must be etched in 1 + 1 HNO_3, rinsed in distilled-deionized water and acetone, and dried prior to use.

REFERENCE METHODS OF ANALYSIS: Titrimetry (high precision NBL method) verified with NBL CRM 112-A Uranium Metal Standard and thermal ionization mass spectrometry verified with NBL CRM U930 Uranium Isotopic Standard.

June 1978
Argonne, Illinois

Carleton D. Bingham
Director

Annex 4: The certificate of CETAMA MP2 plutonium metal

CETAMA

COMMISSARIAT A L'ENERGIE ATOMIQUE

COMMISSION D'ETABLISSEMENT DES METHODES D'ANALYSE

cea

REFERENCE MATERIAL CERTIFICATE

PLUTONIUM METAL
"MP2"

Sample n° Xxxx Mass : 0.xxxxxx ± 0.000012 g

(For X and x values see list page 4)

The reference material to which this certificate relates is intended for the calibration of chemical composition measurement. The overall chemical content of plutonium is certified. The confidence interval associated with the certified value for a single sample, takes into account uncertainties associated to with analysis and heteregenity of metal. This content, expressed as a percentage of mass, was the following on 12 march 2001 for a single sample with a probability level of 0.95.

99.90 ± 0.04 %

THE TRUE MASS OF THE SAMPLE A ± **12** µg, RELATED TO A VACUUM, IS THAT INDICATED IN THIS CERTIFICATE AND ON THE AMPOULE.

The possibility of surface oxidation makes it impossible to envisage weighing at the time of use

Isotopique composition is certified on 12 march 2001 : see certificate IRMM page3

The preparation, analysis and certification of the plutonium to which this certificate relates was carried out by different units of the CEA group under the supervision of the Committee for Establishing Analysis Methods (CETAMA).

CETAMA CRM manager

CETAMA
CEA VALRHO Marcoule
30207 BAGNOLS SUR CEZE CEDEX
Téléphone 04.66.79.69.88 - Télécopie 04.66.79.69.89

ISO 9001 BUREAU VERITAS Certification

Version : 10.2007

On 12/03/2001, the metal contained around:

- by weight, 489 $mg.kg^{-1}$ of uranium,
- by weight, 438 $mg.kg^{-1}$ of américium..

UTILISATION

The sample, which consists of a piece of metal, is supplied in a double glass ampoule filled with pure nitrogen at a pressure of around 0.1 Pascal.

The ampoule must be opened with care inside a glove box. All the sample must be transferred to the dissolver.

Cover with 0.1 $mol.l^{-1}$ hydrochloric acid. The ampoule must be thoroughly washed with the same acid to recover any particles of metal which may have become separated. In 2 ml fractions, add the necessary quantity of 12 $mol.l^{-1}$ hydrochloric acid of guaranteed purity to obtain a 4 $mol.l^{-1}$ hydrochloric acid solution. Allow dissolving to proceed without heating for 10 to 15 minutes, then heat to boiling point. If there are still particles of plutonium at the bottom of the dissolver after heating for two hours, add 2 ml of 12 $mol.l^{-1}$ hydrochloric acid and 2 drops of 1 $mol.l^{-1}$ hydrofluoric acid and continue heating for another two hours. Repeat the operation if necessary until the material is totally dissolved.
If plutonium fluoride precipitates out, add a few drops of aluminium nitrate (approximately one $mol.l^{-1}$)..
Allow to cool and adjust to the required volume.

ADDITIONAL INFORMATION

The certified plutonium content has been deduced from analysis of impurities carried out by five laboratories and checked by chemical assay of the plutonium in two different laboratories using three different methods of analysis.
Spark Source Mass Spectrometry has given a full analysis of the impurities and, where concentration levels allowed, inductively-coupled plasma atomic emission spectrometry has been used to establish the concentrations of some of them.
The uranium was determined by laser spectrofluorimetry and the americium by gamma spectrometry.Carbon was determined by coulometry, after transformation into gaseous form by combustion in oxygen.
The gases were analysed by chromatography in the aqueous phase:
- for nitrogen and oxygen after extraction by high temperature stream under an inert gas,
- for hydrogen after diffusion in a vacuum.

CETAMA
CEA VALRHO Marcoule
30207 BAGNOLS SUR CEZE CEDEX
Téléphone 04.66.79.69.88 - Télécopie 04.66.79.69.89

IRMM

Institute for Reference Materials and Measurements

CERTIFICATE OF ISOTOPIC COMPOSITION

Geel, 30 May 2001

1. Applicant: Mr G. Lamarque
   Président de la Cetama

2. Sample Identification: MP2 (Pu metal)

3. Isotopic composition:

isotope amount ratio(s)	
$n(^{238}Pu)/n(^{239}Pu)$	0.000 033 15(41)
$n(^{240}Pu)/n(^{239}Pu)$	0.022 437 4(99)
$n(^{241}Pu)/n(^{239}Pu)$	0.000 298 0(17)
$n(^{242}Pu)/n(^{239}Pu)$	0.000 070 87(71)

	amount fraction (·100)		mass fraction (·100)
$n(^{238}Pu)/n(Pu)$	0.003 241(40)	$m(^{238}Pu)/m(Pu)$	0.003 227(40)
$n(^{239}Pu)/n(Pu)$	97.767 05(98)	$m(^{239}Pu)/m(Pu)$	97.757 76(98)
$n(^{240}Pu)/n(Pu)$	2.193 64(94)	$m(^{240}Pu)/m(Pu)$	2.202 62(95)
$n(^{241}Pu)/n(Pu)$	0.029 14(17)	$m(^{241}Pu)/m(Pu)$	0.029 38(17)
$n(^{242}Pu)/n(Pu)$	0.006 929(69)	$m(^{242}Pu)/m(Pu)$	0.007 015(70)

molar mass: 239.074 888(11) $g \cdot mol^{-1}$

4. Reference number: IMN 10031

5. Remarks:

The above values are valid for 12 March 2001. All uncertainties indicated are expanded uncertainties $U = k \cdot u_c$ where u_c is the combined standard uncertainty calculated according to the ISO/BIPM guide. The uncertainties are given in parentheses and include a coverage factor k=2. They apply to the last two digits of the value. The values certified are traceable to the SI.
The primary certified values are the isotope amount ratios; other values are derived from them. Reproducing the derived values may result in differences due to rounding errors.
Mass spectrometric measurements were performed by A Verbruggen and F Kehoe by TIMS on samples chemically prepared by F Kehoe. A Verbruggen was responsible for the preparation and issuance of the certificate.

A Verbruggen
Isotope Measurements Unit

Copy: R Wellum
F Kehoe

B-2440 GEEL (Belgium)
Tel. +32-14-571 608 - Fax +32-14-571 863

European Commission - JRC

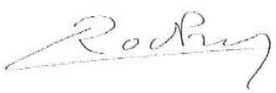
30207 BAGNOLS SUR CEZE CEDEX
Téléphone 04.66.79.69.88 - Télécopie 04.66.79.69.89

Packaging list for IRMM

The numbers of the ingots and the associated masses are as follows:

Ingot number	Mass (g)
A934	0.587859
A949	0.430987
A952	0.567216
A968	0.434526
A975	0.510770
C321	0.640299
C569	0.592943
C581	0.632827
A123	0.414082
A174	0.602206
A307	0.434852
A314	0.561821
A345	0.514834
A451	0.436194
A518	0.624022
A662	0.469822
A035	0.479086
A453	0.598728
A455	0.563210

CETAMA CRM manager



CETAMA
CEA VALRHO Marcoule
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Annex 5: The certificate of isotopic abundances of CETAMA MP2 by IRMM

EUROPEAN COMMISSION
DIRECTORATE GENERAL JRC
JOINT RESEARCH CENTRE
IRMM
Institute for Reference Materials and Measurements

CERTIFICATE of a reference measurement

IM/MeaC/07/116

11 April 2007

SUBJECT : Recertification of CEA CETAMA MP2

1. Applicant: A. Verbruggen

2. Sample Identification:
   - CEA/CETAMA/MP2
   - Chemical form: Pu metal provided by CEA/CETAMA

3. Measurands:
   - Isotopic composition

isotope amount ratio(s)	
$n(^{238}Pu)/\ n(^{239}Pu)$	0.000 030 83(29)
$n(^{240}Pu)/\ n(^{239}Pu)$	0.022 432 4(51)
$n(^{241}Pu)/\ n(^{239}Pu)$	0.000 237 8(31)
$n(^{242}Pu)/\ n(^{239}Pu)$	0.000 075 70(78)

amount fraction (·100)		mass fraction (·100)	
$n(^{238}Pu)/n(Pu)$	0.003 015(29)	$m(^{238}Pu)/m(Pu)$	0.003 002(28)
$n(^{239}Pu)/n(Pu)$	97.773 05(58)	$m(^{239}Pu)/m(Pu)$	97.763 80(59)
$n(^{240}Pu)/n(Pu)$	2.193 28(49)	$m(^{240}Pu)/m(Pu)$	2.202 27(49)
$n(^{241}Pu)/n(Pu)$	0.023 25(30)	$m(^{241}Pu)/m(Pu)$	0.023 44(31)
$n(^{242}Pu)/n(Pu)$	0.007 402(76)	$m(^{242}Pu)/m(Pu)$	0.007 494(77)

molar mass: 239.074 790 8(91) $g \cdot mol^{-1}$

4. Date of sample receipt : n.a.
   Date of completion of measurement : 7 November 2006

5. All uncertainties indicated are expanded uncertainties $U = k \cdot u_c$ where u_c is the combined standard uncertainty estimated following the ISO/BIPM guide[1]. They are given in parentheses and include a coverage factor k=2. They apply to the last two digits of the value. The values certified are traceable to the SI. The primary certified values are the isotope amount ratio ; other values are derived from them. Reproducing the derived values may result in difference due to rounding errors.

[1] International Organisation for Standardisation, Guide to the expression of Uncertainty in Measurement, ©ISO, ISBN 92-67-10188-9, Geneva, Switserland, 1993

Uncertainty budget :

Quantity	Value	Standard Uncertainty	Index
Atomic mass ^{239}Pu	239.05215760 g/mol	$5.1 \cdot 10^{-6}$ g/mol	59.6 %
Measurement ratio 240/239	0.02243535 mol/mol	$3.81 \cdot 10^{-6}$ mol/mol	14.9 %
Measurement ratio 241/239	$240 \cdot 10^{-6}$ mol/mol	$450 \cdot 10^{-9}$ mol/mol	0.9 %
Measurement ratio 242/239	$75 \cdot 10^{-6}$ mol/mol	$175 \cdot 10^{-9}$ mol/mol	0.4 %
$variability_{241/239}$	0.0 mol/mol	$2.65 \cdot 10^{-6}$ mol/mol	21.0 %
$variability_{242/239}$	0.0 mol/mol	$650 \cdot 10^{-9}$ mol/mol	3.0 %
M_{Pu}	239.07478500 g/mol	$6.46 \cdot 10^{-6}$ g/mol	

6. The traceability to SI is established through standards from IRMM-290.

7. Analytical measurement procedure
   - Mass spectrometric measurments were performed by H Kühn an F Kehoe for the $[n(^{238}Pu)/n(^{239}Pu)]$, $[n(^{240}Pu)/n(^{239}Pu)]$, $[n(^{241}Pu)/n(^{239}Pu)]$ and $[n(^{242}Pu)/n(^{239}Pu)]$ using the MAT262 TIMS, sample solutions were prepared for TIMS analysis by F Kehoe. A. Verbruggen was responsible for preparation and issuance of the certificate.
   - The atomic masses, used in the calculation are from G. Audi and A.H. Wapstra.[2]
   - Reference numbers of the measurement data: measurements number T26629, T26A03, T26B07, logged in S:\D04-IM\Secure Data\Project Data\MP2 (based on 081a and LSD1027i)\MP2 IA Summary MAT262 measurements.
   - Full details of the preparation and the certification procedure can be found in certification report EUR*****.

8. These samples will be stored for a minimum period of six months from the date of this certificate

André Verbruggen
Group leader Nuclear Chemistry

Stephan Richter
Group leader Nuclear Mass Spectrometry

Copies
P Taylor, IM unit head
Y Aregbe, Action leader Nuclear Safeguards
F Kehoe
H Kühn

[2] G. Audi and A.H. Wapstra, The 2003 atomic mass evaluation, Nucl Phys A729 (2003) 337-676

Annex 6: The certificate of isotopic composition of EC NRM 101 by IRMM

European Commission
JOINT
RESEARCH
CENTRE

Institute for Reference Materials and Measurements
Steenweg op Retie,2440 Geel,Belgium
Tel.(014)571.211-Telex 33589 EURAT B
Telefax 014/58.42.73

CERTIFICATE OF ISOTOPIC COMPOSITION
****

1. Applicant : Dr.K.Mayer
Stable Isotope Measurements
IRMM

2. Sample identification : EC 101

3. Results :

	Amount Ratio(s)	Mass Ratio(s)	Uncertainty (computed on a 2s basis for each element)
n(234U)/n(238U)	0.00005548		+/- 0.00000022
n(235U)/n(238U)	0.007293		+/- 0.0000036
n(236U)/n(238U)	0.000000151		+/- 0.000000040

4. Reference number : SMS 7315

5. Remarks : This sample will be stored for a minimum period of six months from the date of this certificate.

Request received at laboratory : 1995.06.23
Sample received at laboratory : 1995.06.23
Measurement achieved : 1995.06.23
Telephone or telex communication :

Mass spectrometric measurements were performed by W.De Bolle (n(235U)/n(238U) ratio by UF6) and A.Alonso (THMS) on samples chemically prepared by A.Alonso.

The values certified are traceable to the SI system and its unit for amount of substance: the mole.

c. P.De Bievre / A.Alonso

W.DE BOLLE
Stable Isotope Measurements

Annex 7: Report of analysis for NBL CRM-116

EUROPEAN COMMISSION
JOINT RESEARCH CENTRE

Institute for Reference Materials and Measurements (Geel)

INTERNAL TEST REPORT # 2731 - NBL CRM-116

Requested by: R. Jakopic, SN3S Unit

Samples

Sample ID	Applicant sample identification
19732	NBL CRM-116

Date of receipt of samples: 15/04/2013.....

Condition of the samples: U nitrate solution.....
.....

Sample ID	Analyte	Result (± expanded uncertainty[1])	Unit	Method[2]
19732 / CRM116	$n(^{238}U)/n(^{235}U)$	0.057975(17)	mol / mol	RM WI/0348
19732 / CRM116	$n(^{234}U)/n(^{235}U)$	0.0106853(11)	mol / mol	RM WI/0348
19732 / CRM116	$n(^{236}U)/n(^{235}U)$	0.00448811(46)	mol / mol	RM WI/0348

Notes:

Notes *(to be deleted if not applicable, also the logo!)*		
	1	Uncertainties are given as *(e.g. expanded (k=2) uncertainties according to the ISO Guide to the Expression of Uncertainty (GUM), corresponding to an approximate 95% confidence interval)*

Files name(s) of raw data:

Data are stored in:
"S:\D02-RM\Nuclear Safeguards\Nuclear\TRITON DATA - SHARED\MTE for EC101 CRM116 SLD 1027o", MTE measurement file: "T130418 EC101 CRM116.xls".....

30/4/2013
.....
Date

.....
Signature
Analyst

.....
Signature
Laboratory Responsible

Annex 8: The certificate of IRMM-046b

CERTIFICATE
SPIKE ISOTOPIC REFERENCE MATERIAL IRMM-046b

$4.650\ 4(18) \cdot 10^{-7}$ mol (^{242}Pu) · g^{-1} (solution)
$4.115\ 38(85) \cdot 10^{-6}$ mol (^{233}U) · g^{-1} (solution)

The Spike Isotopic Reference Material is supplied with an isotope amount content of ^{233}U and ^{242}Pu as certified above.

The amount of other uranium and plutonium isotopes present are related to the ^{233}U and ^{242}Pu content through the following certified amount ratios:

$n(^{238}Pu)/n(^{242}Pu)$	:	0.005 332(20)
$n(^{239}Pu)/n(^{242}Pu)$	:	0.002 212(16)
$n(^{240}Pu)/n(^{242}Pu)$	:	0.046 066(63)
$n(^{241}Pu)/n(^{242}Pu)$	:	0.002 9998(86)
$n(^{244}Pu)/n(^{242}Pu)$	:	0.000 237(31)

$n(^{234}U)/n(^{233}U)$	:	0.009 396(12)
$n(^{235}U)/n(^{233}U)$	:	0.002 252 0(60)
$n(^{236}U)/n(^{233}U)$	:	0.000 280 0(40)
$n(^{238}U)/n(^{233}U)$	:	0.008 186(11)

This corresponds to an isotopic composition with the following abundances:

amount fraction (·100)		mass fraction (·100)	
$n(^{238}Pu)/n(Pu)$	0.504 5(18)	$m(^{238}Pu)/m(Pu)$	0.496 4(18)
$n(^{239}Pu)/n(Pu)$	0.209 3(15)	$m(^{239}Pu)/m(Pu)$	0.206 8(15)
$n(^{240}Pu)/n(Pu)$	4.358 9(57)	$m(^{240}Pu)/m(Pu)$	4.324 8(57)
$n(^{241}Pu)/n(Pu)$	0.283 85(81)	$m(^{241}Pu)/m(Pu)$	0.282 81(81)
$n(^{242}Pu)/n(Pu)$	94.621 0(67)	$m(^{242}Pu)/m(Pu)$	94.666 5(67)
$n(^{244}Pu)/n(Pu)$	0.022 4(29)	$m(^{244}Pu)/m(Pu)$	0.022 6(30)

The molar mass of the plutonium in this sample is 241.942 44(15) g·mol^{-1}

06/2010

	amount fraction (·100)		mass fraction (·100)
$n(^{233}U)/n(U)$	98.028 3(17)	$m(^{233}U)/m(U)$	98.005 3(17)
$n(^{234}U)/n(U)$	0.921 1(12)	$m(^{234}U)/m(U)$	0.924 8(12)
$n(^{235}U)/n(U)$	0.220 76(59)	$m(^{235}U)/m(U)$	0.222 61(59)
$n(^{236}U)/n(U)$	0.027 45(39)	$m(^{236}U)/m(U)$	0.027 80(40)
$n(^{238}U)/n(U)$	0.802 5(11)	$m(^{238}U)/m(U)$	0.819 5(11)

The molar mass of the uranium in this sample is 233.094 320(57) $g \cdot mol^{-1}$

From the certified values, the following amount and mass contents are derived:

$4.914\ 7(19) \cdot 10^{-7}$	mol (Pu) · g^{-1} (solution)
$1.125\ 67(43) \cdot 10^{-4}$	g (^{242}Pu) · g^{-1} (solution)
$1.189\ 09(46) \cdot 10^{-4}$	g (Pu) · g^{-1} (solution)

and

$4.198\ 16(87) \cdot 10^{-6}$	mol (U) · g^{-1} (solution)
$0.959\ 05(20) \cdot 10^{-3}$	g (^{233}U) · g^{-1} (solution)
$0.978\ 57(20) \cdot 10^{-3}$	g (U) · g^{-1} (solution)

NOTES

1. All uncertainties indicated are expanded uncertainties $U = k \cdot u_c$ where u_c is the combined standard uncertainty estimated according to the ISO/BIPM Guide to the Expression of Uncertainty in Measurement. They are given in parentheses and include a coverage factor $k = 2$. They apply to the last two digits of the value.
2. Values for isotope ratios, isotopic compositions and for concentrations are valid for 1 June 2010. This certificate is valid until June 2013; the validity may be extended after further tests on the stability of the spike material are carried out.
3. Due to radioactive decay, the Pu element concentration decreases by 0.035 % · a^{-1}.
4. The half lives used in the calculations are

^{238}Pu: 8.77 (03) · 10^1 a[(1)]

^{239}Pu: 2.411 (03) · 10^4 a[(1)]

^{240}Pu: 6.563 (07) · 10^3 a[(1)]

^{241}Pu: 1.432 5(24) · 10^1 a[(2)]

^{242}Pu: 3.735 (11) · 10^5 a[(1)]

^{244}Pu: 8.00 (09) · 10^7 a[(1]

(1) IAEA, Decay data of the Transactinium Nuclides, Technical Reports Series No. 261, 1986
(2) R. Wellum, A. Verbruggen, R. Kessel, J. Anal. At. Spectrom., 2009, 24, 801 - 807

5. The atomic masses, used in the calculations, are[3]

^{233}U : 233.039 635 2 (58) g·mol^{-1}
^{234}U : 234.040 952 1 (40) g·mol^{-1}
^{235}U : 235.043 929 9 (40) g·mol^{-1}
^{236}U : 236.045 568 0 (40) g·mol^{-1}
^{238}U : 238.050 788 2 (40) g·mol^{-1}

^{238}Pu : 238.049 559 9 (40) g·mol^{-1}
^{239}Pu : 239.052 163 4 (40) g·mol^{-1}
^{240}Pu : 240.053 813 5 (40) g·mol^{-1}
^{241}Pu : 241.056 851 5 (40) g·mol^{-1}
^{242}Pu : 242.058 742 6 (40) g·mol^{-1}
^{244}Pu : 244.064 204 (10) g·mol^{-1}

6. A unit of IRMM-046b consists of a flame-sealed glass ampoule containing a chemically stable solution of uranium and plutonium in nitric acid. The solution volume is about 10 mL; the molarity is about 5 M.

7. The ampoule should be handled with great care and by experienced personnel in a laboratory environment suitably equipped for the safe handling of radioactive materials.

8. Using this Spike Isotopic Reference Material, ^{239}Pu concentrations in unknown samples can be determined by Isotope Dilution Mass Spectrometry, through a measurement of the isotope dilution ratio $R_B = n(^{239}\text{Pu})/n(^{242}\text{Pu})$ in the blend. They should be computed with the aid of the following formula which allows an easy identification and quantification of the sources of the uncertainties in the procedure :

$$c\left(^{239}Pu\right)_X = \frac{R_Y - R_B}{R_B - R_X} \cdot R_X \cdot \frac{m_Y}{m_X} \cdot c\left(^{242}Pu\right)_Y$$

$$c(Pu)_X = \frac{R_Y - R_B}{R_B - R_X} \cdot \frac{\sum R_{Xi}}{\sum R_{Yi}} \cdot \frac{m_Y}{m_X} \cdot c(Pu)_Y$$

where

R_X	=	amount ratio $n(^{239}\text{Pu})/n(^{242}\text{Pu})$ in the unknown sample material
R_Y	=	amount ratio $n(^{239}\text{Pu})/n(^{242}\text{Pu})$ in the spike material
m_X	=	mass of the unknown sample
m_Y	=	mass of the sample of spike solution used
$c\left(^{239}Pu\right)_X$	=	number of moles ^{239}Pu · kg^{-1} sample material
$c\left(^{242}Pu\right)_Y$	=	number of moles ^{242}Pu · kg^{-1} spike solution
$c(Pu)_X$	=	number of moles Pu · kg^{-1} sample material
$c(Pu)_Y$	=	number of moles Pu · kg^{-1} spike solution.

[3] G. Audi and A.H. Wapstra, The 2003 atomic mass evaluation, Nucl Phys A729 (2003) 337-676.

9. Using this Spike Isotopic Reference Material, ^{235}U concentrations in unknown samples can be determined by Isotope Dilution Mass Spectrometry, through a measurement of the isotope dilution ratio $R_B = n(^{233}U)/n(^{235}U)$ in the blend. They should be computed with the aid of the following formula which allows an easy identification and quantification of the sources of the uncertainties in the procedure :

$$c\left(^{235}U\right)_X = \frac{R_Y - R_B}{R_B - R_X} \cdot \frac{1}{R_Y} \cdot \frac{m_Y}{m_X} \cdot c\left(^{233}U\right)_Y$$

$$c(U)_X = \frac{R_Y - R_B}{R_B - R_X} \cdot \frac{\sum R_{Xi}}{\sum R_{Yi}} \cdot \frac{m_Y}{m_X} \cdot c(U)_Y$$

where

R_X	=	amount ratio $n(^{233}U)/n(^{235}U)$ in the unknown sample material
R_Y	=	amount ratio $n(^{233}U)/n(^{235}U)$ in the spike material
m_X	=	mass of the unknown sample
m_Y	=	mass of the sample of spike solution used
$c\left(^{235}U\right)_X$	=	number of moles $^{235}U \cdot kg^{-1}$ sample material
$c\left(^{233}U\right)_Y$	=	number of moles $^{233}U \cdot kg^{-1}$ spike solution
$c(U)_X$	=	number of moles $U \cdot kg^{-1}$ sample material
$c(U)_Y$	=	number of moles $U \cdot kg^{-1}$ spike solution.

10. The certified values of this Spike Isotopic Reference Material are metrologically traceable to the SI. Measurements calibrated with this Isotopic Reference Materials can therefore provide SI-traceable results.

11. The isotopic measurements by Thermal Ionisation Mass Spectrometry were performed by H. Kühn, F. Kehoe and S. Richter for uranium and for plutonium. Isotopic measurements were calibrated against synthetic plutonium isotope mixtures prepared by J. Broothaerts. Chemical preparation of the samples for isotope measurements was performed by F. Kehoe and R. Jakopič.

Metrological weighings for the preparation and certification were performed by U. Jacobsson and R. Eykens. The ampoulation of this Spike Isotopic Reference Material was accomplished by G. Van Baelen and A. Verbruggen.

The overall co-ordination leading to the establishment, certification and issuance of this Spike Isotopic Reference Material was performed by A. Verbruggen.

Geel, June 2010

H. Emons
Head
Reference Materials Unit

06/2010

Annex 9: Results of the IDMS confirmation measurements (N = 4) for ^{235}U and ^{239}Pu amount contents in the mother solution of IRMM-1027p.

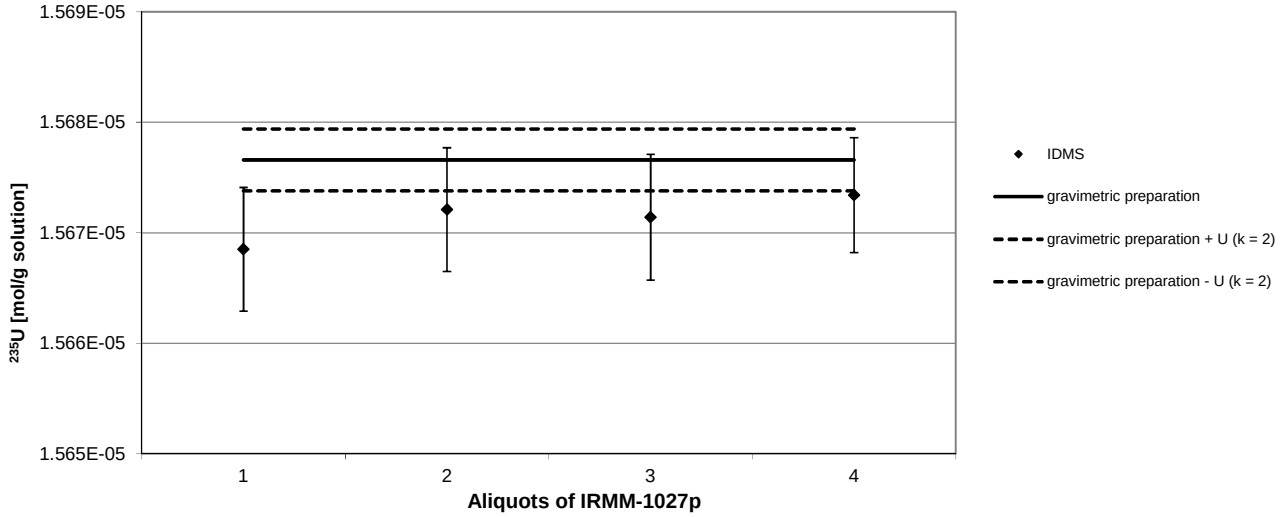

Fig 3. The amount content of ^{235}U in the solution of IRMM-1027p prepared by gravimetric mixing compared with the measured values by IDMS (with expanded uncertainties, coverage factor k = 2).

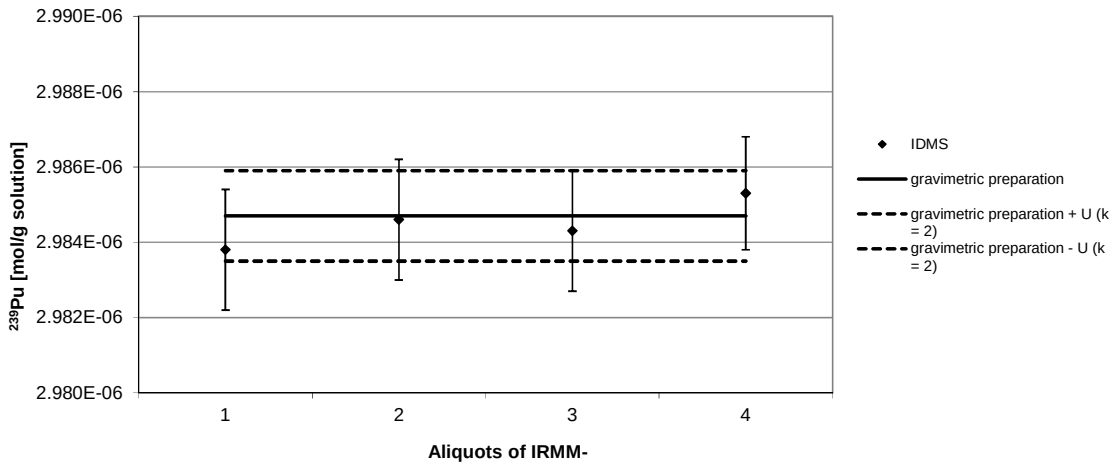

Fig 4. The amount content of ^{239}Pu in the solution of IRMM-1027p prepared by gravimetric mixing compared with the measured values by IDMS (with expanded uncertainties, coverage factor k = 2).

Annex 10: Results of the homogeneity assessment (single value, mean and standard deviation) of the ^{239}Pu, ^{238}U and ^{235}U amount contents in the selected vials of IRMM-1027p.

Unit	^{238}U [µmol/g]			
	Rep.1	Rep.2	Rep.3	Mean ± *s*
112	73.313	73.255	73.308	73.292 ± 0.032
464	73.178	73.293	73.186	73.219 ± 0.064
299	73.244	73.235	73.292	73.257 ± 0.031
553	73.301	73.265	73.248	73.271 ± 0.027
206	73.218	73.281	73.220	73.240 ± 0.036
651	73.303	73.284	73.322	73.303 ± 0.019
943	73.359	73.331	73.346	73.345 ± 0.014
1140	73.365	73.297	73.334	73.332 ± 0.034
801	73.344	73.305	73.298	73.316 ± 0.025
1023	73.347	73.334	73.331	73.337 ± 0.009

Unit	^{235}U [µmol/g]			
	Rep.1	Rep.2	Rep.3	Mean ± *s*
112	15.6859	15.6808	15.6855	15.6841 ± 0.0028
464	15.6716	15.6818	15.6730	15.6755 ± 0.0055
299	15.6765	15.6755	15.6810	15.6777 ± 0.0029
553	15.6814	15.6783	15.6773	15.6790 ± 0.0021
206	15.6706	15.6764	15.6712	15.6728 ± 0.0032
651	15.6816	15.6802	15.6835	15.6817 ±0.0017
943	15.6873	15.6849	15.6872	15.6865 ± 0.0014
1140	15.6901	15.6836	15.6867	15.6868 ± 0.0033
801	15.6839	15.6807	15.6805	15.6817 ± 0.0019
1023	15.6873	15.6878	15.6857	15.6869 ± 0.0011

Unit	^{239}Pu [µmol/g]			
	Rep.1	Rep.2	Rep.3	Mean ± *s*
112	2.98650	2.98631	2.98608	2.98630 ± 0.00021
464	2.98497	2.98589	2.98596	2.98561 ± 0.00055
299	2.98546	2.98460	/	2.98503 ±0.00061
553	2.98639	2.98584	2.98612	2.98612 ± 0.00027
206	2.98392	2.98344	/	2.98368 ± 0.00034
651	2.98568	2.98554	2.98542	2.98555 ± 0.00013
943	2.98512	2.98558	2.98633	2.98568 ± 0.00061
1140	2.98607	2.98770	2.98575	2.98651 ± 0.00104
801	2.98564	2.98459	2.98546	2.98523 ± 0.00056
1023	2.98562	2.98593	2.98731	2.98629 ± 0.00090

Annex 11: Results of the homogeneity assessment of the uranium and plutonium isotope amount ratios in the selected vials of IRMM-1027p.

Unit	$n(^{234}U)/n(^{238}U)$			
	Rep.1	Rep.2	Rep.3	Mean ± *s*
131	0.0022681	0.0022674	0.0022639	0.0022665 ± 0.0000023
562	0.0022654	0.0022681	0.0022661	0.0022666 ± 0.0000014
312	0.0022670	0.0022670	0.0022686	0.0022675 ± 0.0000010
790	0.0022607	0.0022671	0.0022653	0.0022644 ± 0.0000033
415	0.0022662	0.0022648	/	0.0022655 ± 0.0000010
44	0.0022606	0.0022661	0.0022656	0.0022658 ± 0.0000004
948	0.0022611	0.0022681	0.0022651	0.0022666 ± 0.0000021
595	0.00022614	0.0022664	0.0022665	0.0022665 ± 0.0000001
1035	0.0022672	0.0022628	0.0022648	0.0022638 ± 0.0000014
1163	0.0022639	0.0022616	0.0022652	0.0022634 ± 0.0000026

Unit	$n(^{235}U)/n(^{238}U)$			
	Rep.1	Rep.2	Rep.3	Mean ± *s*
131	0.214033	0.214161	0.214069	0.214088 ± 0.000066
562	0.214154	0.214052	0.214054	0.214087 ± 0.000058
312	0.214127	0.213994	0.214027	0.214049 ± 0.000070
790	0.214004	0.214041	0.214046	0.214031 ± 0.000023
415	0.214038	0.214032	/	0.214035 ± 0.000004
44	0.213918	0.213944	0.213970	0.213957 ± 0.000018
948	0.213902	0.214083	0.213987	0.214035 ± 0.000068
595	0.2133983	0.214062	0.214081	0.214071 ± 0.000013
1035	0.214039	0.214016	0.214019	0.214018 ± 0.000002
1163	0.213971	0.213922	0.214124	0.214023 ± 0.000143

Unit	$n(^{240}Pu)/n(^{239}Pu)$			
	Rep.1	Rep.2	Rep.3	Mean ± *s*
131	0.0224164	0.0224243	0.0224213	0.0224207 ± 0.0000040
562	0.0224165	0.0224186	0.0224176	0.0224176 ± 0.0000010
312	0.0224155	0.0224102	0.0224201	0.0224153 ± 0.0000050
790	0.0224351	0.0224232	0.0224176	0.0224253 ± 0.0000090
415	0.0224170	0.0224205	/	0.0224187 ± 0.0000025
44	0.0224106	0.0224113	0.0224068	0.0224096 ± 0.0000024
948	0.0224061	0.0224092	0.0224078	0.0224077 ± 0.0000016
595	0.0224088	0.0224203	0.0224080	0.0224124 ± 0.0000069
1035	0.0224083	0.0224162	0.00224127	0.0224124 ± 0.0000040
1163	0.0224133	0.0224058	/	0.0224096 ± 0.0000053

Unit	$n(^{241}Pu)/n(^{239}Pu)$			
	Rep.1	Rep.2	Rep.3	Mean ± *s*
131	0.0001717	0.0001731	0.0001711	0.0001720 ± 0.0000010
562	0.0001725	0.0001710	0.0001722	0.0001719 ± 0.0000008
312	0.0001703	0.0001708	0.0001713	0.0001708 ± 0.0000005
790	0.0001720	0.0001721	0.0001698	0.0001713 ± 0.0000013
415	0.0001695	0.0001746	/	0.0001721 ± 0.0000036
44	0.0001765	0.0001720	0.0001709	0.0001732 ± 0.0000029
948	0.0001720	0.0001728	0.0001735	0.0001728 ± 0.0000008
595	0.0001742	0.0001739	0.0001727	0.0001736 ± 0.0000008
1035	0.0001704	0.0001717	0.0001697	0.0001706 ± 0.0000010
1163	0.0001739	0.0001705	/	0.001722 ± 0.0000024

Unit	$n(^{242}Pu)/n(^{239}Pu)$			
	Rep. 1	Rep.2	Rep.3	Mean ± *s*
131	0.0000758	0.0000771	0.0000759	0.0000763 ± 0.0000008
562	0.0000771	0.0000805	0.0000728	0.0000768 ± 0.0000039
312	0.0000759	0.0000803	0.0000745	0.0000769 ± 0.0000030
790	0.0000806	0.0000772	0.0000743	0.0000774 ± 0.0000032
415	0.0000748	0.0000750	/	0.0000749 ± 0.0000001
44	0.0000728	0.0000781	0.0000757	0.0000755 ± 0.0000027
948	0.0000789	0.0000784	0.0000752	0.0000775 ± 0.0000020
595	0.0000737	0.0000739	0.0000740	0.0000739 ± 0.0000001
1035	0.0000759	0.0000787	0.0000733	0.0000760 ± 0.0000027
1163	0.0000780	0.0000741	/	0.0000761 ± 0.0000028

Annex 12: Results of the confirmation measurements (N = 3) of ^{235}U, ^{238}U and ^{239}Pu amount contents in the selected vials of IRMM-1027p.

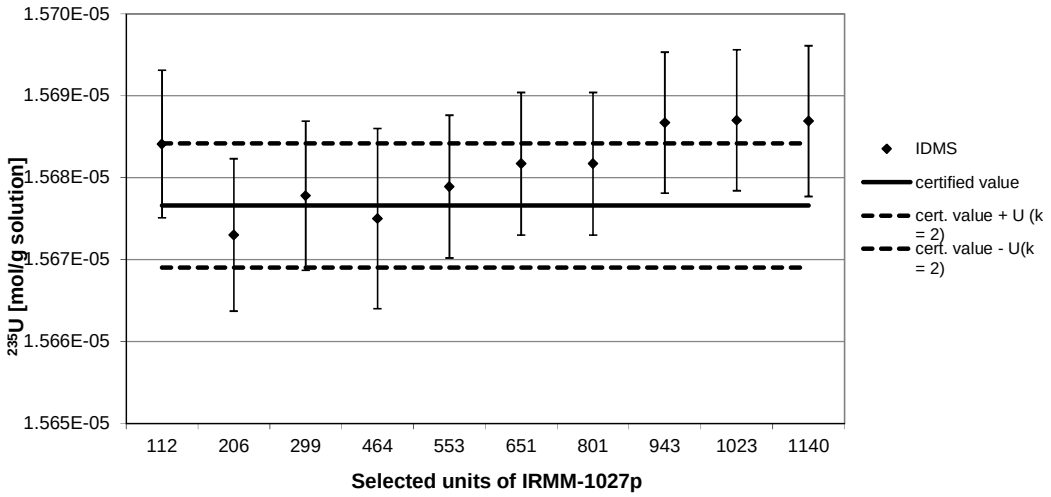

Fig 5. The certified amount content of ^{235}U in the selected vials of IRMM-1027p prepared by gravimetric mixing compared with the measured values by IDMS (with expanded uncertainties, coverage factor k = 2).

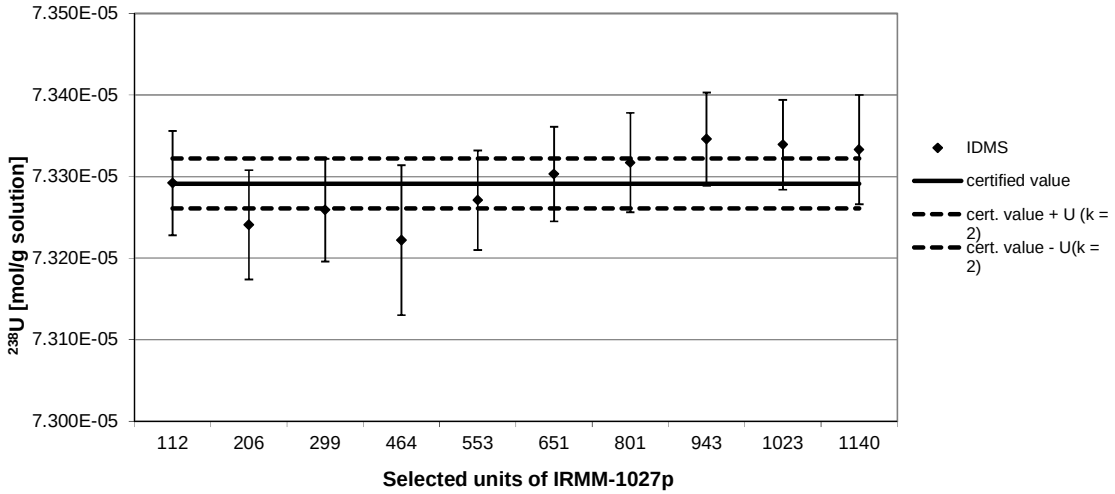

Fig 6. The certified amount content of ^{238}U in the selected vials of IRMM-1027p prepared by gravimetric mixing compared with the measured values by IDMS (with expanded uncertainties, coverage factor k = 2).

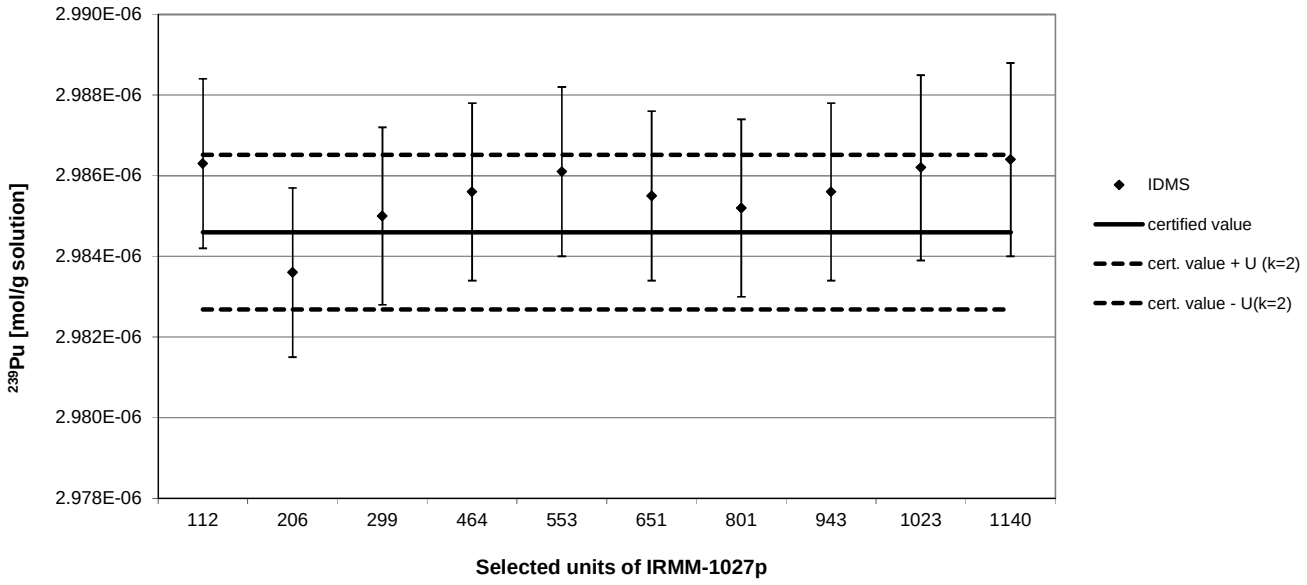

Fig 7. The certified amount content of ^{239}Pu in the selected vials of IRMM-1027p prepared by gravimetric mixing compared with the measured values by IDMS (with expanded uncertainties, coverage factor k = 2)

Annex 13: Results of the confirmation measurements (N = 3) of the uranium and plutonium isotope amount ratios in the selected vials of IRMM-1027p.

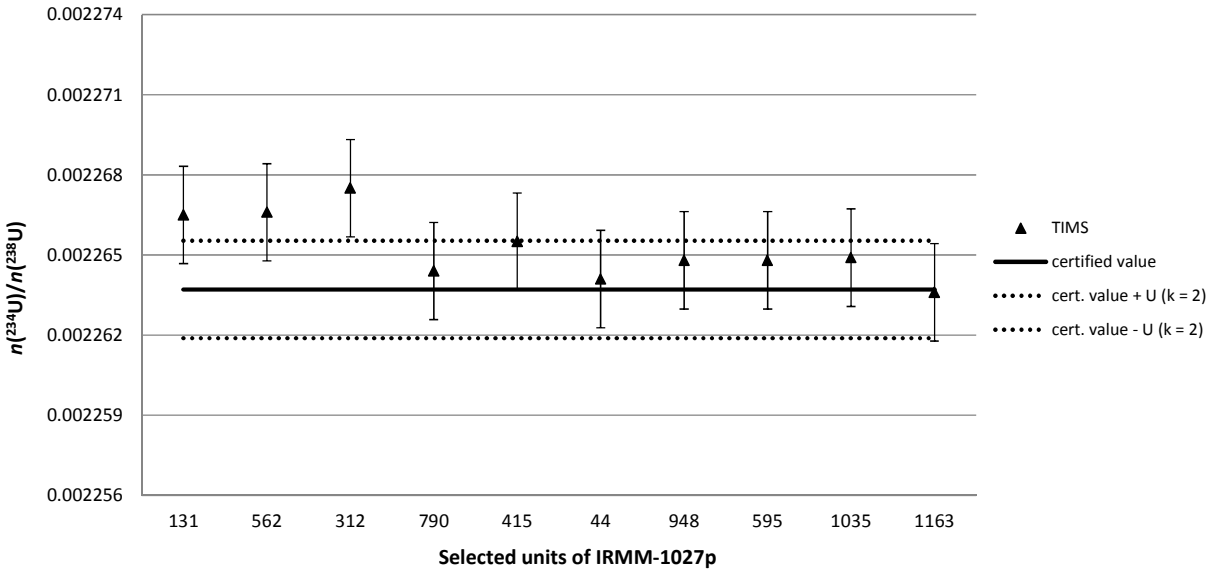

Fig 8. The certified $n(^{234}U)/n(^{238}U)$ amount ratio in the selected vials of IRMM-1027p prepared by gravimetric mixing compared with the measured values by TIMS (with expanded uncertainties, coverage factor k = 2).

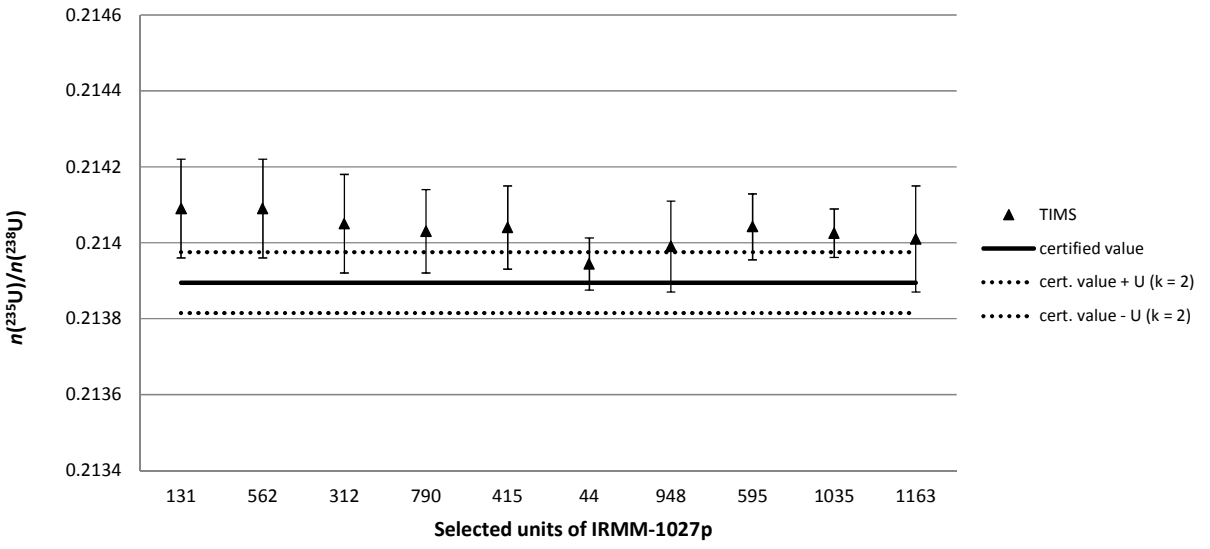

Fig 9. The certified $n(^{235}U)/n(^{238}U)$ amount ratio in the selected vials of IRMM-1027p prepared by gravimetric mixing compared with the measured values by TIMS (with expanded uncertainties, coverage factor k = 2).

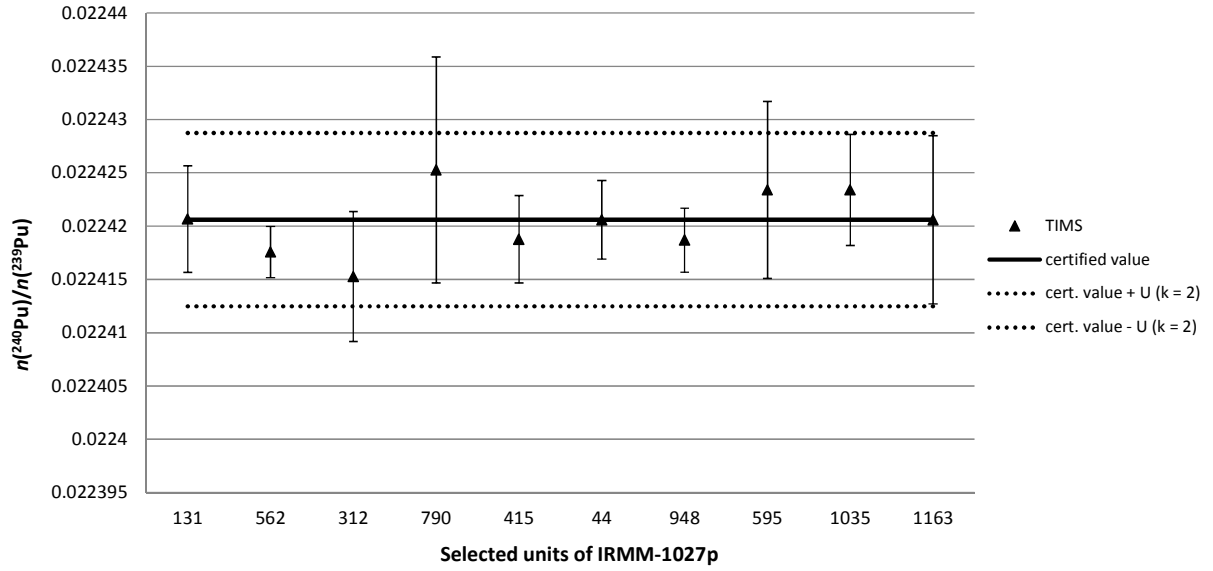

Fig 10. The certified $n(^{240}Pu)/n(^{239}Pu)$ amount ratio in the selected vials of IRMM-1027p prepared by gravimetric mixing compared with the measured values by TIMS (with expanded uncertainties, coverage factor $k = 2$).

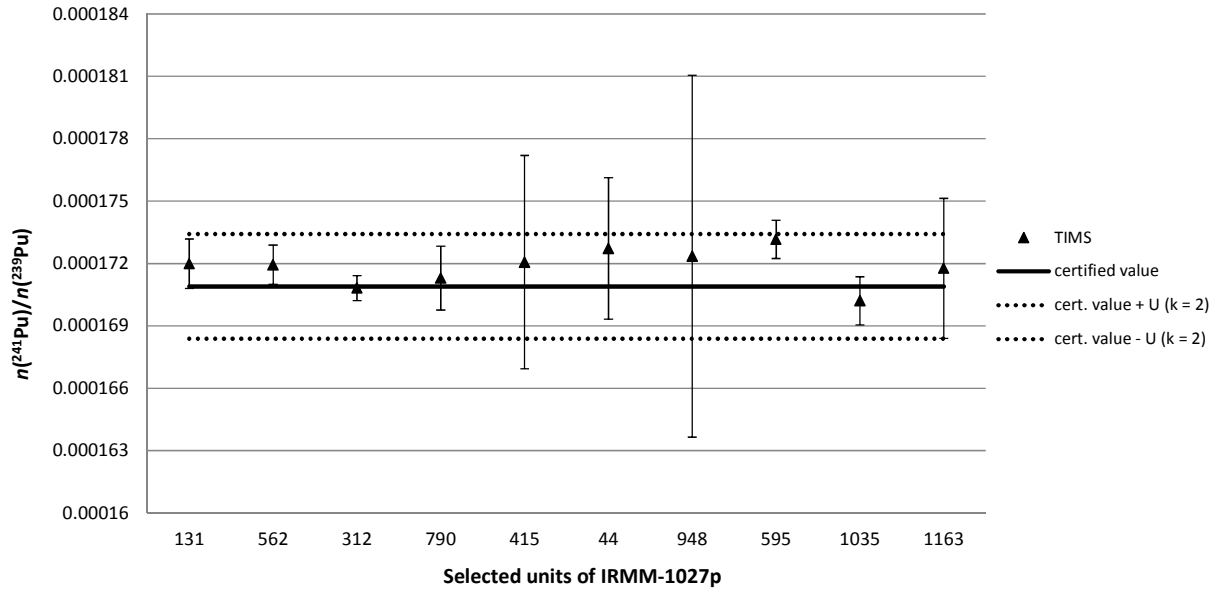

Fig 11. The certified $n(^{241}Pu)/n(^{239}Pu)$ amount ratio in the selected vials of IRMM-1027p prepared by gravimetric mixing compared with the measured values by TIMS (with expanded uncertainties, coverage factor $k = 2$).

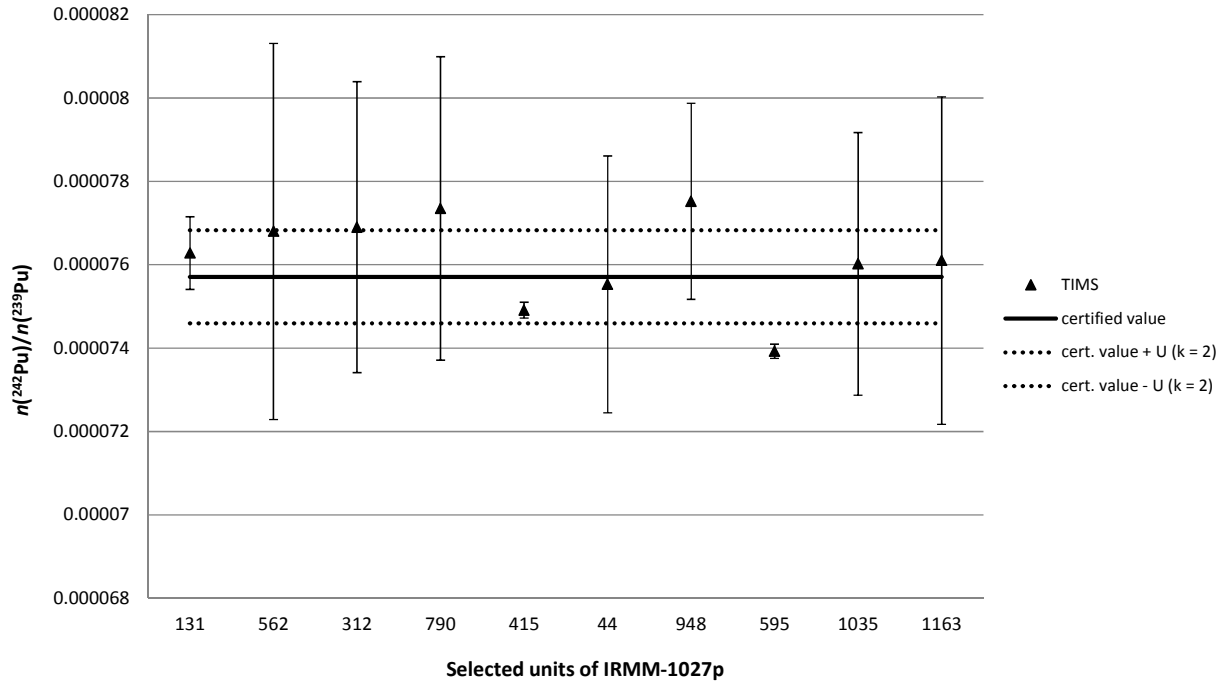

Fig 12. The certified $n(^{242}Pu)/n(^{239}Pu)$ amount ratio in the selected vials of IRMM-1027p prepared by gravimetric mixing compared with the measured values by TIMS (with expanded uncertainties, coverage factor $k = 2$).

Annex 14: The weighing certificate of the aliquots of dispensed solution per unit before drying.

European Commission	**Certificate of weighing**	Institute for Reference Materials and Measurements

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Applicant:	R. Jakopič	**Unit/group**: SN3S/Metro
Project:	Preparation and certification of IRMM-1027p	
Description:	Dispensing of IRMM-1027p mother solution into single vials	
Weighing date: 22-26 April 2013		

The certified masses of an aliquot of the nitrate solution per unit of IRMM-1027p before drying are shown in Annex.

Observations:
The dispensing and weighing were performed according to working instruction RM-WI-0368 "LSD automated system equipment manual" on balance Sartorius TE124 installed in the dispensing robot box with IRMM inventory No. 2006 00290 17.

Traceability:
The certified masses are traceable to the International Kilogram Prototype via regular calibrations of the IRMM principal mass standards. The mass standard identified as H208 (cylinder + vial certificate IRMM E3162) was used to verify the balance performance in the mass determinations.

Uncertainty:
The uncertainty on the mass determinations has a value of ± 0.0006 g .The reported uncertainties is expanded uncertainties $U = k \cdot u_c$ where u_c is the combined standard uncertainty calculated according to the ISO/IEC Guide to the expression of Uncertainty in Measurement. The coverage factor $k = 2$ corresponds to a coverage probability of about 95%.

Nuclear Chemistry Laboratory

Analyst

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Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
0001	2.5351	0051	2.5513	0101	2.5708	0151	2.5666
0002	2.5758	0052	2.5549	0102	2.5317	0152	2.5391
0003	2.5632	0053	2.5519	0103	2.5705	0153	2.5638
0004	2.5552	0054	2.5539	0104	2.5309	0154	2.5377
0005	2.5570	0055	2.5519	0105	2.5715	0155	2.5680
0006	2.5563	0056	2.5536	0106	2.5311	0156	2.5385
0007	2.5568	0057	2.5520	0107	2.5705	0157	2.5647
0008	2.5571	0058	2.5533	0108	2.5334	0158	2.5372
0009	2.5568	0059	2.5514	0109	2.5319	0159	2.5686
0010	2.5573	0060	2.5533	0110	2.5600	0160	2.5375
0011	2.5570	0061	2.5523	0111	2.5549	0161	2.5655
0012	2.5572	0062	2.5515	0112	2.5548	0162	2.5385
0013	2.5569	0063	2.5531	0113	2.5531	0163	2.5634
0014	2.5570	0064	2.5520	0114	2.5391	0164	2.5400
0015	2.5570	0065	2.5517	0115	2.5652	0165	2.5669
0016	2.5573	0066	2.5529	0116	2.5362	0166	2.5417
0017	2.5569	0067	2.5526	0117	2.5667	0167	2.5377
0018	2.5570	0068	2.5510	0118	2.5384	0168	2.5789
0019	2.5570	0069	2.5515	0119	2.5619	0169	2.5429
0020	2.5560	0070	2.5526	0120	2.5379	0170	2.5420
0021	2.5572	0071	2.5512	0121	2.5660	0171	2.5687
0022	2.5564	0072	2.5522	0122	2.5374	0172	2.5418
0023	2.5563	0073	2.5525	0123	2.5645	0173	2.5401
0024	2.5565	0074	2.5514	0124	2.5369	0174	2.5764
0025	2.5554	0075	2.5519	0125	2.5650	0175	2.5419
0026	2.5561	0076	2.5273	0126	2.5368	0176	2.5441
0027	2.5544	0077	2.5692	0127	2.5655	0177	2.5576
0028	2.5569	0078	2.5597	0128	2.5368	0178	2.5605
0029	2.5549	0079	2.5275	0129	2.5650	0179	2.5578
0030	2.5549	0080	2.5680	0130	2.5368	0180	2.5507
0031	2.5557	0081	2.5594	0131	2.5658	0181	2.5529
0032	2.5546	0082	2.5274	0132	2.5370	0182	2.5515
0033	2.5549	0083	2.5657	0133	2.5646	0183	2.5526
0034	2.5551	0084	2.5640	0134	2.5374	0184	2.5522
0035	2.5540	0085	2.5283	0135	2.5657	0185	2.5528
0036	2.5569	0086	2.5693	0136	2.5361	0186	2.5521
0037	2.5531	0087	2.5576	0137	2.5683	0187	2.5521
0038	2.5551	0088	2.5268	0138	2.5359	0188	2.5520
0039	2.5541	0089	2.5678	0139	2.5671	0189	2.5520
0040	2.5544	0090	2.5629	0140	2.5366	0190	2.5523
0041	2.5537	0091	2.5261	0141	2.5670	0191	2.5516
0042	2.5550	0092	2.5680	0142	2.5376	0192	2.5523
0043	2.5529	0093	2.5612	0143	2.5665	0193	2.5543
0044	2.5545	0094	2.5279	0144	2.5359	0194	2.5516
0045	2.5526	0095	2.5679	0145	2.5692	0195	2.5514
0046	2.5544	0096	2.5573	0146	2.5369	0196	2.5524
0047	2.5530	0097	2.5310	0147	2.5661	0197	2.5517
0048	2.5537	0098	2.5692	0148	2.5372	0198	2.5520
0049	2.5533	0099	2.5559	0149	2.5685	0199	2.5516
0050	2.5533	0100	2.5311	0150	2.5370	0200	2.5523

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Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
0201	2.5518	0251	2.5518	0301	2.5390	0351	2.5329
0202	2.5520	0252	2.5528	0302	2.5408	0352	2.5724
0203	2.5520	0253	2.5518	0303	2.5764	0353	2.5316
0204	2.5519	0254	2.5525	0304	2.5375	0354	N/A
0205	2.5515	0255	2.5515	0305	2.5637	0355	2.5735
0206	2.5522	0256	2.5522	0306	2.5397	0356	2.5316
0207	2.5524	0257	2.5524	0307	2.5646	0357	2.5723
0208	2.5516	0258	2.5514	0308	2.5387	0358	2.5315
0209	2.5522	0259	2.5520	0309	2.5661	0359	2.5723
0210	2.5514	0260	2.5505	0310	2.5385	0360	2.5297
0211	2.5520	0261	2.5547	0311	2.5669	0361	2.5716
0212	2.5519	0262	2.5276	0312	2.5392	0362	2.5587
0213	2.5520	0263	2.5701	0313	2.5641	0363	2.5290
0214	2.5523	0264	N/A	0314	2.5404	0364	2.5713
0215	2.5521	0265	2.5302	0315	2.5734	0365	2.5584
0216	2.5522	0266	2.5704	0316	2.5237	0366	2.5279
0217	2.5515	0267	2.5417	0317	2.5628	0367	2.5739
0218	2.5522	0268	2.5357	0318	2.5578	0368	2.5555
0219	2.5519	0269	2.5726	0319	2.5422	0369	2.5290
0220	2.5518	0270	2.5335	0320	2.5564	0370	2.5707
0221	2.5523	0271	2.5708	0321	2.5546	0371	2.5618
0222	2.5519	0272	2.5331	0322	2.5531	0372	2.5278
0223	2.5520	0273	2.5712	0323	2.5525	0373	2.5691
0224	2.5541	0274	2.5714	0324	2.5532	0374	2.5616
0225	2.5516	0275	2.5330	0325	2.5527	0375	2.5278
0226	2.5518	0276	2.5358	0326	2.5530	0376	2.5687
0227	2.5523	0277	2.5668	0327	2.5527	0377	2.5620
0228	2.5528	0278	2.5364	0328	2.5521	0378	2.5281
0229	2.5519	0279	2.5684	0329	2.5518	0379	2.5685
0230	2.5529	0280	2.5361	0330	2.5520	0380	2.5619
0231	2.5520	0281	2.5688	0331	2.5513	0381	2.5260
0232	2.5521	0282	2.5377	0332	2.5499	0382	2.5706
0233	2.5524	0283	2.5649	0333	2.5490	0383	2.5614
0234	2.5520	0284	2.5365	0334	2.5496	0384	2.5270
0235	2.5516	0285	2.5696	0335	2.5476	0385	2.5732
0236	2.5529	0286	2.5372	0336	2.5464	0386	2.5575
0237	2.5517	0287	2.5255	0337	2.5769	0387	2.5303
0238	2.5549	0288	2.5759	0338	2.5470	0388	2.5696
0239	2.5516	0289	2.5399	0339	2.5451	0389	2.5584
0240	2.5515	0290	2.5396	0340	2.5653	0390	2.5279
0241	2.5520	0291	2.5772	0341	2.5341	0391	2.5706
0242	2.5512	0292	2.5381	0342	2.5733	0392	2.5622
0243	2.5527	0293	2.5404	0343	2.5329	0393	2.5291
0244	2.5524	0294	2.5775	0344	2.5726	0394	2.5746
0245	2.5521	0295	2.5386	0345	2.5330	0395	2.5305
0246	2.5519	0296	2.5398	0346	2.5725	0396	2.5723
0247	2.5524	0297	2.5781	0347	2.5335	0397	2.5318
0248	2.5521	0298	2.5386	0348	2.5726	0398	2.5736
0249	2.5527	0299	2.5400	0349	2.5338	0399	2.5551
0250	2.5520	0300	2.5774	0350	2.5708	0400	2.5317

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
0401	2.5733	0451	2.5550	0501	2.5716	0551	2.5467
0402	2.5552	0452	2.5510	0502	2.5359	0552	2.5707
0403	2.5323	0453	2.5552	0503	2.5746	0553	2.5453
0404	2.5758	0454	2.5519	0504	2.5341	0554	2.5440
0405	2.5318	0455	2.5550	0505	2.5759	0555	2.5690
0406	2.5744	0456	2.5512	0506	2.5344	0556	2.5435
0407	2.5332	0457	2.5553	0507	2.5718	0557	2.5455
0408	2.5741	0458	2.5508	0508	2.5345	0558	2.5703
0409	2.5334	0459	2.5543	0509	2.5724	0559	2.5470
0410	2.5727	0460	2.5538	0510	2.5330	0560	2.5507
0411	2.5391	0461	2.5518	0511	2.5728	0561	2.5502
0412	2.5433	0462	2.5548	0512	2.5303	0562	2.5473
0413	2.5778	0463	2.5511	0513	2.5725	0563	2.5493
0414	2.5371	0464	2.5547	0514	2.5297	0564	2.5488
0415	2.5679	0465	2.5505	0515	2.5721	0565	2.5783
0416	2.5333	0466	2.5549	0516	2.5356	0566	2.5474
0417	2.5738	0467	2.5508	0517	2.5741	0567	2.5493
0418	2.5340	0468	2.5550	0518	2.5376	0568	2.5456
0419	2.5728	0469	2.5522	0519	2.5500	0569	2.5496
0420	2.5362	0470	2.5536	0520	2.5549	0570	2.5484
0421	2.5659	0471	2.5509	0521	2.5525	0571	2.5735
0422	2.5367	0472	2.5538	0522	2.5533	0572	2.5497
0423	2.5725	0473	2.5509	0523	2.5534	0573	2.5508
0424	2.5521	0474	2.5560	0524	2.5532	0574	2.5526
0425	2.5539	0475	2.5504	0525	2.5529	0575	2.5535
0426	2.5535	0476	2.5561	0526	2.5529	0576	2.5383
0427	2.5509	0477	2.5507	0527	2.5518	0577	2.5554
0428	2.5542	0478	2.5558	0528	2.5511	0578	2.5541
0429	2.5542	0479	2.5504	0529	2.5507	0579	2.5513
0430	2.5529	0480	2.5553	0530	2.5775	0580	2.5461
0431	2.5530	0481	2.5512	0531	2.5504	0581	2.5562
0432	2.5537	0482	2.5541	0532	2.5508	0582	2.5531
0433	2.5520	0483	2.5509	0533	2.5504	0583	2.5533
0434	2.5523	0484	2.5541	0534	2.5493	0584	2.5529
0435	2.5545	0485	2.5529	0535	2.5504	0585	2.5530
0436	2.5511	0486	2.5534	0536	2.5459	0586	2.5529
0437	2.5559	0487	2.5531	0537	2.5744	0587	2.5533
0438	2.5512	0488	2.5530	0538	2.5478	0588	2.5524
0439	2.5551	0489	2.5526	0539	2.5472	0589	2.5519
0440	2.5505	0490	2.5519	0540	2.5470	0590	2.5520
0441	2.5562	0491	2.5525	0541	2.5689	0591	2.5525
0442	2.5506	0492	2.5550	0542	2.5320	0592	2.5519
0443	2.5557	0493	2.5524	0543	2.5549	0593	2.5517
0444	2.5511	0494	2.5544	0544	2.5531	0594	2.5520
0445	2.5555	0495	2.5522	0545	2.5533	0595	2.5518
0446	2.5517	0496	2.5534	0546	2.5545	0596	2.5512
0447	2.5550	0497	2.5513	0547	2.5530	0597	2.5504
0448	2.5502	0498	2.5533	0548	2.5494	0598	2.5508
0449	2.5557	0499	2.5534	0549	2.5498	0599	2.5500
0450	2.5511	0500	2.5304	0550	2.5484	0600	2.5485

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Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
0601	2.5721	0651	2.5299	0701	2.5528	0751	2.5532
0602	2.5454	0652	2.5738	0702	2.5532	0752	2.5534
0603	2.5466	0653	2.5310	0703	2.5528	0753	2.5536
0604	2.5460	0654	2.5741	0704	2.5532	0754	2.5535
0605	2.5753	0655	2.5547	0705	2.5530	0755	2.5531
0606	2.5440	0656	2.5305	0706	2.5533	0756	2.5534
0607	2.5463	0657	2.5730	0707	2.5530	0757	2.5533
0608	2.5465	0658	2.5570	0708	2.5527	0758	2.5533
0609	2.5536	0659	2.5286	0709	2.5532	0759	2.5535
0610	2.5501	0660	2.5723	0710	2.5532	0760	2.5534
0611	2.5493	0661	2.5594	0711	2.5528	0761	2.5535
0612	2.5757	0662	2.5272	0712	2.5532	0762	2.5537
0613	2.5437	0663	2.5716	0713	2.5526	0763	2.5531
0614	2.5448	0664	2.5608	0714	2.5537	0764	2.5536
0615	2.5441	0665	2.5270	0715	2.5530	0765	2.5531
0616	2.5819	0666	2.5706	0716	2.5530	0766	2.5536
0617	2.5416	0667	2.5619	0717	2.5532	0767	2.5537
0618	2.5429	0668	2.5264	0718	2.5532	0768	2.5535
0619	2.5741	0669	2.5702	0719	2.5534	0769	2.5544
0620	2.5401	0670	2.5625	0720	2.5530	0770	2.5528
0621	2.5430	0671	2.5499	0721	2.5529	0771	2.5531
0622	2.5773	0672	2.5526	0722	2.5537	0772	2.5531
0623	2.5391	0673	2.5559	0723	2.5527	0773	2.5533
0624	2.5420	0674	2.5515	0724	2.5533	0774	2.5532
0625	2.5785	0675	2.5527	0725	2.5532	0775	2.5539
0626	2.5382	0676	2.5516	0726	2.5534	0776	2.5528
0627	2.5404	0677	2.5544	0727	2.5532	0777	2.5543
0628	2.5804	0678	2.5517	0728	2.5530	0778	2.5531
0629	2.5371	0679	2.5528	0729	2.5530	0779	2.5537
0630	2.5669	0680	2.5519	0730	2.5529	0780	2.5537
0631	2.5356	0681	2.5536	0731	2.5533	0781	2.5538
0632	2.5737	0682	2.5529	0732	2.5536	0782	2.5535
0633	2.5365	0683	2.5532	0733	2.5533	0783	2.5515
0634	2.5673	0684	2.5534	0734	2.5534	0784	2.5544
0635	2.5358	0685	2.5434	0735	2.5538	0785	2.5529
0636	2.5727	0686	2.5549	0736	2.5529	0786	2.5539
0637	2.5351	0687	2.5513	0737	2.5486	0787	2.5532
0638	2.5707	0688	2.5555	0738	2.5538	0788	2.5541
0639	2.5342	0689	2.5524	0739	2.5523	0789	2.5534
0640	2.5726	0690	2.5534	0740	2.5545	0790	2.5535
0641	2.5427	0691	2.5528	0741	2.5530	0791	2.5533
0642	2.5657	0692	2.5529	0742	2.5533	0792	2.5539
0643	2.5335	0693	2.5531	0743	2.5436	0793	2.5532
0644	2.5749	0694	2.5529	0744	2.5571	0794	2.5539
0645	2.5316	0695	2.5523	0745	2.5521	0795	2.5538
0646	2.5747	0696	2.5528	0746	2.5539	0796	2.5533
0647	2.5311	0697	2.5530	0747	2.5532	0797	2.5534
0648	2.5739	0698	2.5532	0748	2.5533	0798	2.5520
0649	2.5313	0699	2.5532	0749	2.5539	0799	2.5544
0650	2.5731	0700	2.5528	0750	2.5534	0800	2.5520

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Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
0801	2.5518	0851	2.5477	0901	2.5527	0951	2.5530
0802	2.5501	0852	2.5484	0902	2.5538	0952	2.5526
0803	2.5506	0853	2.5481	0903	2.5533	0953	2.5517
0804	2.5510	0854	2.5727	0904	2.5538	0954	2.5524
0805	2.5520	0855	2.5460	0905	2.5536	0955	2.5529
0806	2.5523	0856	2.5473	0906	2.5538	0956	2.5522
0807	2.5513	0857	2.5472	0907	2.5534	0957	2.5527
0808	2.5501	0858	2.5759	0908	2.5534	0958	2.5525
0809	2.5474	0859	2.5474	0909	2.5535	0959	2.5476
0810	2.5743	0860	2.5469	0910	2.5541	0960	2.5511
0811	2.5480	0861	2.5474	0911	2.5532	0961	2.5530
0812	2.5488	0862	2.5741	0912	2.5540	0962	2.5510
0813	2.5497	0863	2.5478	0913	2.5535	0963	2.5503
0814	2.5476	0864	2.5489	0914	2.5537	0964	2.5512
0815	2.5727	0865	2.5498	0915	2.5537	0965	2.5507
0816	2.5477	0866	2.5491	0916	2.5538	0966	2.5502
0817	2.5491	0867	2.5469	0917	2.5534	0967	2.5496
0818	2.5388	0868	2.5767	0918	2.5307	0968	2.5496
0819	2.5502	0869	2.5475	0919	2.5483	0969	2.5762
0820	2.5480	0870	2.5483	0920	2.5725	0970	2.5505
0821	2.5489	0871	2.5498	0921	2.5553	0971	2.5516
0822	2.5485	0872	2.5495	0922	2.5528	0972	2.5491
0823	2.5728	0873	2.5466	0923	2.5536	0973	2.5434
0824	2.5465	0874	2.5783	0924	2.5541	0974	2.5762
0825	2.5484	0875	2.5485	0925	2.5534	0975	2.5450
0826	2.5484	0876	2.5481	0926	2.5529	0976	2.5451
0827	2.5734	0877	2.5469	0927	2.5541	0977	2.5709
0828	2.5474	0878	2.5471	0928	2.5537	0978	2.5444
0829	2.5470	0879	2.5746	0929	2.5538	0979	2.5439
0830	2.5474	0880	2.5462	0930	2.5534	0980	2.5700
0831	2.5711	0881	2.5482	0931	2.5535	0981	2.5443
0832	2.5451	0882	2.5500	0932	2.5541	0982	2.5433
0833	2.5479	0883	2.5485	0933	2.5536	0983	2.5727
0834	2.5470	0884	2.5743	0934	2.5540	0984	2.5438
0835	2.5754	0885	2.5469	0935	2.5532	0985	2.5431
0836	2.5466	0886	2.5484	0936	2.5592	0986	2.5735
0837	2.5478	0887	2.5453	0937	2.5537	0987	2.5446
0838	2.5481	0888	2.5738	0938	2.5511	0988	2.5430
0839	2.5435	0889	2.5436	0939	2.5552	0989	2.5729
0840	2.5724	0890	2.5506	0940	2.5539	0990	2.5436
0841	2.5461	0891	2.5428	0941	2.5544	0991	2.5433
0842	2.5470	0892	2.5788	0942	2.5539	0992	2.5737
0843	2.5483	0893	2.5464	0943	2.5529	0993	2.5428
0844	2.5730	0894	2.5603	0944	2.5541	0994	2.5416
0845	2.5478	0895	2.5524	0945	2.5535	0995	2.5773
0846	2.5475	0896	2.5539	0946	2.5534	0996	2.5406
0847	2.5480	0897	2.5524	0947	2.5538	0997	2.5421
0848	2.5471	0898	2.5546	0948	2.5525	0998	2.5774
0849	2.5802	0899	2.5513	0949	2.5534	0999	2.5424
0850	2.5479	0900	2.5564	0950	2.5529	1000	2.5426

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Certificate of weighing Annex

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Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
1001	2.5745	1051	2.5706	1101	2.5735	1151	2.5546
1002	2.5423	1052	2.5363	1102	2.5342	1152	2.5287
1003	2.5413	1053	2.5601	1103	2.5727	1153	2.5709
1004	2.5774	1054	2.5350	1104	2.5338	1154	2.5537
1005	2.5422	1055	2.5749	1105	2.5729	1155	2.5544
1006	2.5408	1056	2.5361	1106	2.5328	1156	2.5547
1007	2.5776	1057	2.5711	1107	2.5739	1157	2.5547
1008	2.5406	1058	2.5341	1108	2.5334	1158	2.5540
1009	2.5407	1059	2.5719	1109	2.5746	1159	2.5546
1010	2.5797	1060	2.5360	1110	2.5333	1160	2.5548
1011	2.5407	1061	2.5691	1111	2.5733	1161	2.5551
1012	2.5408	1062	2.5358	1112	2.5323	1162	2.5530
1013	2.5789	1063	2.5709	1113	2.5669	1163	2.5544
1014	2.5398	1064	2.5346	1114	2.5335	1164	2.5545
1015	2.5471	1065	2.5723	1115	2.5729	1165	2.5544
1016	2.5440	1066	2.5354	1116	2.5324	1166	2.5541
1017	2.5644	1067	2.5720	1117	2.5731	1167	2.5547
1018	2.5400	1068	2.5354	1118	2.5324	1168	2.5540
1019	2.5694	1069	2.5722	1119	2.5733	1169	2.5540
1020	2.5383	1070	2.5353	1120	2.5563	1170	2.5543
1021	2.5689	1071	2.5721	1121	2.5317	1171	2.5543
1022	2.5380	1072	2.5352	1122	2.5728	1172	2.5539
1023	2.5702	1073	2.5722	1123	2.5563	1173	2.5542
1024	2.5388	1074	2.5349	1124	2.5308	1174	2.5538
1025	2.5673	1075	2.5721	1125	2.5733	1175	2.5539
1026	2.5374	1076	2.5354	1126	2.5584	1176	2.5537
1027	2.5715	1077	2.5727	1127	2.5310	1177	2.5536
1028	2.5385	1078	2.5354	1128	2.5726	1178	2.5535
1029	2.5686	1079	2.5718	1129	2.5585	1179	2.5535
1030	2.5380	1080	2.5357	1130	2.5318	1180	2.5535
1031	2.5702	1081	2.5723	1131	2.5723	1181	2.5535
1032	2.5371	1082	2.5342	1132	2.5581	1182	2.5535
1033	2.5702	1083	2.5733	1133	2.5304	1183	2.5535
1034	2.5387	1084	2.5342	1134	2.5711	1184	2.5540
1035	2.5679	1085	2.5736	1135	2.5601	1185	2.5570
1036	2.5373	1086	2.5334	1136	2.5291	1186	2.5059
1037	2.5701	1087	2.5742	1137	2.5719		
1038	2.5373	1088	2.5329	1138	2.5605		
1039	2.5696	1089	2.5746	1139	2.5305		
1040	2.5361	1090	2.5321	1140	2.5712		
1041	2.5709	1091	2.5749	1141	2.5606		
1042	2.5360	1092	2.5329	1142	2.5288		
1043	2.5710	1093	2.5745	1143	2.5716		
1044	2.5373	1094	2.5336	1144	2.5618		
1045	2.5694	1095	2.5702	1145	2.5284		
1046	2.5374	1096	2.5340	1146	2.5712		
1047	2.5706	1097	2.5737	1147	2.5626		
1048	2.5370	1098	2.5338	1148	2.5285		
1049	2.5706	1099	2.5737	1149	2.5717		
1050	2.5360	1100	2.5336	1150	2.5615		

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Annex 15: The weighing certificate of the metals and the mother solution for the preparation of IRMM-1027p

Certificate of weighing

Institute for Reference Materials and Measurements

E. 3789 **Issued date**: 25 October 2013 **Page** 1 **of** 1

Applicant: R. Jakopič **Unit/group**: SN3S/Metro

Project: Preparation and certification of IRMM-1027p

Description: Mother solution IRMM-1027p

Date of request: 12 May 2011

Weighing date: 15 June 2011 and 02 November 2012

The reported results apply only to the objects / samples described in this certificate.

	Mass [g]	Uncertainty [g]
Mass of Pu metal (MP2)	2.2443	0.0002
Mass of U metal (CRM-116)	11.747	0.002
Mass of U metal (EC-NRM-101)	53.324	0.006
Mass of IRMM-1027p	3070.76	0.09

Observations:
Masses were determined by substitution weighing on balances AT 261 and At 201 with IRMM inventory No 1999 00337 27 and 1996 00547 73 and balance PR 5002 with inventory No. 9800298.

Traceability:
The certified mass values are traceable to the International Kilogram Prototype via regular calibrations of the IRMM principal kilogram. The sets of working mass standards M 3 and M 10 were used as reference in the mass determination.

Uncertainty:
All reported uncertainties are expanded uncertainties $U = k \cdot u_c$ where u_c is the combined standard uncertainty calculated according to the ISO/IEC Guide to the expression of Uncertainty in Measurement. The coverage factor $k = 2$ corresponds to a coverage probability of about 95 %.

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Mass Metrology Service

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Annex 16: Uncertainty budget for the plutonium gravimetric mixture of IRMM-1027p.

Plutonium gravimetric mixture for IRMM-1027p

Author: Rozle Jakopic

A plutonium gravimetric mixture was prepared by dissolving plutonium MP2 metal (CEA/CETAMA) in nitric acid.

Input parameters:

a) Mass of plutonium metal and the nitrate solution (weighing certificate E3789) b) Purity of plutonium metal (metal certificate) c) Plutonium isotope amount ratios (IRMM certificate, issued 11 April 2007) d) Atomic masses for plutonium isotopes from G. Audi et al. Nuclear Physics A729, 337-676, 2003 e) Half-lives from Laboratorie National Henri Becquerel, http://www.nucleide.org/$DDEP_{WG}$/DDEPdata.htm

Purity of MP2 metal on 1 Nov 2013 was calculated from the the purity on 1 Jan 2007 (99.875 +/-0.040), which was derived from the original CETAMA certificate (99.90 +/- 0.04).

All the data are decayed to 1 November 2013 (reference date)

Model Equation:

{Molar mass of plutonium in MP2, 1 Jan 2007}

$$M_{Pu} = M_{238Pu}\cdot f_{238Pu} + M_{239Pu}\cdot f_{239Pu} + M_{240Pu}\cdot f_{240Pu} + M_{241Pu}\cdot f_{241Pu} + M_{242Pu}\cdot f_{242Pu};$$

{Isotope amount fraction in MP2, 1 Jan 2007}

$$f_{238Pu} = R_{238Pu/239Pu}/\Sigma R_{Pu};$$

$$f_{239Pu} = 1/\Sigma R_{Pu};$$

$$f_{240Pu} = R_{240Pu/239Pu}/\Sigma R_{Pu};$$

$$f_{241Pu} = R_{241Pu/239Pu}/\Sigma R_{Pu};$$

$$f_{242Pu} = R_{242Pu/239Pu}/\Sigma R_{Pu};$$

$$\Sigma R_{Pu} = R_{238Pu/239Pu} + 1 + R_{240Pu/239Pu} + R_{241Pu/239Pu} + R_{242Pu/239Pu};$$

{Isotope mass fractios in MP2, 1 Jan 2007}

$$w_{238Pu} = f_{238Pu}\cdot M_{238Pu}/M_{Pu};$$

$$w_{239Pu} = f_{239Pu}\cdot M_{239Pu}/M_{Pu};$$

$$w_{240Pu} = f_{240Pu}\cdot M_{240Pu}/M_{Pu};$$

$$w_{241Pu} = f_{241Pu}\cdot M_{241Pu}/M_{Pu};$$

$$w_{242Pu} = f_{242Pu}\cdot M_{242Pu}/M_{Pu};$$

{Decayed isotope amount ratios in gravimetric mixture, IRMM-1027p, 1 November 2013}

$$Rd_{238Pu/239Pu} = R_{238Pu/239Pu}\cdot(e^{\wedge}(-\lambda_{238}\cdot\Delta t)/e^{\wedge}(-\lambda_{239}\cdot\Delta t));$$

$$Rd_{240Pu/239Pu} = R_{240Pu/239Pu}\cdot(e^{\wedge}(-\lambda_{240}\cdot\Delta t)/e^{\wedge}(-\lambda_{239}\cdot\Delta t));$$

$$Rd_{241Pu/239Pu} = R_{241Pu/239Pu}\cdot(e^{\wedge}(-\lambda_{241}\cdot\Delta t)/e^{\wedge}(-\lambda_{239}\cdot\Delta t));$$

$Rd_{242Pu/239Pu} = R_{242Pu/239Pu} \cdot (e^{\wedge}(-\lambda_{242} \cdot \Delta t)/e^{\wedge}(-\lambda_{239} \cdot \Delta t))$;

$\Sigma Rd_{Pu} = Rd_{238Pu/239Pu} + 1 + Rd_{240Pu/239Pu} + Rd_{241Pu/239Pu} + Rd_{242Pu/239Pu}$;

{Decayed and normalised isotope amount fractios in gravimetric mixture, IRMM-1027p, 1 November 2013}

$fdnorm_{238Pu} = Rd_{238Pu/239Pu}/\Sigma Rd_{Pu}$;

$fdnorm_{239Pu} = 1/\Sigma Rd_{Pu}$;

$fdnorm_{240Pu} = Rd_{240Pu/239Pu}/\Sigma Rd_{Pu}$;

$fdnorm_{241Pu} = Rd_{241Pu/239Pu}/\Sigma Rd_{Pu}$;

$fdnorm_{242Pu} = Rd_{242Pu/239Pu}/\Sigma Rd_{Pu}$;

{Decayed molar mass of plutonium in gravimetric mixtures, IRMM-1027p, 1 November 2013}

$Md_{Pu} = M_{238Pu} \cdot fdnorm_{238Pu} + M_{239Pu} \cdot fdnorm_{239Pu} + M_{240Pu} \cdot fdnorm_{240Pu} + M_{241Pu} \cdot fdnorm_{241Pu} + M_{242Pu} \cdot fdnorm_{242Pu}$;

{Decayed and normalised isotope mass fractios in gravimetric mixture, IRMM-1027p, 1 November 2013}

$wdnorm_{238Pu} = fdnorm_{238Pu} \cdot M_{238Pu}/Md_{Pu}$;

$wdnorm_{239Pu} = fdnorm_{239Pu} \cdot M_{239Pu}/Md_{Pu}$;

$wdnorm_{240Pu} = fdnorm_{240Pu} \cdot M_{240Pu}/Md_{Pu}$;

$wdnorm_{241Pu} = fdnorm_{241Pu} \cdot M_{241Pu}/Md_{Pu}$;

$wdnorm_{242Pu} = fdnorm_{242Pu} \cdot M_{242Pu}/Md_{Pu}$;

{Decayed amount ratios for purity calculation, 1 November 2013}

$fd_{238Pu}=f_{238Pu}*e^{\wedge}(-\lambda_{238}*\Delta t)$;

$fd_{239Pu}=f_{239Pu}*e^{\wedge}(-\lambda_{239}*\Delta t)$;

$fd_{240Pu}=f_{240Pu}*e^{\wedge}(-\lambda_{240}*\Delta t)$;

$fd_{241Pu}=f_{241Pu}*e^{\wedge}(-\lambda_{241}*\Delta t)$;

$fd_{242Pu}=f_{242Pu}*e^{\wedge}(-\lambda_{242}*\Delta t)$;

{Decayed isotope masses for purity calculation, 1 November 2013}

$md_{238Pu}=fd_{238Pu}*M_{238Pu}*m_{Pu}/M_{Pu}$;

$md_{239Pu}=fd_{239Pu}*M_{239Pu}*m_{Pu}/M_{Pu}$;

$md_{240Pu}=fd_{240Pu}*M_{240Pu}*m_{Pu}/M_{Pu}$;

$md_{241Pu}=fd_{241Pu}*M_{241Pu}*m_{Pu}/M_{Pu}$;

$md_{242Pu}=fd_{242Pu}*M_{242Pu}*m_{Pu}/M_{Pu}$;

$\Sigma md_{Pu}= md_{238Pu}+md_{239Pu}+md_{240Pu}+md_{241Pu}+md_{242Pu}$;

$\eta_{Pufinal}=\eta_{PuMP2}*\Sigma md_{Pu}/m_{Pu}$;

{Decay constants}

$ln_2 = ln(2)$;

$\lambda_{238} = ln_2 / \tau_{238}$;

$\lambda_{239} = ln_2 / \tau_{239}$;

$\lambda_{240} = ln_2 / \tau_{240}$;

$\lambda_{241} = ln_2 / \tau_{241}$;

$\lambda_{242} = ln_2 / \tau_{242}$;

{Plutonium mass fraction in gravimetric mixture, IRMM-1027p, 1 November 2013}

$\gamma_{Pumixture}=(m_{PuMP2}*\eta_{Pufinal})/m_{solution1027p}$;

$\gamma_{Pumixture239}=\gamma_{Pumixture}*wdnorm_{239Pu}$;

$m_{239Puvial1}=\gamma_{Pumixture239}*m_{vial1}$;

{Plutonium amount content in gravimetric mixture, IRMM-1027p, 1 November 2013}

$c_{Pumixture}=\gamma_{Pumixture}/Md_{Pu}$;

$c_{Pumixture239} = c_{Pumixture}*fdnorm_{239Pu}$;

List of Quantities:

Quantity	Unit	Definition
Δt	a	time difference between certification date MP2 (1 Jan 2007) and reference date (1 Nov 2013)
$Rd_{238Pu/239Pu}$	mol/mol	decayed $^{238}Pu/^{239}Pu$ amount ratio in IRMM-1027p, 1 Nov 2013
$Rd_{240Pu/239Pu}$	mol/mol	decayed $^{240}Pu/^{239}Pu$ amount ratio in IRMM-1027p, 1 Nov 2013
$Rd_{241Pu/239Pu}$	mol/mol	decayed $^{241}Pu/^{239}Pu$ amount ratio in IRMM-1027p, 1 Nov 2013
$Rd_{242Pu/239Pu}$	mol/mol	decayed $^{242}Pu/^{239}Pu$ amount ratio in IRMM-1027p, 1 Nov 2013
$R_{238Pu/239Pu}$	mol/mol	$^{238}Pu/^{239}Pu$ amount ratio in MP2, 1 Jan 2007
$R_{240Pu/239Pu}$	mol/mol	$^{240}Pu/^{239}Pu$ amount ratio in MP2, 1 Jan 2007
$R_{241Pu/239Pu}$	mol/mol	$^{241}Pu/^{239}Pu$ amount ratio in MP2, 1 Jan 2007
$R_{242Pu/239Pu}$	mol/mol	$^{242}Pu/^{239}Pu$ amount ratio in MP2, 1 Jan 2007
M_{Pu}	g/mol	molar mass of Pu in MP2, 1 Jan 2007
f_{238Pu}	mol/mol	^{238}Pu amount fraction in MP2, 1 Jan 2007
f_{239Pu}	mol/mol	^{239}Pu amount fraction in MP2, 1 Jan 2007
f_{240Pu}	mol/mol	^{240}Pu amount fraction in MP2, 1 Jan 2007
f_{241Pu}	mol/mol	^{241}Pu amount fraction in MP2, 1 Jan 2007
f_{242Pu}	mol/mol	^{242}Pu amount fraction in MP2, 1 Jan 2007
e		

Quantity	Unit	Definition
ΣR_{Pu}	mol/mol	Sum of amount ratios in MP2, 1 Jan 2007
λ_{238}	a^{-1}	Decay constant ^{238}Pu
λ_{239}	a^{-1}	Decay constant ^{239}Pu
λ_{240}	a^{-1}	Decay constant ^{240}Pu
λ_{241}	a^{-1}	Decay constant ^{241}Pu
λ_{242}	a^{-1}	Decay constant ^{242}Pu
M_{238Pu}	g/mol	Atomic mass of ^{238}Pu
M_{239Pu}	g/mol	Atomic mass of ^{239}Pu
M_{240Pu}	g/mol	Atomic mass of ^{240}Pu
M_{241Pu}	g/mol	Atomic mass of ^{241}Pu
M_{242Pu}	g/mol	Atomic mass of ^{242}Pu
ΣRd_{Pu}	mol/mol	Sum of decayed amount ratios in gravimetric mixture, IRMM-1027p, 1 November 2013
$fdnorm_{238Pu}$	mol/mol	Decayed and normalised ^{238}Pu amount fraction in gravimetric mixture, IRMM-1027p, 1 November 2013
$fdnorm_{239Pu}$	mol/mol	Decayed and normalised ^{239}Pu amount fraction in gravimetric mixture, IRMM-1027p, 1 November 2013
$fdnorm_{240Pu}$	mol/mol	Decayed and normalised ^{240}Pu amount fraction in gravimetric mixture, IRMM-1027p, 1 November 2013
$fdnorm_{241Pu}$	mol/mol	Decayed and normalised ^{241}Pu amount fraction in gravimetric mixture, IRMM-1027p, 1 November 2013
$fdnorm_{242Pu}$	mol/mol	Decayed and normalised ^{242}Pu amount fraction in gravimetric mixture, IRMM-1027p, 1 November 2013
Md_{Pu}	g/mol	Decayed molar mass of Pu in gravimetric mixture, IRMM-1027p, 1 November 2013
$wdnorm_{238Pu}$	g/g	Decayed and normalised ^{238}Pu mass fraction in gravimetric mixture, IRMM-1027p, 1 November 2013
$wdnorm_{239Pu}$	g/g	Decayed and normalised ^{239}Pu mass fraction in gravimetric mixture, IRMM-1027p, 1 November 2013
$wdnorm_{240Pu}$	g/g	Decayed and normalised ^{240}Pu mass fraction in gravimetric mixture, IRMM-1027p, 1 November 2013
$wdnorm_{241Pu}$	g/g	Decayed and normalised ^{241}Pu mass fraction in gravimetric mixture, IRMM-1027p, 1 November 2013
$wdnorm_{242Pu}$	g/g	Decayed and normalised ^{242}Pu mass fraction in gravimetric mixture, IRMM-1027p, 1 November 2013
$\eta_{Pufinal}$	g/g	Purity of MP2 metal, 1 November 2013
ln_2		
τ_{238}	a	Half-life ^{238}Pu
τ_{239}	a	Half-life ^{239}Pu

Quantity	Unit	Definition
τ_{240}	a	Half-life ^{240}Pu
τ_{241}	a	Half-life ^{241}Pu
τ_{242}	a	Half-life ^{242}Pu
$\gamma_{Pumixture}$	g/g	Pu mass fraction in IRMM-1027p
m_{PuMP2}	g	Mass of plutonium MP2 metal
$m_{solution1027p}$	g	Mass of gravimetric mixture, IRMM-1027p
$\gamma_{Pumixture239}$	g/g	^{239}Pu mass fraction in IRMM-1027p
$c_{Pumixture}$	mol/g	Pu amount content in IRMM-1027p
$c_{Pumixture239}$	mol/g	^{239}Pu amount content in IRMM-1027p
m_{Pu}	g	
md_{238Pu}	g	Decayed mass of ^{238}Pu, from 1 Jan 2007 to 1 November 2013
md_{239Pu}	g	Decayed mass of ^{239}Pu, from 1 Jan 2007 to 1 November 2013
md_{240Pu}	g	Decayed mass of ^{240}Pu, from 1 Jan 2007 to 1 November 2013
md_{241Pu}	g	Decayed mass of ^{241}Pu, from 1 Jan 2007 to 1 November 2013
md_{242Pu}	g	Decayed mass of ^{242}Pu, from 1 Jan 2007 to 1 November 2013
Σmd_{Pu}	g	Sum of decayed Pu masses
η_{PuMP2}	g/g	Purity of MP2 metal, 1 Jan 2007
w_{238Pu}	g/g	^{238}Pu mass fraction in MP2, 1 Jan 2007
w_{239Pu}	g/g	^{239}Pu mass fraction in MP2, 1 Jan 2007
w_{240Pu}	g/g	^{240}Pu mass fraction in MP2, 1 Jan 2007
w_{241Pu}	g/g	^{241}Pu mass fraction in MP2, 1 Jan 2007
w_{242Pu}	g/g	^{242}Pu mass fraction in MP2, 1 Jan 2007
fd_{238Pu}	mol/mol	Decayed ^{238}Pu amount fraction in MP2, from 1 Jan 2007 to 1 November 2013
fd_{239Pu}	mol/mol	Decayed ^{239}Pu amount fraction in MP2, from 1 Jan 2007 to 1 November 2013
fd_{240Pu}	mol/mol	Decayed ^{240}Pu amount fraction in MP2, from 1 Jan 2007 to 1 November 2013
fd_{241Pu}	mol/mol	Decayed ^{241}Pu amount fraction in MP2, from 1 Jan 2007 to 1 November 2013
fd_{242Pu}	mol/mol	Decayed ^{242}Pu amount fraction in MP2, from 1 Jan 2007 to 1 November 2013
$m_{239Puvial1}$		
m_{vial1}		

Δt: Type B rectangular distribution
Value: 6.833676 a
Halfwidth of Limits: 0.038 a

01/01/2007, 01/11/2013, delta t= 2496 days / 365.25 = 6.833676 a

$R_{238Pu/239Pu}$: Type B normal distribution
Value: 0.00003083 mol/mol
Expanded Uncertainty: 0.00000029 mol/mol
Coverage Factor: 2

IRMM MP2 certificate 2007

$R_{240Pu/239Pu}$: Type B normal distribution
Value: 0.0224324 mol/mol
Expanded Uncertainty: 0.0000051 mol/mol
Coverage Factor: 2

IRMM MP2 certificate 2007

$R_{241Pu/239Pu}$: Type B normal distribution
Value: 0.0002378 mol/mol
Expanded Uncertainty: 0.0000031 mol/mol
Coverage Factor: 2

IRMM MP2 certificate 2007

$R_{242Pu/239Pu}$: Type B normal distribution
Value: 0.00007570 mol/mol
Expanded Uncertainty: 0.00000078 mol/mol
Coverage Factor: 2

IRMM MP2 certificate 2007

e: Constant
Value: 2.71828182845904523536

M_{238Pu}: Type B normal distribution
Value: 238.0495599 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al.,The AME2003 atomic mass evaluation, Nuclear Physics A 729, 337-676, 2003

M_{239Pu}: Type B normal distribution
Value: 239.0521634 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al.,The AME2003 atomic mass evaluation, Nuclear Physics A 729, 337-676, 2003

M_{240Pu}: Type B normal distribution
Value: 240.0538135 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al.,The AME2003 atomic mass evaluation, Nuclear Physics A 729, 337-676, 2003

M_{241Pu}: Type B normal distribution
Value: 241.0568515 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al.,The AME2003 atomic mass evaluation, Nuclear Physics A 729, 337-676, 2003

M_{242Pu}: Type B normal distribution
Value: 242.0587426 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al.,The AME2003 atomic mass evaluation, Nuclear Physics A 729, 337-676, 2003

τ_{238}: Type B normal distribution
Value: 87.74 a
Expanded Uncertainty: 0.03 a
Coverage Factor: 1

Laboratorie National Henri Becquerel, http://www.nucleide.org/$DDEP_{WG}$/DDEPdata.htm

τ_{239}: Type B normal distribution
Value: 24100 a
Expanded Uncertainty: 11 a
Coverage Factor: 1

Laboratorie National Henri Becquerel, http://www.nucleide.org/$DDEP_{WG}$/DDEPdata.htm

τ_{240}: Type B normal distribution
Value: 6561 a
Expanded Uncertainty: 7 a
Coverage Factor: 1

Laboratorie National Henri Becquerel, http://www.nucleide.org/$DDEP_{WG}$/DDEPdata.htm

τ_{241}: Type B normal distribution
Value: 14.325 a
Expanded Uncertainty: 0.024 a
Coverage Factor: 2

Wellum et al., J. Anal. At. Spectrom., 2009, 24, 801-807

τ_{242}: Type B normal distribution
Value: 373000 a
Expanded Uncertainty: 3000 a
Coverage Factor: 1

Laboratorie National Henri Becquerel, http://www.nucleide.org/DDEP$_{WG}$/DDEPdata.htm

m_{PuMP2}: Type B normal distribution
Value: 2.2443 g
Expanded Uncertainty: 0.0002 g
Coverage Factor: 2

weighing certificate E3789

$m_{solution1027p}$: Type B normal distribution
Value: 3070.76 g
Expanded Uncertainty: 0.09 g
Coverage Factor: 2

weighing certificate E3789

m_{Pu}: Type B normal distribution
Value: 1.00 g
Expanded Uncertainty: 0 g
Coverage Factor: 1

η_{PuMP2}: Import
Filename: Decay MP2 from 12-03-2001 to 01-01-2007.smu
Symbol: $\eta_{Pufinal}$

m_{vial1}: Type B normal distribution
Value: 2.5351
Expanded Uncertainty: 0.0006
Coverage Factor: 2

mass of Vial No. 1

Input Correlation:

The abundance set for Pu is assumed as uncorrelated.

Interim Results:

Quantity	Value	Standard Uncertainty
M_{Pu}	239.07479084 g/mol	$4.49 \cdot 10^{-6}$ g/mol
f_{238Pu}	$30.143 \cdot 10^{-6}$ mol/mol	$142 \cdot 10^{-9}$ mol/mol
f_{239Pu}	0.97773050 mol/mol	$2.88 \cdot 10^{-6}$ mol/mol
f_{240Pu}	0.02193284 mol/mol	$2.44 \cdot 10^{-6}$ mol/mol
f_{241Pu}	$232.50 \cdot 10^{-6}$ mol/mol	$1.52 \cdot 10^{-6}$ mol/mol
f_{242Pu}	$74.014 \cdot 10^{-6}$ mol/mol	$381 \cdot 10^{-9}$ mol/mol
ΣR_{Pu}	1.02277673 mol/mol	$3.01 \cdot 10^{-6}$ mol/mol
λ_{238}	$7.90001 \cdot 10^{-3}$ a^{-1}	$2.70 \cdot 10^{-6}$ a^{-1}
λ_{239}	$28.7613 \cdot 10^{-6}$ a^{-1}	$13.1 \cdot 10^{-9}$ a^{-1}
λ_{240}	$105.647 \cdot 10^{-6}$ a^{-1}	$113 \cdot 10^{-9}$ a^{-1}
λ_{241}	0.0483872 a^{-1}	$40.5 \cdot 10^{-6}$ a^{-1}
λ_{242}	$1.8583 \cdot 10^{-6}$ a^{-1}	$14.9 \cdot 10^{-9}$ a^{-1}
ΣRd_{Pu}	1.02269643 mol/mol	$2.82 \cdot 10^{-6}$ mol/mol
md_{238Pu}	$28.437 \cdot 10^{-6}$ g	$134 \cdot 10^{-9}$ g
md_{239Pu}	0.97744583 g	$2.96 \cdot 10^{-6}$ g
md_{240Pu}	0.02200676 g	$2.45 \cdot 10^{-6}$ g
md_{241Pu}	$168.43 \cdot 10^{-6}$ g	$1.11 \cdot 10^{-6}$ g
md_{242Pu}	$74.937 \cdot 10^{-6}$ g	$386 \cdot 10^{-9}$ g
Σmd_{Pu}	0.999724392 g	$959 \cdot 10^{-9}$ g
w_{238Pu}	$30.014 \cdot 10^{-6}$ g/g	$141 \cdot 10^{-9}$ g/g
w_{239Pu}	0.97763796 g/g	$2.90 \cdot 10^{-6}$ g/g
w_{240Pu}	0.02202266 g/g	$2.45 \cdot 10^{-6}$ g/g
w_{241Pu}	$234.43 \cdot 10^{-6}$ g/g	$1.53 \cdot 10^{-6}$ g/g
w_{242Pu}	$74.938 \cdot 10^{-6}$ g/g	$386 \cdot 10^{-9}$ g/g
fd_{238Pu}	$28.559 \cdot 10^{-6}$ mol/mol	$134 \cdot 10^{-9}$ mol/mol
fd_{239Pu}	0.97753835 mol/mol	$2.95 \cdot 10^{-6}$ mol/mol
fd_{240Pu}	0.02191701 mol/mol	$2.44 \cdot 10^{-6}$ mol/mol
fd_{241Pu}	$167.04 \cdot 10^{-6}$ mol/mol	$1.10 \cdot 10^{-6}$ mol/mol
fd_{242Pu}	$74.013 \cdot 10^{-6}$ mol/mol	$381 \cdot 10^{-9}$ mol/mol

Uncertainty Budgets:

$Rd_{240Pu/239Pu}$: decayed $^{240}Pu/^{239}Pu$ amount ratio in IRMM-1027p, 1 Nov 2013

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$R_{240Pu/239Pu}$	0.02243240 mol/mol	$2.55 \cdot 10^{-6}$ mol/mol	normal	1.0	$2.5 \cdot 10^{-6}$ mol/mol	100.0 %
$Rd_{240Pu/239Pu}$	0.02242062 mol/mol	$2.55 \cdot 10^{-6}$ mol/mol				

$Rd_{241Pu/239Pu}$: decayed $^{241}Pu/^{239}Pu$ amount ratio in IRMM-1027p, 1 Nov 2013

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
Δt	6.8337 a	0.0219 a	rectangular	$-8.3 \cdot 10^{-6}$	$-180 \cdot 10^{-9}$ mol/mol	2.6 %
$R_{241Pu/239Pu}$	$237.80 \cdot 10^{-6}$ mol/mol	$1.55 \cdot 10^{-6}$ mol/mol	normal	0.72	$1.1 \cdot 10^{-6}$ mol/mol	97.2 %
τ_{241}	14.3250 a	0.0120 a	normal	$3.9 \cdot 10^{-6}$	$47 \cdot 10^{-9}$ mol/mol	0.2 %
$Rd_{241Pu/239Pu}$	$170.88 \cdot 10^{-6}$ mol/mol	$1.13 \cdot 10^{-6}$ mol/mol				

$Rd_{242Pu/239Pu}$: decayed $^{242}Pu/^{239}Pu$ amount ratio in IRMM-1027p, 1 Nov 2013

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$R_{242Pu/239Pu}$	$75.700 \cdot 10^{-6}$ mol/mol	$390 \cdot 10^{-9}$ mol/mol	normal	1.0	$390 \cdot 10^{-9}$ mol/mol	100.0 %
$Rd_{242Pu/239Pu}$	$75.714 \cdot 10^{-6}$ mol/mol	$390 \cdot 10^{-9}$ mol/mol				

$\gamma_{Pumixture239}$: ^{239}Pu mass fraction in IRMM-1027p

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
m_{PuMP2}	2.244300 g	$100 \cdot 10^{-6}$ g	normal	$320 \cdot 10^{-6}$	$32 \cdot 10^{-9}$ g/g	4.7 %
$m_{solution1027p}$	3070.7600 g	0.0450 g	normal	0.0	$-10 \cdot 10^{-9}$ g/g	0.5 %
η_{PuMP2}	0.998746 g/g	$200 \cdot 10^{-6}$ g/g		$710 \cdot 10^{-6}$	$140 \cdot 10^{-9}$ g/g	94.8 %
$\gamma_{Pumixture239}$	$713.482 \cdot 10^{-6}$ g/g	$147 \cdot 10^{-9}$ g/g				

$c_{Pumixture239}$: ^{239}Pu amount content in IRMM-1027p

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
m_{PuMP2}	2.244300 g	$100 \cdot 10^{-6}$ g	normal	$1.3 \cdot 10^{-6}$	$130 \cdot 10^{-12}$ mol/g	4.7 %
$m_{solution1027p}$	3070.7600 g	0.0450 g	normal	0.0	$-44 \cdot 10^{-12}$ mol/g	0.5 %
η_{PuMP2}	0.998746 g/g	$200 \cdot 10^{-6}$ g/g		$3.0 \cdot 10^{-6}$	$600 \cdot 10^{-12}$ mol/g	94.8 %
$c_{Pumixture239}$	$2.984627 \cdot 10^{-6}$ mol/g	$614 \cdot 10^{-12}$ mol/g				

$m_{239Puvial1}$:

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
m_{PuMP2}	2.244300 g	$100 \cdot 10^{-6}$ g	normal	$810 \cdot 10^{-6}$	$81 \cdot 10^{-9}$	3.5 %
$m_{solution1027p}$	3070.7600 g	0.0450 g	normal	0.0	$-27 \cdot 10^{-9}$	0.4 %
η_{PuMP2}	0.998746 g/g	$200 \cdot 10^{-6}$ g/g		$1.8 \cdot 10^{-3}$	$360 \cdot 10^{-9}$	71.2 %
m_{vial1}	2.535100	$300 \cdot 10^{-6}$	normal	$710 \cdot 10^{-6}$	$210 \cdot 10^{-9}$	24.9 %
$m_{239Puvial1}$	$1.808747 \cdot 10^{-3}$	$429 \cdot 10^{-9}$				

Results:

Quantity	Value	Expanded Uncertainty	Coverage factor	Coverage
$Rd_{238Pu/239Pu}$	$29.22 \cdot 10^{-6}$ mol/mol	$280 \cdot 10^{-9}$ mol/mol	2.00	manual
$Rd_{240Pu/239Pu}$	0.0224206 mol/mol	$5.1 \cdot 10^{-6}$ mol/mol	2.00	manual
$Rd_{241Pu/239Pu}$	$170.9 \cdot 10^{-6}$ mol/mol	$2.3 \cdot 10^{-6}$ mol/mol	2.00	manual
$Rd_{242Pu/239Pu}$	$75.71 \cdot 10^{-6}$ mol/mol	$780 \cdot 10^{-9}$ mol/mol	2.00	manual
$fdnorm_{238Pu}$	$28.57 \cdot 10^{-6}$ mol/mol	$270 \cdot 10^{-9}$ mol/mol	2.00	manual
$fdnorm_{239Pu}$	0.9778073 mol/mol	$5.4 \cdot 10^{-6}$ mol/mol	2.00	manual
$fdnorm_{240Pu}$	0.0219230 mol/mol	$4.9 \cdot 10^{-6}$ mol/mol	2.00	manual
$fdnorm_{241Pu}$	$167.1 \cdot 10^{-6}$ mol/mol	$2.2 \cdot 10^{-6}$ mol/mol	2.00	manual
$fdnorm_{242Pu}$	$74.03 \cdot 10^{-6}$ mol/mol	$760 \cdot 10^{-9}$ mol/mol	2.00	manual
Md_{Pu}	239.0746515 g/mol	$8.0 \cdot 10^{-6}$ g/mol	2.00	manual
$wdnorm_{238Pu}$	$28.44 \cdot 10^{-6}$ g/g	$270 \cdot 10^{-9}$ g/g	2.00	manual
$wdnorm_{239Pu}$	0.9777153 g/g	$5.4 \cdot 10^{-6}$ g/g	2.00	manual
$wdnorm_{240Pu}$	0.0220128 g/g	$4.9 \cdot 10^{-6}$ g/g	2.00	manual
$wdnorm_{241Pu}$	$168.5 \cdot 10^{-6}$ g/g	$2.2 \cdot 10^{-6}$ g/g	2.00	manual
$wdnorm_{242Pu}$	$74.96 \cdot 10^{-6}$ g/g	$770 \cdot 10^{-9}$ g/g	2.00	manual
$\eta_{Pufinal}$	0.99847 g/g	$400 \cdot 10^{-6}$ g/g	2.00	manual
$\gamma_{Pumixture}$	$729.74 \cdot 10^{-6}$ g/g	$300 \cdot 10^{-9}$ g/g	2.00	manual
$\gamma_{Pumixture239}$	$713.48 \cdot 10^{-6}$ g/g	$290 \cdot 10^{-9}$ g/g	2.00	manual
$c_{Pumixture}$	$3.0524 \cdot 10^{-6}$ mol/g	$1.3 \cdot 10^{-9}$ mol/g	2.00	manual
$c_{Pumixture239}$	$2.9846 \cdot 10^{-6}$ mol/g	$1.2 \cdot 10^{-9}$ mol/g	2.00	manual
$m_{239Puvial1}$	$1.80875 \cdot 10^{-3}$	0.047 % (relative)	2.00	manual

Annex 17: Uncertainty budget for the uranium gravimetric mixture of IRMM-1027p.

Uranium gravimetric mixture for IRMM-1027p

Author: Rozle Jakopic

A uranium gravimetric mixture was prepared by dissolving natural uranium (EC NRM 101) and enriched uranium (NBL CRM-116) metals in nitric acid solution.

Input parameters: a) masses of the metals and the nitrate solution (E3789) b) purity of the metals (metal certificates) c) uranium isotope amount ratios of the metals (certificate) d) atomic masses for uranium isotopes from G. Audi et al., Nuclear Physics A 729, 337-676, 2003

Model Equation:

{Molar mass of uranium in gravimetric mixture, IRMM-1027p}

$M_U = M_{233U} \cdot f_{233U} + M_{234U} \cdot f_{234U} + M_{235U} \cdot f_{235U} + M_{236U} \cdot f_{236U} + M_{238U} \cdot f_{238U}$;

{Isotope amount fraction in gravimetric mixture, IRMM-1027p}

$f_{233U} = R_{233U/238U}/\Sigma R_U$;

$f_{234U} = R_{234U/238U}/\Sigma R_U$;

$f_{235U} = R_{235U/238U}/\Sigma R_U$;

$f_{236U} = R_{236U/238U}/\Sigma R_U$;

$f_{238U} = 1/\Sigma R_U$;

$\Sigma R_U = R_{233U/238U} + R_{234U/238U} + R_{235U/238U} + R_{236U/238U} + 1$;

{Isotope mass fraction in gravimetric mixture, IRMM-1027p}

$w_{233U} = f_{233U} \cdot M_{233U}/M_U$;

$w_{234U} = f_{234U} \cdot M_{234U}/M_U$;

$w_{235U} = f_{235U} \cdot M_{235U}/M_U$;

$w_{236U} = f_{236U} \cdot M_{236U}/M_U$;

$w_{238U} = f_{238U} \cdot M_{238U}/M_U$;

{Isotope amount ratios in gravimetric mixture, IRMM-1027p}

$R_{233U/238U} = n_{233U}/n_{238U}$;

$R_{234U/238U} = n_{234U}/n_{238U}$;

$R_{235U/238U} = n_{235U}/n_{238U}$;

$R_{236U/238U} = n_{236U}/n_{238U}$;

{Amount of uranium isotopes in gravimetric mixture, IRMM-1027p}

$n_{233U} = (n_{233.a} + n_{233.b})$;

$n_{234U} = (n_{234.a} + n_{234.b})$;

$n_{235U} = (n_{235.a} + n_{235.b})$;

$n_{236U} = (n_{236.a} + n_{236.b})$;

$n_{238U} = (n_{238.a} + n_{238.b})$;

{uranium mass fraction in gravimetric mixture, IRMM-1027p}

$\gamma_{Umixture}=(m_{UCRM116}*\eta_{purityCRM116}+m_{UEC101}*\eta_{purityEC101})/m_{solution1027p}$;

$\gamma_{235Umixture}=\gamma_{Umixture}*w_{235U}$;

$\gamma_{238Umixture}=\gamma_{Umixture}*w_{238U}$;

$m_{235U}=\gamma_{235Umixture}*m_{vial1}$;

$m_{238U}=\gamma_{238Umixture}*m_{vial1}$;

{uranium amount content in gravimetric mixture, IRMM-1027p}

$c_{Umixture}=\gamma_{Umixture}/M_U$;

$c_{235Umixture}=c_{Umixture}*f_{235U}$;

$c_{238Umixture}=c_{Umixture}*f_{238U}$;

{Amount of uranium isotopes in EC NRM 101}

$n_{233.a} = m_{UEC101} *\eta_{purityEC101} * f_{233Ua} / M_{Ua}$;

$n_{234.a} = m_{UEC101} *\eta_{purityEC101} * f_{234Ua} / M_{Ua}$;

$n_{235.a} = m_{UEC101} *\eta_{purityEC101} * f_{235Ua} / M_{Ua}$;

$n_{236.a} = m_{UEC101} *\eta_{purityEC101} * f_{236Ua} / M_{Ua}$;

$n_{238.a} = m_{UEC101} *\eta_{purityEC101} * f_{238Ua} / M_{Ua}$;

{Amount of uranium isotopes in NBL CRM-116}

$n_{233.b} = m_{UCRM116} *\eta_{purityCRM116} * f_{233Ub} / M_{Ub}$;

$n_{234.b} = m_{UCRM116} *\eta_{purityCRM116} * f_{234Ub} / M_{Ub}$;

$n_{235.b} = m_{UCRM116} *\eta_{purityCRM116} * f_{235Ub} / M_{Ub}$;

$n_{236.b} = m_{UCRM116} *\eta_{purityCRM116} * f_{236Ub} / M_{Ub}$;

$n_{238.b} = m_{UCRM116} *\eta_{purityCRM116} * f_{238Ub} / M_{Ub}$;

{Isotope amount fraction of uranium in EC NRM 101}

$f_{233Ua} = R_{233U/238Ua}/\Sigma R_{Ua}$;

$f_{234Ua} = R_{234U/238Ua}/\Sigma R_{Ua}$;

$f_{235Ua} = R_{235U/238Ua}/\Sigma R_{Ua}$;

$f_{236Ua} = R_{236U/238Ua}/\Sigma R_{Ua}$;

$f_{238Ua} = 1/\Sigma R_{Ua}$;

$\Sigma R_{Ua} = R_{233U/238Ua} + R_{234U/238Ua} + R_{235U/238Ua} + R_{236U/238Ua} + 1$;

{Molar mass of uranium in EC NRM 101}

$M_{Ua} = M_{233U} \cdot f_{233Ua} + M_{234U} \cdot f_{234Ua} + M_{235U} \cdot f_{235Ua} + M_{236U} \cdot f_{236Ua} + M_{238U} \cdot f_{238Ua}$;

$w_{233Ua} = f_{233Ua} * M_{233U} / M_{Ua}$;

$w_{234Ua} = f_{234Ua} * M_{234U} / M_{Ua}$;

$w_{235Ua} = f_{235Ua} * M_{235U} / M_{Ua}$;

$w_{236Ua} = f_{236Ua} * M_{236U} / M_{Ua}$;

$w_{238Ua} = f_{238Ua} * M_{238U} / M_{Ua}$;

{Isotope amount fraction of uranium n NBL CRM-116}

$f_{233Ub} = R_{233U/235Ub} / \Sigma R_{Ub}$;

$f_{234Ub} = R_{234U/235Ub} / \Sigma R_{Ub}$;

$f_{238Ub} = R_{238U/235Ub} / \Sigma R_{Ub}$;

$f_{236Ub} = R_{236U/235Ub} / \Sigma R_{Ub}$;

$f_{235Ub} = 1 / \Sigma R_{Ub}$;

$\Sigma R_{Ub} = R_{233U/235Ub} + R_{234U/235Ub} + R_{238U/235Ub} + R_{236U/235Ub} + 1$;

{Molar mass of uranium in NBL CRM-116}

$M_{Ub} = M_{233U} \cdot f_{233Ub} + M_{234U} \cdot f_{234Ub} + M_{235U} \cdot f_{235Ub} + M_{236U} \cdot f_{236Ub} + M_{238U} \cdot f_{238Ub}$;

$w_{233Ub} = f_{233Ub} * M_{233U} / M_{Ub}$;

$w_{234Ub} = f_{234Ub} * M_{234U} / M_{Ub}$;

$w_{235Ub} = f_{235Ub} * M_{235U} / M_{Ub}$;

$w_{236Ub} = f_{236Ub} * M_{236U} / M_{Ub}$;

$w_{238Ub} = f_{238Ub} * M_{238U} / M_{Ub}$;

List of Quantities:

Quantity	Unit	Definition
$\gamma_{Umixture}$	g/g	U mass fraction in IRMM-1027p
$\gamma_{235Umixture}$	g/g	^{235}U mass fraction in IRMM-1027p
$\gamma_{238Umixture}$	g/g	^{238}U mass fraction in IRMM-1027p
$c_{Umixture}$	mol/g	U amount content in IRMM-1027p
$c_{235Umixture}$	mol/g	^{235}U amount content in IRMM-1027p
$c_{238Umixture}$	mol/g	^{238}U amount content in IRMM-1027p
M_U	g/mol	Molar mass of U in IRMM-1027p
$R_{233U/238U}$	mol/mol	$^{233}U/^{238}U$ amount ratio in IRMM-1027p
$R_{234U/238U}$	mol/mol	$^{234}U/^{238}U$ amount ratio in IRMM-1027p

Quantity	Unit	Definition
$R_{235U/238U}$	mol/mol	$^{235}U/^{238}U$ amount ratio in IRMM-1027p
$R_{236U/238U}$	mol/mol	$^{236}U/^{238}U$ amount ratio in IRMM-1027p
f_{233U}	mol/mol	^{233}U amount fraction in IRMM-1027p
f_{234U}	mol/mol	^{234}U amount fraction in IRMM-1027p
f_{235U}	mol/mol	^{235}U amount fraction in IRMM-1027p
f_{236U}	mol/mol	^{236}U amount fraction in IRMM-1027p
f_{238U}	mol/mol	^{238}U amount fraction in IRMM-1027p
w_{233U}	g/g	^{233}U mass fraction in IRMM-1027p
w_{234U}	g/g	^{234}U mass fraction in IRMM-1027p
w_{235U}	g/g	^{235}U mass fraction in IRMM-1027p
w_{236U}	g/g	^{236}U mass fraction in IRMM-1027p
w_{238U}	g/g	^{238}U mass fraction in IRMM-1027p
n_{233U}	mol	Amount of U-233 in the mixture
n_{234U}	mol	Amount of U-234 in the mixture
n_{235U}	mol	Amount of U-235 in the mixture
n_{236U}	mol	Amount of U-236 in the mixture
n_{238U}	mol	Amount of U-238 in the mixture
M_{233U}	g/mol	Atomic mass of ^{233}U
M_{234U}	g/mol	Atomic mass of ^{234}U
M_{235U}	g/mol	Atomic mass of ^{235}U
M_{236U}	g/mol	Atomic mass of ^{236}U
M_{238U}	g/mol	Atomic mass of ^{238}U
$m_{solution1027p}$	g	Mass of gravimetric mixture, IRMM-1027p
m_{UEC101}	g	Mass of natural uranium metal, EC-NRM 101
$\eta_{purityEC101}$	g/g	Purity of natural uranium metal, EC NRM 101
$m_{UCRM116}$	g	Mass of enriched uranium metal, NBL CRM-116
$\eta_{purityCRM116}$	g/g	Purity of enriched uranium metal, NBL CRM-116
M_{Ua}	g/mol	Molar mass of U in EC NRM 101
f_{233Ua}		^{233}U amount fraction in EC NRM 101
f_{234Ua}		^{234}U amount fraction in EC NRM 101
f_{235Ua}		^{235}U amount fraction in EC NRM 101
f_{236Ua}		^{236}U amount fraction in EC NRM 101
f_{238Ua}		^{238}U amount fraction in EC NRM 101
M_{Ub}	g/mol	Molar mass of U in NBL CRM-116
f_{233Ub}		^{233}U amount fraction in NBL CRM-116

Quantity	Unit	Definition
f_{234Ub}		^{234}U amount fraction in NBL CRM-116
f_{235Ub}		^{235}U amount fraction in NBL CRM-116
f_{236Ub}		^{236}U amount fraction in NBL CRM-116
f_{238Ub}		^{238}U amount fraction in NBL CRM-116
$n_{233.a}$	mol	^{233} U amount in EC NRM 101
$n_{234.a}$	mol	^{234} U amount in EC NRM 101
$n_{235.a}$	mol	^{235} U amount in EC NRM 101
$n_{236.a}$	mol	^{236} U amount in EC NRM 101
$n_{238.a}$	mol	^{238} U amount in EC NRM 101
$n_{233.b}$	mol	^{233} U amount in NBL CRM-116
$n_{234.b}$	mol	^{234} U amount in NBL CRM-116
$n_{235.b}$	mol	^{235} U amount in NBL CRM-116
$n_{236.b}$	mol	^{236} U amount in NBL CRM-116
$n_{238.b}$	mol	^{238} U amount in NBL CRM-116
$R_{233U/238Ua}$	mol/mol	$^{233}U/^{238}U$ amount ratio in EC NRM 101
$R_{234U/238Ua}$	mol/mol	$^{234}U/^{238}U$ amount ratio in EC NRM 101
$R_{235U/238Ua}$	mol/mol	$^{235}U/^{238}U$ amount ratio in EC NRM 101
$R_{236U/238Ua}$	mol/mol	$^{236}U/^{238}U$ amount ratio in EC NRM 101
$R_{233U/235Ub}$	mol/mol	$^{233}U/^{235}U$ amount ratio in NBL CRM-116
$R_{234U/235Ub}$	mol/mol	$^{234}U/^{235}U$ amount ratio in NBL CRM-116
$R_{238U/235Ub}$	mol/mol	$^{238}U/^{235}U$ amount ratio in NBL CRM-116
$R_{236U/235Ub}$	mol/mol	$^{236}U/^{235}U$ amount ratio in NBL CRM-116
ΣR_U	mol/mol	Sum of amount ratios in gravimteric mixture, IRMM-1027p
ΣR_{Ua}	mol/mol	Sum of amount ratios in EC- NRM 101
ΣR_{Ub}	mol/mol	Sum of amount ratios in NBL CRM-116
m_{235U}	g	mass of ^{235}U in vial No1
m_{vial1}	g	mass of dispensed solution in vial No 1
m_{238U}	g	mass of ^{238}U in vial No 1
w_{233Ua}	g/g	^{233}U mass fraction in EC 101
w_{234Ua}	g/g	^{234}U mass fraction in EC 101
w_{235Ua}	g/g	^{235}U mass fraction in EC 101
w_{236Ua}	g/g	^{236}U mass fraction in EC 101
w_{238Ua}	g/g	^{238}U mass fraction in EC 101
w_{233Ub}	g/g	^{233}U mass fraction in CRM 116
w_{234Ub}	g/g	^{234}U mass fraction in CRM 116

Quantity	Unit	Definition
w_{235Ub}	g/g	^{235}U mass fraction in CRM 116
w_{236Ub}	g/g	^{236}U mass fraction in CRM 116
w_{238Ub}	g/g	^{238}U mass fraction in CRM 116

M_{233U}: Type B normal distribution
Value: 233.0396352 g/mol
Expanded Uncertainty: 0.0000058 g/mol
Coverage Factor: 2

G. Audi et al., The AME2003 atomic mass evaluation, Nuclear Physics A 729, 337-676, 2003

M_{234U}: Type B normal distribution
Value: 234.0409521 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al., The AME2003 atomic mass evaluation, Nuclear Physics A 729, 337-676, 2003

M_{235U}: Type B normal distribution
Value: 235.0439299 g/mol
Expanded Uncertainty: 0.00000040 g/mol
Coverage Factor: 2

G. Audi et al., The AME2003 atomic mass evaluation, Nuclear Physics A 729, 337-676, 2003

M_{236U}: Type B normal distribution
Value: 236.0455680 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al., The AME2003 atomic mass evaluation, Nuclear Physics A 729, 337-676, 2003

M_{238U}: Type B normal distribution
Value: 238.0507882 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al., The AME2003 atomic mass evaluation, Nuclear Physics A 729, 337-676, 2003

$m_{solution1027p}$: Type B normal distribution
Value: 3070.76 g
Expanded Uncertainty: 0.09 g
Coverage Factor: 2

weighing certificate E3789

m_{UEC101}: Type B normal distribution
Value: 53.324 g
Expanded Uncertainty: 0.006 g
Coverage Factor: 2

weighing certificate E3789

$\eta_{purityEC101}$: Type B normal distribution
Value: 0.99985 g/g
Expanded Uncertainty: 0.00005 g/g
Coverage Factor: 2

EC NRM 101 certificate

$m_{UCRM116}$: Type B normal distribution
Value: 11.747 g
Expanded Uncertainty: 0.002 g
Coverage Factor: 2

weighing certificate E3789

$\eta_{purityCRM116}$: Type B normal distribution
Value: 0.999672 g/g
Expanded Uncertainty: 0.000069 g/g
Coverage Factor: 2

NBL CRM-116 certificate

$R_{233U/238Ua}$: Type B normal distribution
Value: 0 mol/mol
Expanded Uncertainty: 0 mol/mol
Coverage Factor: 1

Certificate of isotopic coposition (IRMM, W. De Bolle)

$R_{234U/238Ua}$: Type B normal distribution
Value: 0.00005548 mol/mol
Expanded Uncertainty: 0.00000011 mol/mol
Coverage Factor: 1

Certificate of isotopic coposition (IRMM, W. De Bolle)

$R_{235U/238Ua}$: Type B normal distribution
Value: 0.0072593 mol/mol
Expanded Uncertainty: 0.0000018 mol/mol
Coverage Factor: 1

Certificate of isotopic coposition (IRMM, W. De Bolle)

$R_{236U/238Ua}$: Type B normal distribution
Value: 0.000000151 mol/mol
Expanded Uncertainty: 0.000000020 mol/mol
Coverage Factor: 1

Certificate of isotopic coposition (IRMM, W. De Bolle)

$R_{233U/235Ub}$: Type B normal distribution
Value: 0 mol/mol
Expanded Uncertainty: 0 mol/mol
Coverage Factor: 1

Report of Analysis, IRMM 2013

$R_{234U/235Ub}$: Type B normal distribution
Value: 0.0106853 mol/mol
Expanded Uncertainty: 0.0000011 mol/mol
Coverage Factor: 2

Report of Analysis, IRMM 2013

$R_{238U/235Ub}$: Type B normal distribution
Value: 0.057975 mol/mol
Expanded Uncertainty: 0.000017 mol/mol
Coverage Factor: 2

Report of Analysis, IRMM 2013

$R_{236U/235Ub}$: Type B normal distribution
Value: 0.00448811 mol/mol
Expanded Uncertainty: 0.00000046 mol/mol
Coverage Factor: 1

Report of Analysis, IRMM 2013

m_{vial1}: Type B normal distribution
Value: 2.5351 g
Expanded Uncertainty: 0.0006 g
Coverage Factor: 2

vial No. 1

Interim Results:

Quantity	Value	Standard Uncertainty
n_{234U}	$509.4702 \cdot 10^{-6}$ mol	$57.8 \cdot 10^{-9}$ mol
n_{235U}	0.04813920 mol	$4.31 \cdot 10^{-6}$ mol
n_{236U}	$208.8429 \cdot 10^{-6}$ mol	$29.1 \cdot 10^{-9}$ mol
n_{238U}	0.2250603 mol	$13.7 \cdot 10^{-6}$ mol
M_{Ua}	238.02889787 g/mol	$5.71 \cdot 10^{-6}$ g/mol
f_{234Ua}	$55.077 \cdot 10^{-6}$	$109 \cdot 10^{-9}$
f_{235Ua}	$7.20658 \cdot 10^{-3}$	$1.77 \cdot 10^{-6}$
f_{236Ua}	$149.9 \cdot 10^{-9}$	$19.9 \cdot 10^{-9}$
f_{238Ua}	0.99273819	$1.78 \cdot 10^{-6}$
M_{Ub}	235.2005727 g/mol	$22.6 \cdot 10^{-6}$ g/mol
f_{234Ub}	$9.956964 \cdot 10^{-3}$	$514 \cdot 10^{-9}$
f_{235Ub}	0.93183756	$7.41 \cdot 10^{-6}$
f_{236Ub}	$4.182189 \cdot 10^{-3}$	$428 \cdot 10^{-9}$
f_{238Ub}	0.05402328	$7.49 \cdot 10^{-6}$
$n_{234.a}$	$12.3367 \cdot 10^{-6}$ mol	$24.5 \cdot 10^{-9}$ mol
$n_{235.a}$	$1.614200 \cdot 10^{-3}$ mol	$410 \cdot 10^{-9}$ mol
$n_{236.a}$	$33.58 \cdot 10^{-9}$ mol	$4.45 \cdot 10^{-9}$ mol
$n_{238.a}$	0.2223630 mol	$13.7 \cdot 10^{-6}$ mol
$n_{234.b}$	$497.1335 \cdot 10^{-6}$ mol	$52.4 \cdot 10^{-9}$ mol
$n_{235.b}$	0.04652500 mol	$4.29 \cdot 10^{-6}$ mol
$n_{236.b}$	$208.8093 \cdot 10^{-6}$ mol	$28.7 \cdot 10^{-9}$ mol
$n_{238.b}$	$2.697287 \cdot 10^{-3}$ mol	$448 \cdot 10^{-9}$ mol
ΣR_U	1.2170863 mol/mol	$23.1 \cdot 10^{-6}$ mol/mol
ΣR_{Ua}	1.00731493 mol/mol	$1.80 \cdot 10^{-6}$ mol/mol
ΣR_{Ub}	1.07314841 mol/mol	$8.53 \cdot 10^{-6}$ mol/mol
w_{234Ua}	$54.154 \cdot 10^{-6}$ g/g	$107 \cdot 10^{-9}$ g/g
w_{235Ua}	$7.11621 \cdot 10^{-3}$ g/g	$1.75 \cdot 10^{-6}$ g/g
w_{236Ua}	$148.7 \cdot 10^{-9}$ g/g	$19.7 \cdot 10^{-9}$ g/g
w_{238Ua}	0.99282949 g/g	$1.76 \cdot 10^{-6}$ g/g
w_{234Ub}	$9.907873 \cdot 10^{-3}$ g/g	$511 \cdot 10^{-9}$ g/g
w_{235Ub}	0.93121696 g/g	$7.49 \cdot 10^{-6}$ g/g
w_{236Ub}	$4.197215 \cdot 10^{-3}$ g/g	$430 \cdot 10^{-9}$ g/g
w_{238Ub}	0.05467795 g/g	$7.58 \cdot 10^{-6}$ g/g

Uncertainty Budgets:

$\gamma_{235Umixture}$: ^{235}U mass fraction in IRMM-1027p

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$m_{solution1027p}$	3070.7600 g	0.0450 g	normal	$-1.2 \cdot 10^{-6}$	$-54 \cdot 10^{-9}$ g/g	2.6 %
$m_{UCRM116}$	11.74700 g	$1.00 \cdot 10^{-3}$ g	normal	$300 \cdot 10^{-6}$	$300 \cdot 10^{-9}$ g/g	82.3 %
$\eta_{purityCRM116}$	0.9996720 g/g	$34.5 \cdot 10^{-6}$ g/g	normal	$3.6 \cdot 10^{-3}$	$120 \cdot 10^{-9}$ g/g	13.5 %
$R_{235U/238Ua}$	$7.25930 \cdot 10^{-3}$ mol/mol	$1.80 \cdot 10^{-6}$ mol/mol	normal	0.017	$30 \cdot 10^{-9}$ g/g	0.8 %
$R_{238U/235Ub}$	0.05797500 mol/mol	$8.50 \cdot 10^{-6}$ mol/mol	normal	$-3.4 \cdot 10^{-3}$	$-29 \cdot 10^{-9}$ g/g	0.7 %
$\gamma_{235Umixture}$	$3.684699 \cdot 10^{-3}$ g/g	$334 \cdot 10^{-9}$ g/g				

$\gamma_{238Umixture}$: ^{238}U mass fraction in IRMM-1027p

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$m_{solution1027p}$	3070.7600 g	0.0450 g	normal	$-5.7 \cdot 10^{-6}$	$-260 \cdot 10^{-9}$ g/g	5.5 %
m_{UEC101}	53.32400 g	$3.00 \cdot 10^{-3}$ g	normal	$320 \cdot 10^{-6}$	$970 \cdot 10^{-9}$ g/g	78.8 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0 \cdot 10^{-6}$ g/g	normal	0.017	$430 \cdot 10^{-9}$ g/g	15.6 %
$\gamma_{238Umixture}$	0.01744708 g/g	$1.09 \cdot 10^{-6}$ g/g				

$c_{235Umixture}$: ^{235}U amount content in IRMM-1027p

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$m_{solution1027p}$	3070.7600 g	0.0450 g	normal	$-5.1 \cdot 10^{-9}$	$-230 \cdot 10^{-12}$ mol/g	2.6 %
$m_{UCRM116}$	11.74700 g	$1.00 \cdot 10^{-3}$ g	normal	$1.3 \cdot 10^{-6}$	$1.3 \cdot 10^{-9}$ mol/g	82.3 %
$\eta_{purityCRM116}$	0.9996720 g/g	$34.5 \cdot 10^{-6}$ g/g	normal	$15 \cdot 10^{-6}$	$520 \cdot 10^{-12}$ mol/g	13.5 %
$R_{235U/238Ua}$	$7.25930 \cdot 10^{-3}$ mol/mol	$1.80 \cdot 10^{-6}$ mol/mol	normal	$72 \cdot 10^{-6}$	$130 \cdot 10^{-12}$ mol/g	0.8 %
$R_{238U/235Ub}$	0.05797500 mol/mol	$8.50 \cdot 10^{-6}$ mol/mol	normal	$-14 \cdot 10^{-6}$	$-120 \cdot 10^{-12}$ mol/g	0.7 %
$c_{235Umixture}$	$15.67664 \cdot 10^{-6}$ mol/g	$1.42 \cdot 10^{-9}$ mol/g				

$c_{238Umixture}$: ^{238}U amount content in IRMM-1027p

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$m_{solution1027p}$	3070.7600 g	0.0450 g	normal	$-24 \cdot 10^{-9}$	$-1.1 \cdot 10^{-9}$ mol/g	5.5 %
m_{UEC101}	53.32400 g	$3.00 \cdot 10^{-3}$ g	normal	$1.4 \cdot 10^{-6}$	$4.1 \cdot 10^{-9}$ mol/g	78.8 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0 \cdot 10^{-6}$ g/g	normal	$72 \cdot 10^{-6}$	$1.8 \cdot 10^{-9}$ mol/g	15.6 %
$c_{238Umixture}$	$73.29141 \cdot 10^{-6}$ mol/g	$4.59 \cdot 10^{-9}$ mol/g				

$R_{234U/238U}$: $^{234}U/^{238}U$ amount ratio in IRMM-1027p

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
m_{UEC101}	53.32400 g	$3.00 \cdot 10^{-3}$ g	normal	$-41 \cdot 10^{-6}$	$-120 \cdot 10^{-9}$ mol/mol	18.1 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0 \cdot 10^{-6}$ g/g	normal	$-2.2 \cdot 10^{-3}$	$-55 \cdot 10^{-9}$ mol/mol	3.6 %
$m_{UCRM116}$	11.74700 g	$1.00 \cdot 10^{-3}$ g	normal	$190 \cdot 10^{-6}$	$190 \cdot 10^{-9}$ mol/mol	41.4 %
$\eta_{purityCRM116}$	0.9996720 g/g	$34.5 \cdot 10^{-6}$ g/g	normal	$2.2 \cdot 10^{-3}$	$75 \cdot 10^{-9}$ mol/mol	6.8 %
$R_{234U/238Ua}$	$55.480 \cdot 10^{-6}$ mol/mol	$110 \cdot 10^{-9}$ mol/mol	normal	0.99	$110 \cdot 10^{-9}$ mol/mol	14.3 %
$R_{234U/235Ub}$	0.010685300 mol/mol	$550 \cdot 10^{-9}$ mol/mol	normal	0.20	$110 \cdot 10^{-9}$ mol/mol	15.2 %
$R_{238U/235Ub}$	0.05797500 mol/mol	$8.50 \cdot 10^{-6}$ mol/mol	normal	$-2.5 \cdot 10^{-3}$	$-21 \cdot 10^{-9}$ mol/mol	0.6 %
$R_{234U/238U}$	$2.263705 \cdot 10^{-3}$ mol/mol	$288 \cdot 10^{-9}$ mol/mol				

$R_{235U/238U}$: $^{235}U/^{238}U$ amount ratio in IRMM-1027p

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
m_{UEC101}	53.32400 g	$3.00 \cdot 10^{-3}$ g	normal	$-3.8 \cdot 10^{-3}$	$-11 \cdot 10^{-6}$ mol/mol	25.5 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0 \cdot 10^{-6}$ g/g	normal	-0.20	$-5.1 \cdot 10^{-6}$ mol/mol	5.0 %
$m_{UCRM116}$	11.74700 g	$1.00 \cdot 10^{-3}$ g	normal	0.017	$17 \cdot 10^{-6}$ mol/mol	58.3 %
$\eta_{purityCRM116}$	0.9996720 g/g	$34.5 \cdot 10^{-6}$ g/g	normal	0.20	$7.0 \cdot 10^{-6}$ mol/mol	9.6 %
$R_{235U/238Ua}$	$7.25930 \cdot 10^{-3}$ mol/mol	$1.80 \cdot 10^{-6}$ mol/mol	normal	1.2	$2.1 \cdot 10^{-6}$ mol/mol	0.9 %
$R_{238U/235Ub}$	0.05797500 mol/mol	$8.50 \cdot 10^{-6}$ mol/mol	normal	-0.24	$-2.0 \cdot 10^{-6}$ mol/mol	0.8 %
$R_{235U/238U}$	0.2138946 mol/mol	$22.8 \cdot 10^{-6}$ mol/mol				

$R_{236U/238U}$: $^{236}U/^{238}U$ amount ratio in IRMM-1027p

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
m_{UEC101}	53.32400 g	$3.00 \cdot 10^{-3}$ g	normal	$-17 \cdot 10^{-6}$	$-52 \cdot 10^{-9}$ mol/mol	13.5 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0 \cdot 10^{-6}$ g/g	normal	$-920 \cdot 10^{-6}$	$-23 \cdot 10^{-9}$ mol/mol	2.7 %
$m_{UCRM116}$	11.74700 g	$1.00 \cdot 10^{-3}$ g	normal	$78 \cdot 10^{-6}$	$78 \cdot 10^{-9}$ mol/mol	30.9 %
$\eta_{purityCRM116}$	0.9996720 g/g	$34.5 \cdot 10^{-6}$ g/g	normal	$920 \cdot 10^{-6}$	$32 \cdot 10^{-9}$ mol/mol	5.1 %
$R_{236U/238Ua}$	$151.0 \cdot 10^{-9}$ mol/mol	$20.0 \cdot 10^{-9}$ mol/mol	normal	0.99	$20 \cdot 10^{-9}$ mol/mol	2.0 %
$R_{238U/235Ub}$	0.05797500 mol/mol	$8.50 \cdot 10^{-6}$ mol/mol	normal	$-1.1 \cdot 10^{-3}$	$-9.0 \cdot 10^{-9}$ mol/mol	0.4 %
$R_{236U/235Ub}$	$4.488110 \cdot 10^{-3}$ mol/mol	$460 \cdot 10^{-9}$ mol/mol	normal	0.21	$95 \cdot 10^{-9}$ mol/mol	45.5 %
$R_{236U/238U}$	$927.942 \cdot 10^{-6}$ mol/mol	$140 \cdot 10^{-9}$ mol/mol				

m_{235U}: mass of ^{235}U in vial No1

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$m_{solution1027p}$	3070.7600 g	0.0450 g	normal	$-3.0 \cdot 10^{-6}$	$-140 \cdot 10^{-9}$ g	1.0 %
$m_{UCRM116}$	11.74700 g	$1.00 \cdot 10^{-3}$ g	normal	$770 \cdot 10^{-6}$	$770 \cdot 10^{-9}$ g	30.4 %
$\eta_{purityCRM116}$	0.9996720 g/g	$34.5 \cdot 10^{-6}$ g/g	normal	$9.0 \cdot 10^{-3}$	$310 \cdot 10^{-9}$ g	5.0 %
$R_{235U/238Ua}$	$7.25930 \cdot 10^{-3}$ mol/mol	$1.80 \cdot 10^{-6}$ mol/mol	normal	0.043	$77 \cdot 10^{-9}$ g	0.3 %
$R_{238U/235Ub}$	0.05797500 mol/mol	$8.50 \cdot 10^{-6}$ mol/mol	normal	$-8.5 \cdot 10^{-3}$	$-72 \cdot 10^{-9}$ g	0.3 %
m_{vial1}	2.535100 g	$300 \cdot 10^{-6}$ g	normal	$3.7 \cdot 10^{-3}$	$1.1 \cdot 10^{-6}$ g	63.0 %
m_{235U}	$9.34108 \cdot 10^{-3}$ g	$1.39 \cdot 10^{-6}$ g				

m_{238U}: mass of ^{238}U in vial No 1

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$m_{solution1027p}$	3070.7600 g	0.0450 g	normal	$-14 \cdot 10^{-6}$	$-650 \cdot 10^{-9}$ g	1.2 %
m_{UEC101}	53.32400 g	$3.00 \cdot 10^{-3}$ g	normal	$820 \cdot 10^{-6}$	$2.5 \cdot 10^{-6}$ g	17.2 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0 \cdot 10^{-6}$ g/g	normal	0.044	$1.1 \cdot 10^{-6}$ g	3.4 %
m_{vial1}	2.535100 g	$300 \cdot 10^{-6}$ g	normal	0.017	$5.2 \cdot 10^{-6}$ g	78.1 %
m_{238U}	0.04423009 g	$5.92 \cdot 10^{-6}$ g				

Results:

Quantity	Value	Expanded Uncertainty	Coverage factor	Coverage
$\gamma_{Umixture}$	0.0211867 g/g	$2.3 \cdot 10^{-6}$ g/g	2.00	manual
$\gamma_{235Umixture}$	$3.68470 \cdot 10^{-3}$ g/g	$670 \cdot 10^{-9}$ g/g	2.00	manual
$\gamma_{238Umixture}$	0.0174471 g/g	$2.2 \cdot 10^{-6}$ g/g	2.00	manual
$c_{Umixture}$	$89.2020 \cdot 10^{-6}$ mol/g	$9.8 \cdot 10^{-9}$ mol/g	2.00	manual
$c_{235Umixture}$	$15.6766 \cdot 10^{-6}$ mol/g	$2.8 \cdot 10^{-9}$ mol/g	2.00	manual
$c_{238Umixture}$	$73.2914 \cdot 10^{-6}$ mol/g	$9.2 \cdot 10^{-9}$ mol/g	2.00	manual
M_U	237.513366 g/mol	$94 \cdot 10^{-6}$ g/mol	2.00	manual
$R_{233U/238U}$	0.0 mol/mol	0.0 mol/mol	2.00	manual
$R_{234U/238U}$	$2.26371 \cdot 10^{-3}$ mol/mol	$580 \cdot 10^{-9}$ mol/mol	2.00	manual
$R_{235U/238U}$	0.213895 mol/mol	$46 \cdot 10^{-6}$ mol/mol	2.00	manual
$R_{236U/238U}$	$927.94 \cdot 10^{-6}$ mol/mol	$280 \cdot 10^{-9}$ mol/mol	2.00	manual
f_{233U}	0.0 mol/mol	0.0 mol/mol	2.00	manual
f_{234U}	$1.85994 \cdot 10^{-3}$ mol/mol	$420 \cdot 10^{-9}$ mol/mol	2.00	manual
f_{235U}	0.175743 mol/mol	$31 \cdot 10^{-6}$ mol/mol	2.00	manual
f_{236U}	$762.43 \cdot 10^{-6}$ mol/mol	$210 \cdot 10^{-9}$ mol/mol	2.00	manual
f_{238U}	0.821634 mol/mol	$31 \cdot 10^{-6}$ mol/mol	2.00	manual
w_{233U}	0.0 g/g	0.0 g/g	2.00	manual
w_{234U}	$1.83275 \cdot 10^{-3}$ g/g	$410 \cdot 10^{-9}$ g/g	2.00	manual
w_{235U}	0.173916 g/g	$30 \cdot 10^{-6}$ g/g	2.00	manual
w_{236U}	$757.72 \cdot 10^{-6}$ g/g	$210 \cdot 10^{-9}$ g/g	2.00	manual
w_{238U}	0.823494 g/g	$31 \cdot 10^{-6}$ g/g	2.00	manual
m_{235U}	$9.3411 \cdot 10^{-3}$ g	0.030 % (relative)	2.00	manual
m_{238U}	0.044230 g	0.027 % (relative)	2.00	manual

European Commission
EUR 26520 EN – Joint Research Centre – Institute for Reference Materials and Measurements

Title: **Preparation and Certification of Large-Sized Dried (LSD) Spike - IRMM-1027p**

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Luxembourg: Publications Office of the European Union

2014 – 105 pp. – 21.0 x 29.7 cm

EUR – Scientific and Technical Research series – ISSN 1831-9424

ISBN 978-92-79-35502-8

doi:10.2787/89614

Abstract

IRMM Large-Sized Dried (LSD) Spikes are widely used as a fundamental part of the fissile material control of irradiated nuclear fuel and have been provided on a regular basis to safeguards authorities and industry for more than 10 years. This report describes the preparation and certification of a new batch of LSD Spikes. IRMM-1027p is a dried nitrate material in cellulose acetate butyrate (CAB), certified for the mass of uranium and plutonium and isotope amount ratios per unit. The material was produced following ISO Guide 34:2009.
The certified reference materials uranium metal EC NRM 101, enriched uranium metal NBL CRM-116 and plutonium metal CETAMA MP2 were used as starting materials to prepare the mother solution. This solution was dispensed by means of an automated robot system into individual units and dried down. A solution of an organic substance, cellulose acetate butyrate (CAB), was dried on the spike material as a stabiliser to retain the dried material at the bottom of the vial.
Between unit-homogeneity was quantified and stability during dispatch and storage were assessed in accordance with ISO Guide 35:2006.
The certified values were obtained from the gravimetric preparation of the mother solution, taking into account the mass, purity and isotopic abundances of the starting materials, the mass of the mother solution, and the mass of an aliquot in each individual unit. The certified values were confirmed by isotope dilution thermal ionisation mass spectrometry (ID-TIMS) and thermal ionisation mass spectrometry (TIMS) as independent confirmation methods.
Uncertainties of the certified values were estimated in compliance with the Guide to the Expression of Uncertainty in Measurement (GUM) and include uncertainties related to possible inhomogeneity and to characterisation.
This spike CRM is applied as a calibrant to measure the uranium and plutonium amount content of dissolved spent nuclear fuel solutions using isotope dilution mass spectrometry (IDMS). Each unit contains about 50 mg of uranium with a relative mass fraction m(235U)/m(U) of 17.4 % and 1.8 mg of plutonium with a relative mass fraction m(239Pu)/m(Pu) of 97.8 % as dried nitrates in CAB. The whole amount of sample per unit has to be used for analysis.

LA-NA-26520-EN-N

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ISBN 978-92-79-35502-8