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CERTIFICATION REPORT

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

Certified reference material for the masses of ^{239}Pu, ^{235}U, ^{238}U and Pu and U isotope amount ratios

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Abstract

Large-Sized Dried (LSD) spikes are 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 15 years. This report describes the preparation and certification of a new batch of LSD spikes. IRMM-1027u is a dried nitrate material in cellulose acetate butyrate with dioctyl phtalate (CAB/DOP) or carboxymethyl cellulose (CMC), certified for the mass of uranium and plutonium and the uranium and plutonium isotope amount ratios per unit. The material was produced in compliance with ISO/IEC 17034:2016 [1] and certified in accordance with ISO Guide 35:2017 [2].

The certified reference materials uranium metal EC NRM 101, enriched uranium metal NBL PO CRM 116-A and plutonium metal CETAMA MP2 were used as starting materials to prepare the mother solution. This solution was dispensed into individual vials by means of an automated robot system and it was dried. A solution of an organic substance either cellulose acetate butyrate with dioctyl phtalate (CAB/DOP) or carboxymethyl cellulose (CMC) was added to the spike material and then the solution was evaporated. The organic matrix serves as a stabiliser to retain the dried nuclear material at the bottom of the vial. In total, 1003 units were produced.

Between-unit homogeneity was quantified and stability during dispatch and storage were assessed in accordance with ISO Guide 35:2017 [2].

The certified values were obtained from the gravimetric preparation of the mother solution, taking into account the mass, purity and isotopic composition 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 mass spectrometry (IDMS) and thermal ionisation mass spectrometry (TIMS) as independent methods on randomly selected units of IRMM-1027u.

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.

The main purpose of this material is for use as a spike isotopic reference material to measure the plutonium and uranium amount content of spent nuclear fuel solutions using IDMS. Each unit contains about 55 mg of uranium with a relative mass fraction $m(^{235}U)/m(U)$ of 18.9 % and 1.8 mg of plutonium with a relative mass fraction $m(^{239}Pu)/m(Pu)$ of 97.8 % as dried nitrates in CAB/DOP or CMC.

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]
$n(^{234}U)/n(^{238}U)$	0.0027174	0.0000022
$n(^{235}U)/n(^{238}U)$	0.237043	0.000031
$n(^{236}U)/n(^{238}U)$	0.0021802	0.0000018
$n(^{240}Pu)/n(^{239}Pu)$	0.0224120	0.0000051
$n(^{241}Pu)/n(^{239}Pu)$	0.0001342	0.0000018
$n(^{242}Pu)/n(^{239}Pu)$	0.00007572	0.00000078

The certified masses and the uncertainties of ^{235}U, ^{238}U and ^{239}Pu per unit are listed in Annex 1 for each individual unit.

1) The certified values are traceable to the values on the respective metal certificates (Annexes 2 - 7). The reference date for the certified values is November 1, 2018.

2) The 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 atomic masses of radionuclides were obtained from M. Wang et al. [4]

The half-lives of radionuclides were obtained from DDEP-BIPM (Table of radionuclides) [5] and R. Wellum et al. [6].

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 the measurement results of analytical techniques applied to industrial nuclear and fissile materials, 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 [7]. 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 the Joint Research Centre of the European Commission (EC-JRC) to meet the existing requirements for reliable isotope reference materials for the accountancy measurements of uranium and plutonium by isotope dilution mass spectrometry (IDMS) in compliance with the ITVs-2010 in spent nuclear fuel. These spikes contain relatively large amounts of uranium and plutonium (about 55 mg U and 2 mg Pu), isotopically different from the uranium and plutonium in the test sample and are in dried nitrate form. Approximately 1000 units of IRMM-1027 LSD spikes are prepared annually to fulfil the demands for fissile material control from European Safeguards Authorities and industry [8, 9].

1.2 Choice of the material

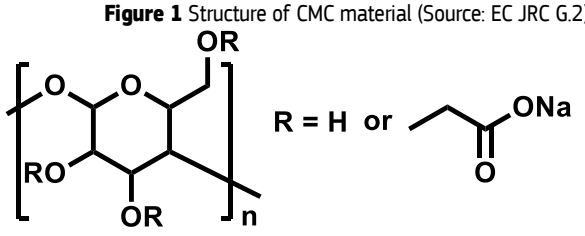
The IRMM-1027u batch of LSD spikes was prepared from natural uranium (EC NRM 101), enriched uranium (NBL PO CRM 116-A) and plutonium (CETAMA MP2) certified reference metals. Each unit of IRMM-1027u contains about 55 mg of uranium with a relative mass fraction $m(^{235}U)/m(U)$ of 18.9 % and 1.8 mg of 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 plutonium and uranium 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 nuclear fuel is needed prior to measurement. As the dried nitrates could flake off the vial surface over time or during transport, an organic polymer is added to retain the material at the bottom of the penicillin vial.

From the batch IRMM-1027f [10] to the batch IRMM-1027s [11], the cellulose acetate butyrate (CAB) has been used as a stabilising material for the IRMM-1027 LSD spikes for transport, thus for short-term stability purposes. The CAB produces a stable layer at the bottom of the vial and guarantees the integrity of the LSD spikes for about 3 years [12]. Customers, however, require a longer shelf-life of IRMM-1027 LSD spikes, hence JRC-Geel and JRC-Karlsruhe joined their forces to investigate new coatings in the framework of the Innovative Nuclear Reference Materials for EURATOM Safeguards and Industry (INS-CRM) exploratory research project. The main objective of the project was to find potential materials that would prolong the shelf-life of LSD spikes from 3 to 5 years or even beyond. The new coatings also should fulfil additional requirements such as ready dissolution in nitric acid and a lack of interference with chemical separations or mass spectrometry measurements. Among the tested materials, the carboxymethyl cellulose (CMC) has shown very promising results [13, 14], hence it was already applied for the batch IRMM-1027t [15].

CMC similarly to CAB, is built up from a repeating anhydroglucose unit but this cellulose derivative is functionalised with carboxymethyl groups (Figure 1), which are converted into a sodium salt. This difference makes the CMC insoluble in most organic solvents. CMC is prepared in nitric acid solution. Upon drying it forms a stable foam (Figure 5b) in which the actinides are embedded. The existing CAB protocol has been further optimised by adding 20 wt % dioctyl phthalate (DOP) relative to the mass of CAB, which acts as a plasticizer thus makes the brittle CAB layer more flexible and longer lasting. This was already applied on the LSD spikes of the IRMM-1027t batch. As a result of the successful outcome of the exploratory research project and the real application on the IRMM-1027t LSD spikes, the same approach was applied when preparing the IRMM-1027u spikes thus they were coated with either CMC or CAB/DOP material.

Figure 1 Structure of CMC material (Source: EC JRC G.2)



1.3 Design of the project

The individual units of IRMM-1027u LSD spikes were prepared by dispensing aliquots (about 2.5 g) of the mother solution into penicillin vials and dried down. The mother solution was prepared gravimetrically by dissolving uranium and plutonium certified reference metals in hydrochloric and nitric acid. Finally, the dried nitrates were treated with CAB/DOP or CMC for preservation during storage and transport.

The certified masses of plutonium and uranium and the certified values of the uranium and plutonium isotope amount ratios are based on the data from the weighing certificates and the certificates of the starting materials (metals). Confirmation measurements and homogeneity assessment were established by IDMS on randomly selected vials. For this project, the homogeneity and the confirmation measurements were performed on the same set of units.

2. Participants

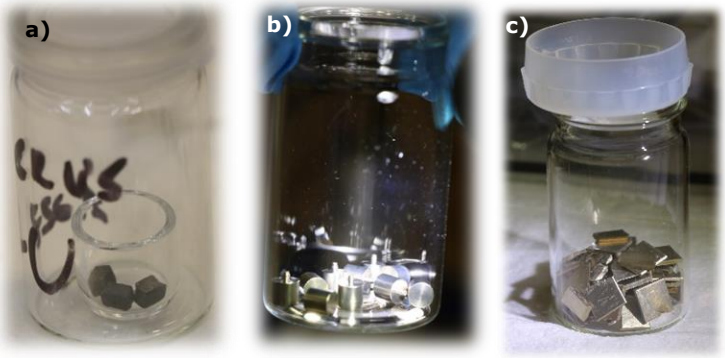
Project management and evaluation, processing, homogeneity study, stability study and characterisation have been performed at the European Commission, Joint Research Centre, Directorate G – Nuclear Safety and Security, G.2 - Standards for Nuclear Safety, Security and Safeguards in Geel, Belgium.

3. Material processing and process control

3.1 Origin and purity of the starting material

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

Figure 2 Starting materials for the preparation of IRMM-1027u LSD spikes: a) Pu MP2 metal b) U NBL PO CRM 116-A metal and c) U EC NRM 101 metal (Source: EC JRC G.2)



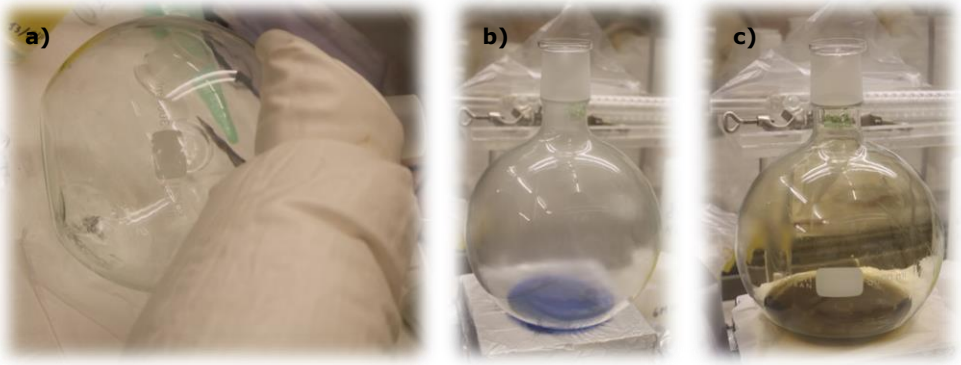
3.2 Processing

Dissolution of the Pu metal

An optimised protocol for the dissolution of Pu MP2 metal was used in one of the previous batch of LSD spikes, IRMM-1027s. The protocol applies an electro-polishing of the Pu metal before the weighing and dissolution of the metal [11]. It has to be mentioned, that this protocol does not comply with MP2 certificate and associated recommendation for use (see Annex 5). As a result, the mass of the sample and Pu content uncertainty values can be altered.

For the 1027u batch, after electro-polishing the selected 3 units of the MP2 metal, the metals were rinsed with deionised water and acetone (*p.a.*, Merck, Darmstadt, Germany) and dried. Then the units were precisely weighed in a dedicated glove-box and after they were transferred to another glove box for dissolution. They were dissolved in about 20 mL hydrochloric acid (c = 6 mol L^{-1}, suprapure, Merck). The reaction was vigorous and fast and no visible remaining Pu metal was left. Then, nitric acid solution (c = 8 mol L^{-1}, *p.a.*, Merck, Darmstadt, Germany) was added to the dissolved Pu solution. No heating or addition of hydrofluoric acid was needed. The flask with the plutonium solution was closed with a stopper and kept in a dedicated glove box to prevent any potential contamination. The dissolution of Pu MP2 metal is shown in Figure 3.

Figure 3 Dissolution of Pu metal: right after adding the units to the a) hydrochloric acid, b) after dissolution in hydrochloric acid, c) after adding nitric acid (Source: EC JRC G.2)

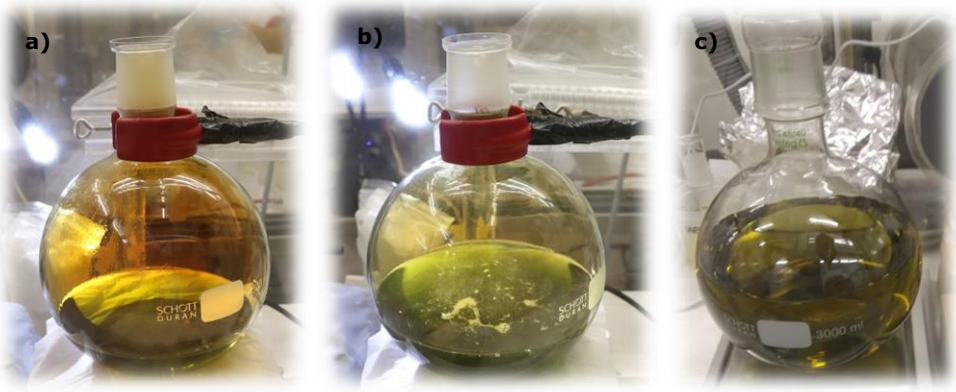


Dissolution of the U metals

The respective units of enriched uranium metal (NBL PO CRM 116-A) and of natural uranium metal (EC NRM 101) were weighed (by substitution method) and added into the prepared plutonium solution. Prior to weighing, the units of NBL PO CRM 116-A metal were etched with nitric acid (c = 8 mol L^{-1}) to remove surface oxidation products as described in the certificate, and subsequently rinsed with deionised water and acetone (*p.a.*, Merck, Darmstadt, Germany) and dried. The units of the EC NRM 101 uranium metal were weighed as provided without any cleaning, as the material was stored in an inert atmosphere (see Figure 2c). The final amounts of concentrated nitric acid and deionised water were added to adjust the concentration of the nitric acid solution (c = 6 mol L^{-1}). The solution was left to homogenise for a few days with occasional swirling by hand, and weighed to determine the final mass of the mother solution, taking into account the necessary corrections for air buoyancy effects. The dissolution of the uranium metals is shown in Figure 4.

Prior to dispensing the mother solution into individual penicillin vials 4 aliquots were analysed by isotope dilution (ID) technique on a TRITON TIMS (Thermo-Fisher, Bremen, Germany) to verify the gravimetrically determined amount contents of plutonium and uranium. Additionally, four aliquots were analysed by thermal ionisation mass spectrometry (TIMS) to verify the uranium and plutonium isotope amount ratios (see Section 3.3 Process Control).

Figure 4 Dissolution of U metals: a) addition of the NBL PO CRM 116-A enriched U metal into the Pu solution, b) addition of the EC NRM 101 natural U metals into the Pu solution c) the mother solution of IRMM-1027u (Source: EC JRC G.2)



Dispensing, drying and application of CAB/DOP and CMC

Dispensing and weighing of the mother solution into individual penicillin vials were performed by a validated automated system, which was installed at the JRC Geel in collaboration with Nucomat (Lokeren, Belgium) [16]. 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 penicillin 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 2.7 kg) was dispensed into 1003 vials over five consecutive working days. In total, up to

vial #1008 can be found in the certificate of dispensing (Annex 12) however three units are excluded from the certification process based on barcode failure and two units because of splashing during dispensing or before drying. Fourteen units have been put aside for experimental purposes and no coating is applied on them.

The drying of the dispensed solution contained in the vials was carried out on a hot plate. The temperature of the solution was kept at maximum 55 °C for several days (typically 4-5 days continuous heating) to evaporate the solution completely.

For the IRMM-1027u LSD spikes, two organic matrices were used: a) 557 units were prepared with CAB containing a plasticizer dioctyl phthalate (DOP) and b) 432 units prepared with CMC. The number of units prepared with the two different coating corresponds to the customers' needs. Fourteen units were not covered and put aside for experimental purposes and five units were excluded from the certification as explained above.

a) CAB/DOP protocol

After the solution in the vials had dried, about 0.7 mL of CAB/DOP solution in acetone was added. CAB/DOP solution was prepared by dissolving 10 g CAB (35-39 g/100 g butyryl content, Acros, New Jersey, USA) and 2 g DOP (Sigma-Aldrich, Merck, Darmstadt, Germany) was made up to 100 g with the addition of acetone. The CAB/DOP solution in the vials was evaporated at room temperature and then heated to about 45 °C to dry completely. Three dedicated glove boxes were used for drying and CAB/DOP application, allowing the preparation of up to 48 units per day in one glove box. The vials were closed with stoppers and aluminium caps, sealed in PVC packages and labelled.

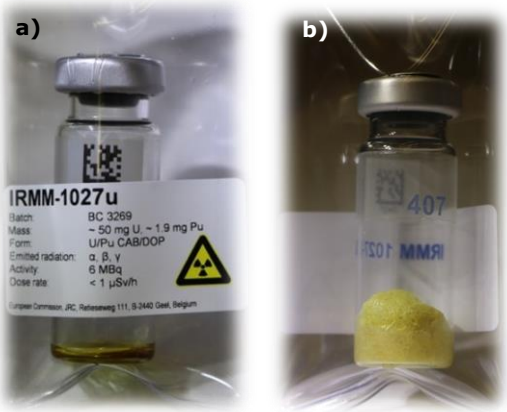
b) CMC protocol

Ten grams of low viscosity carboxymethyl cellulose (CMC) sodium salt (Merck, Darmstadt, Germany) was slowly added into 90 g of nitric acid solution (c = 2 mol L^{-1}, p.a., Merck, Darmstadt, Germany) at 60-70 °C under continuous stirring. The mixture was stirred and heated until the dissolution of CMC was complete (usually 2-3 hours) and then allowed to cool to room temperature. A colourless to slightly yellow, transparent solution was obtained. 1.5 mL of this solution was added to the dried nitrates and heated up to about 52-54 °C. The solution in the vials were kept at this temperature to evaporate the nitric acid solution. Once all the nitric acid had evaporated and the foams were produced, the spikes were removed from the hotplate, cooled and closed with butyl rubber caps. This protocol allows the preparation of up to 24 units per day in one glove box.

CAB/DOP and CMC were added to retain the dried material at the bottom of the penicillin vials in order to resist physical shocks that might be encountered during transport and to avoid flaking of the material during long-term storage. Both cellulose matrixes dissolve readily in warm nitric acid and have no effect on the subsequent IDMS analysis.

One example each of IRMM-1027u LSD spike prepared with CAB/DOP and CMC spikes are shown in Figure 5.

Figure 5 Units of IRMM-1027u LSD spike: a) treated with CAB/DOP and b) treated with CMC (Source: EC JRC G.2)



3.3 Process control

This section describes the measurements performed on the mother solution of IRMM-1027u prior to dispensing into vials to verify the amount contents of uranium and plutonium in the solution from gravimetric preparation. Detailed calculations of the uranium and plutonium amount contents, mass fractions, isotopic compositions and their associated uncertainties from the gravimetric preparation of IRMM-1027u are shown in Annex 14 and Annex 15.

Four aliquots of the mother solution (about 1 g each) were individually spiked with a mixed $^{233}U/^{242}Pu$ spike CRM (*ca.* 2 g IRMM-046c) for ID-TIMS analysis. The certificate of IRMM-046c can be found in Annex 8. Four un-spiked aliquots (about 1 g each) of the IRMM-1027u mother solution were analysed to verify the uranium and plutonium isotope amount ratios by thermal ionisation mass spectrometry (TIMS).

The U-Pu separation of the spiked and un-spiked samples was performed using anion-exchange columns (Bio-Rad AG1-X4, 100-200 mesh, Bio-Rad, Hercules, USA) as described in detail in [17].

The results of the process control measurements for ^{235}U, ^{238}U, and ^{239}Pu amount contents as well as the uranium and plutonium isotope amount ratios in the mother solution of IRMM-1027u were compatible with the values from the gravimetric preparation, except the four aliquots for the $n(^{238}Pu)/n(^{239}Pu)$ amount ratio. A deviating value for the $n(^{238}Pu)/n(^{239}Pu)$ ratio was measured by TIMS compared to the value from the gravimetric preparation of the mother solution. This is due to an isobaric interference with ^{238}U coming from the incomplete removal of uranium in the plutonium fraction. This isotope amount ratio will not be certified and will be given in the certificate as additional material information. A positive bias can be observed in the measurements of the ^{235}U which was also noted in previous batches [15], however no reason was found to explain the bias. The CRM 116-A material is used in the laboratory as quality control material for uranium IDMS (shorthand notation: ID-QC). The stock solution was prepared and verified independently from the IRMM-1027u mother solution. An aliquot of the CRM 116-A ID-QC material solution was spiked with the IRMM-046c ($^{242}Pu/^{233}U$) spike CRM, and measured together with the respective units of the IRMM-1027u LSD spikes. One ID-QC was measured on each sample turret and the result was within the control limit (< 0.1 %). The results of the confirmation measurements for the mother solution of IRMM-1027u are shown in Annex 9 and Annex 10 as relative differences from the gravimetric value. The error bars for the isotope amount ratios are respectively the differences in expanded uncertainties (k=2) derived from three replicate measurements.

The processing steps are shown in Figure 6.

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/IEC 17034:2016 [1] requires reference material (RM) producers to quantify the between unit variation. This aspect is covered in between-unit homogeneity studies.

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. In case of the IRMM-1027 LSD CRM series, the whole amount of sample per unit is used for analysis. Thus, there is no contribution to the combined uncertainty from the within-unit homogeneity.

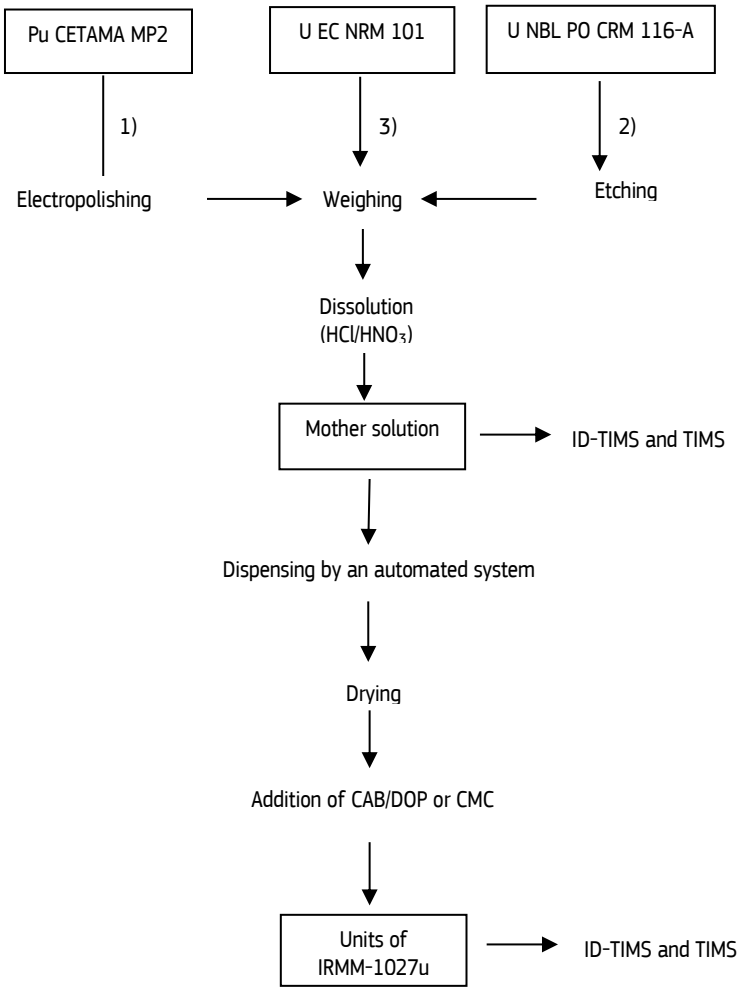
4.1 Between-unit homogeneity

The between-unit homogeneity was evaluated to ensure that the certified values of the CRM are valid for all 1003 units of the material, within the stated uncertainty.

As it was already shown during the certification of the IRMM-1027t [15], there is no difference between the CAB/DOP covered and CMC covered spikes concerning the certified isotope amount contents. In the course of the certification of IRMM-1027u, twelve units were selected to assess the homogeneity for the amount content of ^{235}U, ^{238}U and ^{239}Pu using a random stratified sampling scheme covering the whole batch for the between-unit homogeneity test. The unit numbers are as follows: CAB/DOP: 2, 214, 270, 429, 536, 715, 798, and 946; CMC: 149, 341, 637, and 862. The batch was divided into twelve groups (with a similar number of units) and one unit was selected randomly from each group. The number of selected units for the between-unit homogeneity study should correspond to approximately the cubic root of the total number of the produced units (1003).

In this project, the homogeneity study and the confirmation measurements were performed on the same set of units (see Section 6).

Figure 6 Preparation of IRMM-1027u LSD spikes (Source: EC JRC G.2)



The whole amount of sample per unit (equals minimum sample intake) was taken for analysis. Selected units of IRMM-1027u were spiked with a mixed $^{233}U/^{242}Pu$ spike CRM (IRMM-046c) and after the dissolution of the solid spike and complete mixing with the IRMM-046c material the solution in the vials evaporated to dryness. The U-Pu separation was carried out prior to isotope ratio measurements on each unit in the same way as for the process control measurements (see Section 3.3).

Each sample was measured in three replicates thus three aliquots were taken from the same unit, loaded on three different filaments and measured on the same turret together with isotopic standards (IRMM-074/10 for U and IRMM-290/A3 for Pu) to correct for instrumental mass fractionation. The selected units were measured together with the in-house Isotope Dilution (U/Pu) Quality Control sample (gravimetric mixture of CRM 116-A and NBL-126). This enabled four independent samples plus QC to be measured on the same TIMS turret on the same day. There were three turrets prepared for uranium and three turrets for plutonium IDMS. Therefore, the measurements for all twelve units of IRMM-1027u were performed under intermediate precision conditions rather than repeatability conditions within short intervals of time.

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. The results of the homogeneity study are shown in 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 at a confidence level of 95 %. The data were tested for consistency using the Grubbs outlier test at a confidence level of 95 % on the individual results and on the unit means. In the case of ^{239}Pu amount content, one outlier was detected among the individual results however no technical reason was found to exclude the data thus it was kept and included in the evaluation of homogeneity.

Quantification of between-unit inhomogeneity was accomplished by analysis of variance (ANOVA), which can separate the between-unit standard deviation (s_{bb}) from the within-unit standard deviation (s_{wb}). The latter is equivalent to the method intermediate precision 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 (homoscedasticity). 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.

Table 1 Results of the statistical evaluation of the homogeneity studies of the amount content of ^{235}U, ^{238}U and ^{239}Pu in IRMM-1027u (Source: EC JRC G.2)

	Trends [1)]		Outliers [1)]		Distribution	
	Analytical sequence	Filling sequence	Individual results	Unit means	Individual results	Unit means
^{235}U amount content	no	No	none	none	unimodal	unimodal
^{238}U amount content	no	No	none	none	unimodal	unimodal
^{239}Pu amount content	no	No	yes	none	unimodal	unimodal

[1)] at 95 % confidence level

One has to bear in mind that $s_{bb,rel}$ (between-unit relative standard deviation) and $s_{wb,rel}$ (within-unit relative standard deviation) are estimates of the true standard deviations and consequently, subject to random fluctuations. Therefore, the mean square between units ($MS_{between}$) 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. [18]. 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 (alpha risk).

Relative within-unit standard deviation corresponds here to method intermediate precision ($s_{wb,rel}$), relative between–unit standard deviation ($s_{bb,rel}$) and relative maximum inhomogeneity ($u^*_{bb,rel}$) were calculated as:

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

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

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

MS_{within} mean square within-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 as described earlier in this section. 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 amount content of ^{235}U and ^{238}U. For that reason, the data for the amount content of both U isotopes were first normalised by the respective day mean and the resulting data evaluated using one way-ANOVA. The results of the evaluation of the between-unit variation are summarised in Table 2.

Table 2 Results of the homogeneity studies of the amount content in IRMM-1027u (Source: EC JRC G.2)

	$s_{wb,rel}$ [%]	$s_{bb,rel}$ [%]	$u^*_{bb,rel}$ [%]
^{235}U amount content	0.010	0.0094	0.0033
^{238}U amount content	0.023	0.018	0.0074
^{239}Pu amount content	0.016	0.0095	0.0050

The homogeneity study showed no outlying unit means and no trends in the filling sequence at a 95 % confidence level. 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} or u^*_{bb} is adopted as uncertainty contribution to account for potential inhomogeneity. In case of the IRMM-1027u, for all isotope amount contents the s_{bb} could be used to assess the contribution from the homogeneity study.

4.2 Homogeneity of the U and Pu isotope ratios

The homogeneity assessment of the uranium and plutonium isotope amount ratios was deemed unnecessary. The IRMM-1027u LSD spikes were prepared by dissolution of the plutonium and uranium metals, dispensing of the solution into individual units and drying. Any differences in the isotope amount ratios could only stem from a contamination with plutonium and uranium of a different isotopic composition, from the isotope fractionation during the evaporation of the nitrate solution in the vial and from an incomplete mixing of the uranium metals. Dedicated glove boxes were used for the preparation of the spikes with no other sources of uranium and plutonium, so the contamination can be excluded. The drying temperature was less than 60 °C, where the fractionation effects are negligible. Moreover, the results of the process control measurements (see Section 3.3) for the uranium and plutonium isotope amount ratios agreed with the values from the gravimetric preparation, confirming the isotope mixing of the metals. For these reasons, no heterogeneity of the plutonium and uranium isotope amount ratios is to be expected in the vials of IRMM-1027u.

4.3 Within-unit homogeneity and minimum sample intake

The within-unit homogeneity is closely related to the minimum sample intake. The minimum sample intake is the minimum amount of sample that is representative for the whole unit and thus should be used in an analysis. Using sample sizes equal to or above the minimum sample intake guarantee the certified value within its stated uncertainty.

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-1027u 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-1027u is a mixed U/Pu reference material, consisting of U and Pu radionuclides. It should be noted that the term 'stability' in this context does not refer to radioactive decay. Radionuclides are naturally decaying according to their half-lives, a process which is quantitatively predictable using the decay data [5, 6].

5.1 Short-term stability

In the scope of the preparation and certification of the previous batch IRMM-1027t, a thorough short-term stability study of the CAB with dioctyl phthalate plasticizer (DOP) and with CMC was carried out [15].

The test samples contained CAB/DOP and CMC material without any plutonium and uranyl nitrates. They were stored at 4 °C and 60 °C for one week at each temperature. The reference temperature was set to 18 °C. Six units for each temperature were prepared (36 units in total). Only visual inspection of the selected units was made before and after the test to assess any detachment of the coating/foam.

No flaking - in case of CAB with DOP – and/or fluid material – in case of CMC – could be observed before and after the test. The CAB with DOP coating did not change at all at any of the three temperature points. In case of the CMC foam, an ongoing reaction accelerated by the temperature (at 60°C) could be observed. As the foam still contains unreacted HNO_3 or nitrous gases – being the origin of the brownish colour of the fresh foams – the foam has even further matured and discoloration

can be noticed. However, this colour change of the foam does not affect the integrity or the stability of the material as has been proved during the INS-CRM project [19].

IRMM-1027u LSD spikes are packed and shipped to customers following the legal requirements related to radioprotection measures for transport of radioactive materials [20]. IRMM-1027u LSD spikes are considered stable regarding its isotopic composition and the amount content during dispatch and can be shipped to customers under normal temperature conditions. No additional uncertainty component ($u_{sts,\,rel}$ = 0) was applied.

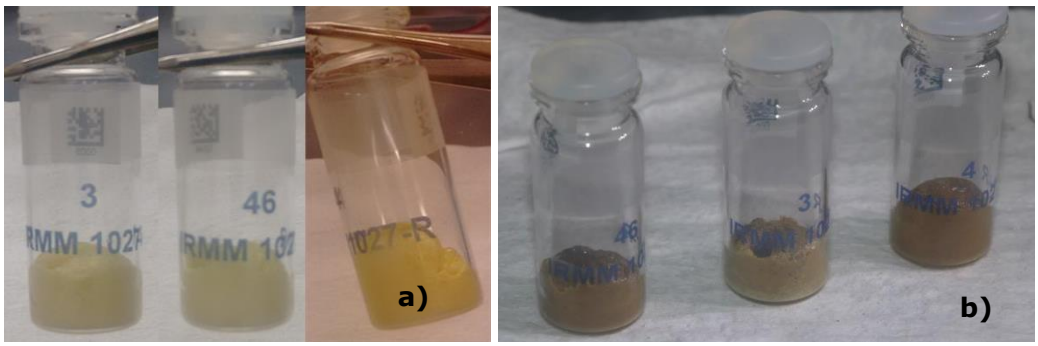
5.2 Long-term stability

The long-term stability of IRMM-1027 LSD spikes prepared with CAB has been demonstrated via the results of the stability monitoring of previous batches of LSD spikes for the period of three years [21] and the verification results of IRMM-1027m over a period of four years after the certification in the context of the inter-calibration of JRC-IRMM spike CRMs [22, 23, 24]. Furthermore, the JRC-Geel (Belgium), the JRC-Karlsruhe (Germany) and the IAEA at Seibersdorf (Austria) are engaged in mutual verification measurements of mixed uranium-plutonium spike reference materials via EC support task to the IAEA [25]. In the frame of this support task, verification measurements of randomly selected IRMM-1027 LSD spikes from different batches are performed up to two years after the issuance of the certificate. This 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 because the verification measurements are performed up to two years after the preparation of the spikes.

The long-term stability of the LSD spikes prepared with CMC can be demonstrated via the results of the INS-CRM exploratory research project [13, 14, 19]. In the study, the stability of the CMC foams is visually inspected at regular time intervals. Discoloration, cavity formation or collapsing of the CMC foam may occur with time. However, as long as the foam adheres to the vial; these effects do not influence the quality of the LSD spikes and therefore, the certified values can be guaranteed. Illustration of the stability of the CMC foam is shown in Figure 7.

After the certification campaign, IRMM-1027u material will be subjected to the post-certification monitoring programme to control its stability. Two units of IRMM-1027u (one CAB/DOP, one CMC) will be analysed every year to verify the certified values. The validity of the material certificate is five years and may be extended after further stability tests are carried out. This extension of the certificate is based on the visual inspection on test samples from previous batches. Test vials of IRMM-1027o covered with CAB/DOP showed no flaking when degrading over time but they became fluid and discoloration was observed after six years.

Figure 7 Stability of the LSD spikes prepared with CMC foam: a) freshly prepared CMC foam, b) CMC foam after about 3 years (Source: EC JRC G.2)



Taking all these considerations into account, no additional uncertainty component ($u_{lts,\,rel}$ = 0) was applied.

To demonstrate the durability and the radiation resistance of CMC, accelerated ageing simulation was carried out using ^{238}Pu in the frame of the exploratory research project [19]. In those spikes, one month life time is equivalent to the expected radiolysis during six months in the IRMM-1027 series LSD spikes. The ^{238}Pu spikes covered with CMC are now intact for 24 months (equals 12 years of LSD lifetime) and their stability will be further observed. These experiments have proven that even if the CMC foam collapses it remains sticky and still adheres well to the wall while fully preserving the integrity of the spike material.

6. Characterisation

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

The material characterisation for the uranium and plutonium isotope amount ratios and for the mass of uranium and plutonium was based on gravimetric preparation of the mother solution, confirmed by independent analysis. The IRMM-1027u series of LSD spikes was prepared by dispensing an aliquot (about 2.5 g) of the mother solution into individual units by an automated system and subsequent drying. The masses of dispensed aliquots per unit before drying are given in Annex 12. The mother solution was prepared by gravimetric mixing of uranium and plutonium metals (see Section 3.2).

Each unit of IRMM-1027u LSD spike is certified for the mass of ^{239}Pu, ^{235}U and ^{238}U and the $n(^{234}U)/n(^{238}U)$, $n(^{235}U)/n(^{238}U)$, $n(^{236}U)/n(^{238}U)$, $n(^{240}Pu)/n(^{239}Pu)$, $n(^{241}Pu)/n(^{239}Pu)$, 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 (Annexes 2 - 4). The purity of the Pu MP2 metal was calculated for November 1, 2018 from the original purity of the CETAMA certificate (Annex 4).

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

The mass of ^{235}U, ^{238}U, ^{239}Pu and the U and Pu isotope amount ratios in each individual unit of IRMM-1027u are calculated from the gravimetric preparation of the mother solution. The following parameters were taken into account: the mass of the metals, their purity and isotopic composition (e.g. isotope amount ratios), the mass of the mother solution and the mass of an aliquot dispensed into each vial. In Table 3, the data supporting the calculation of the masses of ^{235}U, ^{238}U, ^{239}Pu and Pu and U amount ratios of IRMM-1027u are summarised.

Table 3 Gravimetric mixing to prepare the mother solution of IRMM-1027u ((Source: EC JRC G.2)

	MP2	EC NRM 101	NBL PO CRM 116-A	Mother solution
Mass [1] [g]	1.93127	46.26719	11.32258	2623.412
Purity [2] [g/g]	0.9990	0.99985	0.99945	
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	$n(^{233}U)/n(^{235}U)$ 0.0000003863 $n(^{234}U)/n(^{235}U)$ 0.0115836 $n(^{236}U)/n(^{235}U)$ 0.0094713 $n(^{238}U)/n(^{235}U)$ 0.051277	
U amount content [4] [µmol/g]	2.7986			
Isotope amount fraction [4] [mol/mol]	$n(^{235}U)/n(U)$ 0.916107			

[1] The masses of the metals are obtained from the weighing certificate, see Annex 13.

[2] The purity of the metals is obtained from the metal certificates taking into account the decay; for the originals see Annexes 2 – 6, and for the calculated ones see Annexes 14 – 15.

[3] The isotope amount ratios are obtained from the metal certificates; see Annexes 3, 4, 6.

[4] The U isotope amount content and amount fraction are obtained from the metal certificates; see Annex 7.

The uncertainties on the certified mass (u_{char}) of ^{235}U, ^{238}U and ^{239}Pu in the individual units are composed of several contributions, which can be derived from the gravimetric mixture of the mother solution (Table 4). The contributors are the following: the uncertainties on the mass determinations ($u_{char,rel1}$, $u_{char,rel2}$ and $u_{char,rel3}$), the uncertainty on the purity of the

metals ($u_{char,rel4}$), and the uncertainties on the isotope amount ratios ($u_{char,rel5}$). The complete and detailed calculations of the mass fractions, amount fractions and their uncertainty budgets are given in Annex 14 and Annex 15.

The uncertainties of the certified U and Pu isotope amount ratios are composed of several contributions i.e. the uncertainty on the mass determination of the metals, the uncertainty on the purity of the metals, and the uncertainty on the isotope amount ratios. The complete and detailed calculations of the uranium and plutonium isotope amount ratios and their uncertainty budgets are given in Annex 14 and Annex 15. The uranium and plutonium isotope amount ratios from the characterisation assessment (gravimetric preparation) of IRMM-1027u are summarised in Table 5.

Table 4 Uncertainty budgets for the masses of ^{235}U, ^{238}U and ^{239}Pu in the gravimetric mixture in the first unit #1 of IRMM-1027u as an example (Source: EC JRC G.2)

	Relative standard uncertainty contribution					Combined relative uncertainty
	$u_{char,rel1}$ [1] [%]	$u_{char,rel2}$ [2] [%]	$u_{char,rel3}$ [3] [%]	$u_{char,rel4}$ [4] [%]	$u_{char,rel5}$ [5] [%]	$u_{char,rel}$ [6] [%]
^{235}U	0.00049	0.00017	0.012	0.0058	0.00047	0.013
^{238}U	0.00011	0.00017	0.012	0.0025	0.00047	0.012
^{239}Pu	0.0018	0.00017	0.012	0.020	0.00011	0.023

[1] Relative standard uncertainty of the mass determination of the metals, see Annex 14 and 15 denoted as $m_{UCRM116A}$ for ^{235}U, m_{UEC101} for ^{238}U and m_{PuMP2} for ^{239}Pu. The respective uncertainties of the mass determinations can be found in Annex 13.

[2] Relative standard uncertainty of the mass determination of the mother solution, see Annex 14 denoted as $m_{solution1027u}$. The respective uncertainty of the mass determination can be found in Annex 13.

[3] Relative standard uncertainty of the mass determination of the aliquot in the third vial, see Annex 14 denoted as $m_{aliquot3}$. The respective uncertainties of the mass determination can be found in Annex 12.

[4] Relative standard uncertainty of the purity of the metals, see Annex 14 and 15 denoted as $n_{purityEC101}$, $n_{purityCRM116A}$ and $n_{MP2Nov2018}$. The respective purities can be found in the metal certificates Annexes 2 – 4. For the CETAMA MP2 metal, the purity is decayed in a separate GUM file to the 1 January 2007 and from that date ($n_{MP2Jan2007}$) is decayed further to the certification date 1 November 2018.

[5] Relative standard uncertainty of the major isotope amount ratios, see Annex 14 and 15 denoted as $R_{235U/238Ua}$, $R_{238U/235Ub}$ for EC NRM 101 and NBL PO CRM-116-A; and $R_{240Pu/239Pu}$ for CETAMA MP2. The respective isotope amount ratios can be found in Annexes 3, 5 - 7.

[6] The final combined relative uncertainty is calculated using $\sqrt{\sum_{i=1}^{5}(u_{char,rel,i}^2)}$.

Table 5 The U and Pu isotope amount ratios and their standard uncertainties from the characterisation assessment of IRMM-1027u (Source: EC JRC G.2)

	Value [1] [mol/mol]	u_{char} [mol/mol]	$u_{char,\ rel}$ [%]
$n(^{234}U)/n(^{238}U)$	0.0027174	$1.1 \cdot 10^{-6}$	0.041
$n(^{235}U)/n(^{238}U)$	0.237043	$1.6 \cdot 10^{-5}$	0.0067
$n(^{236}U)/n(^{238}U)$	0.0021802	$8.9 \cdot 10^{-7}$	0.041
$n(^{240}Pu)/n(^{239}Pu)$	0.0224120	$2.5 \cdot 10^{-6}$	0.011
$n(^{241}Pu)/n(^{239}Pu)$	0.0001342	$8.8 \cdot 10^{-7}$	0.65
$n(^{242}Pu)/n(^{239}Pu)$	0.00007572	$3.9 \cdot 10^{-7}$	0.52

[1] The reference date for the isotope amount ratios is November 1, 2018.

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 12. 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 (± 0.0006 g, coverage factor k = 2) 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 stability of the balance [16].

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 reference weights (certificate), air buoyancy correction and the stability of the balance used in "SUUS" method.

6.4 Confirmation measurements

The confirmation measurements and the homogeneity study were performed on the same set of units (see Section 6).

Twelve units of IRMM-1027u (8 units with CAB/DOP and 4 units with CMC) were randomly selected from the whole batch and analysed by ID-TIMS to verify the uranium and plutonium amount contents from gravimetric preparation. To each of these units, about 2.0 g of mixed $^{233}U/^{242}Pu$ spike (IRMM-046c) in 5 M HNO_3 was weighed in and evaporated to dryness. Subsequently, the isotopic equilibrium, chemical separation and isotopic measurements on Triton TIMS were carried out as described in [17] (see Annex 16 and Annex 17). The results of the confirmation measurements are shown in Figures 8 - 10.

Figure 8 The amount content of ^{235}U in the selected vials of IRMM-1027u measured by ID-TIMS (CAB/DOP: blue diamonds, CMC: red squares) expressed as the relative difference from the gravimetric value. Error bars show the relative expanded uncertainty (coverage factor k = 2). Red dotted lines show the final relative expanded uncertainty (k = 2) assigned to the gravimetric value (Source: EC JRC G.2)

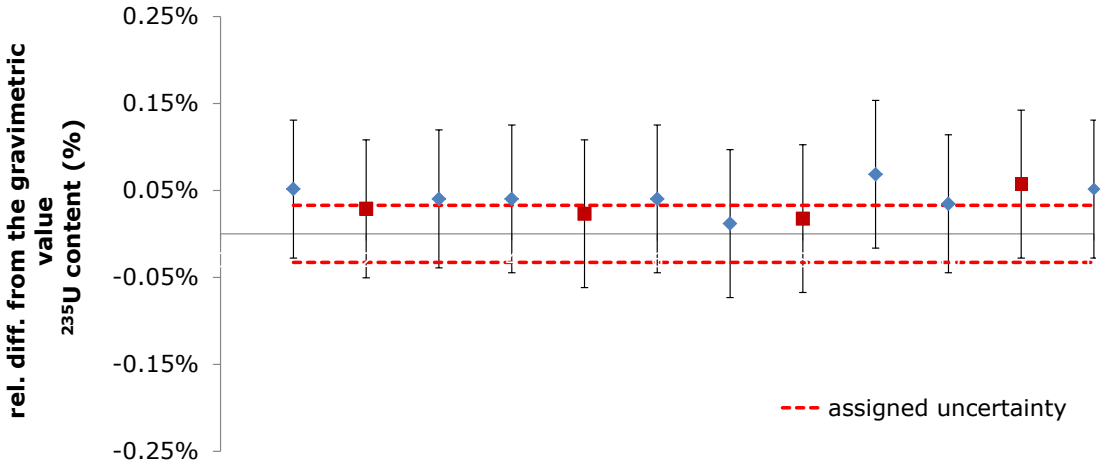


Figure 9 The amount content of ^{238}U in the selected vials of IRMM-1027u measured by ID-TIMS (CAB/DOP: blue diamonds, CMC: red squares) expressed as the relative difference from the gravimetric value. Error bars show the relative expanded uncertainty (coverage factor k = 2). Red dotted lines show the final relative expanded uncertainty (k = 2) assigned to the gravimetric value (Source: EC JRC G.2)

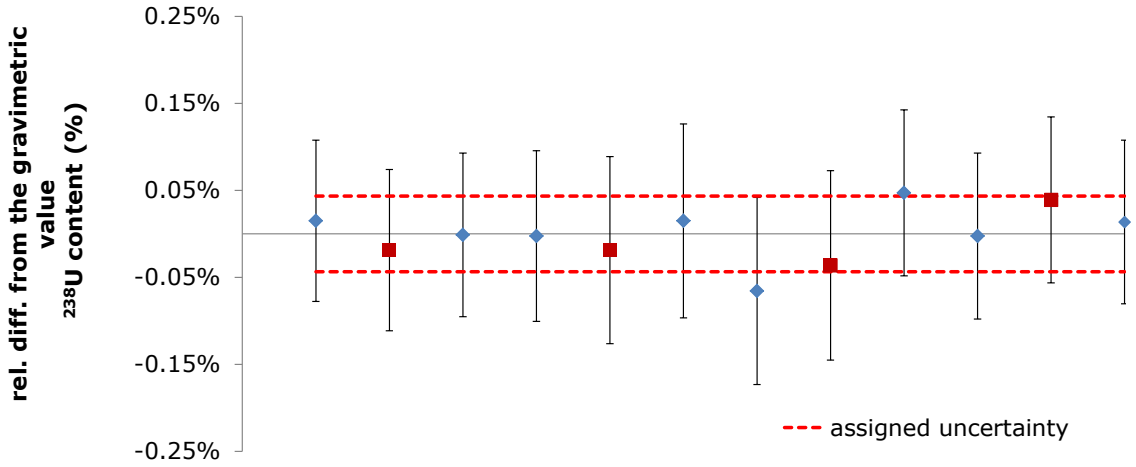
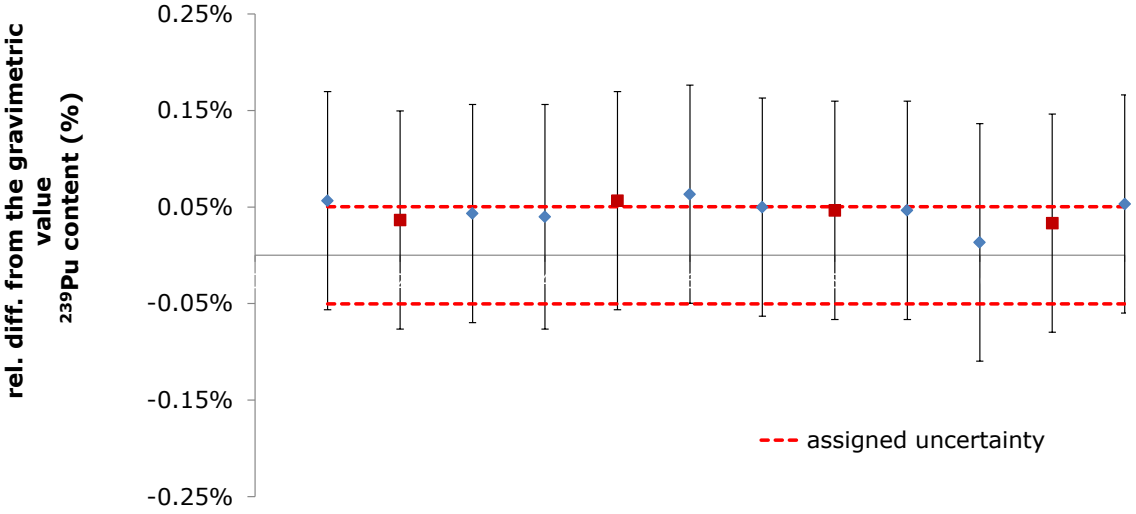


Figure 10 The amount content of ^{239}Pu in the selected vials of IRMM-1027u measured by ID-TIMS (CAB/DOP: blue diamonds, CMC: red squares) expressed as the relative difference from the gravimetric value. Error bars show the relative expanded uncertainty (coverage factor k = 2). Red dotted lines show the final relative expanded uncertainty (k = 2) assigned to the gravimetric value (Source: EC JRC G.2)



The results of the confirmation measurements for the ^{235}U, ^{238}U and ^{239}Pu amount content agreed within measurement uncertainties with the values from the gravimetrical preparation of IRMM-1027u.

Furthermore, the compatibility check was performed for the results of the confirmation measurements (IDMS) using the compatibility equation [26] below:

$$compatibility = \frac{X_{IDMS} - X_{cert}}{\sqrt{u_{IDMS}^2 + u_{cert}^2}} \qquad \text{Equation 4}$$

X_{IDMS} individual result obtained by IDMS

X_{cert} gravimetric value established by characterisation

u_{IDMS} standard uncertainty obtained by IDMS

u_{cert} standard uncertainty of the certified value

The results of the compatibility evaluations are summarised in Table 6.

Table 6 Results of the compatibility evaluation for the ^{235}U, ^{238}U and ^{239}Pu amount content (Source: EC JRC G.2)

Vial No.	^{235}U amount content	^{238}U amount content	^{239}Pu amount content
1027u-2	1.20	0.29	0.91
1027u-149	0.67	-0.36	0.59
1027u-214	0.88	0.02	0.70
1027u-270	0.88	-0.05	0.63
1027u-341	0.51	-0.32	0.91
1027u-429	0.88	0.25	1.02
1027u-536	0.26	-1.13	0.81
1027u-637	0.39	-0.62	0.75
1027u-715	1.60	0.90	0.75
1027u-798	0.76	-0.05	0.20
1027u-862	1.34	0.75	0.54
1027u-946	1.20	0.26	0.86

From Table 6 it can be seen that the compatibility ≥ —2 and ≤ 2 at a 95 % CI for all the ^{235}U, ^{238}U and ^{239}Pu amount contents. It can be concluded that there is no significant difference between the results obtained by IDMS and the values from the gravimetric preparation. Furthermore, there is no significant difference between the vials treated with CAB/DOP and CMC.

It can be also observed that all the IDMS results of the ^{235}U amount content and ^{239}Pu amount content have a positive bias compared to the gravimetric values (Figure 8 and 10). As the CRM 116-A was measured as QC samples together with the 3 sets of sample turrets – the same ID-QC sample as in case of the mother solution (see Section 3.3 Process control) – and all the results were within the acceptance limit (< 0.1 %), the IDMS results were also accepted. The same is valid for the ^{239}Pu amount content measurements, where the NBL-126 was used as ID-QC material. A thorough investigation was made concerning the measurements and calculations but we could not find an explanation for this positive bias. Moreover, as all the results of the IDMS measurements confirmed the gravimetrical values of ^{235}U and ^{239}Pu, this does not affect the certified value and its assigned uncertainty.

The confirmation measurement for the U and Pu isotope amount ratios in the selected vials of IRMM-1027u were deemed unnecessary. The results of the process control measurements (Annex 10) on the mother solution confirmed the complete mixing of the uranium and plutonium metals, and therefore, enabled the characterisation of the uranium and plutonium isotope amount ratios in IRMM-1027u based on the gravimetric preparation. It was already demonstrated in previous batches of IRMM-1027 spikes that there was no significant difference observed between the measured isotope ratios in the mother solution and in the dried spikes [11, 15, 27].

7. Value Assignment

Certified values are values that fulfil the highest standards of accuracy. Certified values for IRMM-1027u were assigned on the basis of the 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 assigned uncertainty consists of uncertainties related to characterisation, u_{char} (Section 6), potential between-unit inhomogeneity, u_{bb} (Section 3) 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 uncertainty of the certified value (U_{CRM}) with a coverage factor k as:

$$U_{CRM} = k \cdot \sqrt{u_{char}^2 + u_{bb}^2} \qquad \text{Equation 5}$$

- u_{char} was estimated as described in Section 6
- u_{bb} – that is substituted in this report by s_{bb} – was estimated as described in Section 3.

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 1003 units are given in Annex 1. The certified isotope amount ratios of uranium and plutonium are summarised in Table 8.

Table 7 Certified masses and their uncertainties in unit #1 of IRMM-1027u as an example (Source: EC JRC G.2)

Mass	Certified value [mg]	$u_{char, rel}$ [%]	$s_{bb, rel}$ [%]	$U_{CRM, rel}$ [1)] [%]	U_{CRM} [1)] [mg]
^{235}U mass	10.5016	0.013	0.0094	0.032	0.0034
^{238}U mass	44.869	0.012	0.018	0.043	0.019
^{239}Pu mass	1.8199	0.023	0.0095	0.050	0.0009

[1)] Expanded (k = 2) uncertainty

Table 8 Certified isotope amount ratios in IRMM-1027u and their uncertainties(Source: EC JRC G.2)

Isotope amount ratios	Certified value [1)] [mol/mol]	$u_{char, rel}$ [%]	$U_{CRM, rel}$ [2)] [%]	U_{CRM} [2)] [mol/mol]
$n(^{234}U)/n(^{238}U)$	0.0027174	0.041	0.083	0.0000022
$n(^{235}U)/n(^{238}U)$	0.237043	0.0067	0.013	0.000031
$n(^{236}U)/n(^{238}U)$	0.0021802	0.041	0.082	0.0000018
$n(^{240}Pu)/n(^{239}Pu)$	0.0224120	0.011	0.022	0.0000051
$n(^{241}Pu)/n(^{239}Pu)$	0.0001342	0.65	1.30	0.0000018
$n(^{242}Pu)/n(^{239}Pu)$	0.00007572	0.52	1.04	0.00000078

[1)] The reference date for the plutonium and uranium isotope amount ratios is November 1, 2018.

[2)] Expanded (k = 2) 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 (see Annexes 14 and 15) are summarised in Table 9.

Table 9 Uranium and plutonium isotopic mass fraction, amount content, mass fraction and isotope amount ratios for the nitrate solution of IRMM-1027u (Source: EC JRC G.2)

	Isotope mass fraction (·100)	
	Value [1] [g/g]	Uncertainty [2] [g/g]
$m(^{234}U)/m(U)$ [3]	0.21565	0.00018
$m(^{235}U)/m(U)$ [3]	18.8919	0.0020
$m(^{236}U)/m(U)$ [3]	0.17450	0.00014
$m(^{238}U)/m(U)$ [3]	80.7179	0.0021
$m(^{238}Pu)/m(Pu)$ [3]	0.002735	0.000026
$m(^{239}Pu)/m(Pu)$ [3]	97.77600	0.00052
$m(^{240}Pu)/m(Pu)$ [3]	2.20054	0.00049
$m(^{241}Pu)/m(Pu)$ [3]	0.01323	0.00017
$m(^{242}Pu)/m(Pu)$ [3]	0.007497	0.000077
	Amount content	
	Value [1] [µmol/g solution]	Uncertainty [2] [4] [µmol/g solution]
^{235}U	17.6409	0.0021
^{238}U	74.4209	0.0038
U	92.4264	0.0043
^{239}Pu	3.0059	0.0012
Pu	3.0739	0.0012
	Mass fraction	
	Value [1] [mg/g solution]	Uncertainty [2] [4] [mg/g solution]
^{235}U	4.14640	0.00050
^{238}U	17.71596	0.00090
U	21.9480	0.00010
^{239}Pu	0.71856	0.00029
Pu	0.73490	0.00030
	Isotope amount ratios	
	Value [1] [mol/mol]	Uncertainty [2] [mol/mol]
$n(^{238}Pu)/n(^{239}Pu)$	0.00002809	0.00000026

[1] The reference date for the plutonium and uranium isotope mass fraction, amount content, mass fractions and isotope amount ratios of the mother solution of IRMM-1027u is November 1, 2018.

[2] Expanded uncertainty with a coverage factor $k = 2$.

[3] Isotope mass fraction is expressed as $^{xxx}U/^{tot}U$ and $^{xxx}Pu/^{tot}Pu$.

[4] Dispensed nitrate solution before drying and application of CAB/DOP or CMC

The atomic masses of radionuclides were obtained from M. Wang et al. [4]

The half-lives of radionuclides were obtained from DDEP-BIPM (Table of radionuclides) [5] and R. Wellum et al. [6]

8. Metrological traceability and commutability

8.1 Metrological traceability

Identity

The measurands are structurally defined and independent of the measurement method.

Quantity value

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

8.2 Commutability

Many measurement procedures include one or more steps, which are selecting specific analytes (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 CLSI Guideline C-53A [28] 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-1027u is a dried nitrate in CAB/DOP or CMC 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 the JRC for its intended use and serves as a spike for determination of uranium and plutonium content by 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-1027u 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 for 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. Heating on a hotplate (avoid boiling) may be applied to facilitate the dissolution process.

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 for use as a spike isotopic reference material to measure the plutonium and uranium amount content in an unknown sample of dissolved nuclear fuel solution using IDMS. The amount content (C_x) of plutonium or uranium can be calculated using the following IDMS equation 6:

$$C_x = C_y \frac{m_y}{m_x} \frac{R_y - R_b}{R_b - R_x} \frac{\Sigma(R_i)_x}{\Sigma(R_i)_y} \quad , \qquad \text{Equation 6}$$

where C_y is the element amount 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. Conclusions

A new batch of IRMM-1027u LSD spikes was prepared and certified in compliance with international guidelines. The material is certified for the U and Pu isotope amount ratios and for the mass of ^{235}U, ^{238}U and ^{239}Pu per vial. This tailor-made CRM is applied for the determination of the U and Pu amount content of dissolved spent nuclear fuel by nuclear safeguards authorities and industry worldwide. Two cellulose materials, CAB/DOP and CMC were used as stabilisers to fix the dried nitrates at the bottom of the vials. Certified values for the masses of ^{235}U, ^{238}U and ^{239}Pu and for the U and Pu isotope amount ratios were established by gravimetric preparation and confirmed by IDMS as independent method of measurement. The uncertainties of the certified values were estimated in compliance with the Guide to the Expression of Uncertainty in Measurement (GUM). They are fit for purpose and enable laboratories to meet the The International Target Values for Measurement Uncertainties in Safeguarding Nuclear Materials (ITVs) ITV2010. A unit of IRMM-1027u contains about 55 mg of uranium with a relative mass fraction $m(^{235}U)/m(U)$ of 18.9 % and 1.8 mg of plutonium with a relative mass fraction $m(^{239}Pu)/m(Pu)$ of 97.8 % as dried nitrates in CAB/DOP or CMC.

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List of abbreviations and definitions

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
CI	Confidence interval
CLSI	Clinical and Laboratory Standards Institute
CMC	Carboxymethyl cellulose
CRM	Certified reference material
DOP	Dioctyl phthalate
EC	European Commission
ESARDA	European Safeguards Research and Development Association
GUM	Guide to the Expression of Uncertainty in Measurement
IAEA	International Atomic Energy Agency
IDMS	Isotope dilution mass spectrometry
ID-TIMS	Isotope dilution thermal ionisation mass spectrometry
ISO	International Organization for Standardization
ITVs	International Target Values
JRC	Joint Research Centre of the European Commission
K	Coverage factor
LSD	Large-Sized dried
M	Mass
M	Molar mass
$MS_{between}$	Mean of squares between-unit from an ANOVA
MS_{within}	Mean of squares within-unit from an ANOVA
n	amount of substance
NBL	New Brunswick laboratory
NML	Nuclear Material Laboratory
p.a.	pro analysis
R_b	Isotope amount ratio in the blend
R_x	Isotope amount ratio in the un-spiked sample
R_y	Isotope amount ratio in the spike
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
s_{wb}	Within-unit standard deviation
$T_{1/2}$	Half life
TE	Total evaporation
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
$\overline{y}$	Arithmetic mean
$\nu_{MSwithin}$	Degrees of freedom of MS_{within}

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Annexes

Annex 1 The certified masses of ^{235}U, ^{238}U and ^{239}Pu per unit (unit #1 – 1008) of IRMM-1027u

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

Unit #	Organic substance	^{238}U		^{235}U		^{239}Pu	
		Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
001	CAB/DOP	44.869	0.019	10.5016	0.0034	1.8199	0.0009
002	CAB/DOP	44.713	0.019	10.4651	0.0034	1.8136	0.0009
003	CMC	44.791	0.019	10.4833	0.0034	1.8167	0.0009
004	CMC	44.724	0.019	10.4676	0.0034	1.8140	0.0009
005	CMC	44.786	0.019	10.4821	0.0034	1.8165	0.0009
006	CMC	44.717	0.019	10.4659	0.0034	1.8137	0.0009
007	CMC	44.782	0.019	10.4813	0.0034	1.8164	0.0009
008	CMC	44.751	0.019	10.4738	0.0034	1.8151	0.0009
009	CMC	44.758	0.019	10.4755	0.0034	1.8154	0.0009
010	CMC	44.696	0.019	10.4610	0.0034	1.8129	0.0009
011	CMC	44.775	0.019	10.4796	0.0034	1.8161	0.0009
012	CMC	44.766	0.019	10.4775	0.0034	1.8157	0.0009
013	CMC	44.759	0.019	10.4759	0.0034	1.8154	0.0009
014	CMC	44.775	0.019	10.4796	0.0034	1.8161	0.0009
015	CMC	44.690	0.019	10.4597	0.0034	1.8126	0.0009
016	CMC	44.807	0.019	10.4871	0.0034	1.8174	0.0009
017	CMC	44.697	0.019	10.4614	0.0034	1.8129	0.0009
018	CMC	44.855	0.019	10.4983	0.0034	1.8193	0.0009
019	CMC	44.727	0.019	10.4684	0.0034	1.8141	0.0009
020	CMC	44.777	0.019	10.4800	0.0034	1.8162	0.0009
021	CMC	44.786	0.019	10.4821	0.0034	1.8165	0.0009
022	CMC	44.733	0.019	10.4697	0.0034	1.8144	0.0009
023	CMC	44.832	0.019	10.4929	0.0034	1.8184	0.0009
024	CMC	44.724	0.019	10.4676	0.0034	1.8140	0.0009
025	CMC	44.761	0.019	10.4763	0.0034	1.8155	0.0009
026	CMC	44.774	0.019	10.4792	0.0034	1.8160	0.0009
027	CMC	44.758	0.019	10.4755	0.0034	1.8154	0.0009
028	CMC	44.754	0.019	10.4746	0.0034	1.8152	0.0009
029	CMC	44.777	0.019	10.4800	0.0034	1.8162	0.0009
030	CMC	44.811	0.019	10.4879	0.0034	1.8175	0.0009
031	CMC	44.708	0.019	10.4639	0.0034	1.8134	0.0009
032	CMC	44.802	0.019	10.4858	0.0034	1.8172	0.0009
033	CMC	44.901	0.019	10.5091	0.0034	1.8212	0.0009
034	CMC	44.634	0.019	10.4464	0.0034	1.8103	0.0009
035	CMC	44.765	0.019	10.4771	0.0034	1.8157	0.0009
036	CMC	44.788	0.019	10.4825	0.0034	1.8166	0.0009
037	CMC	44.793	0.019	10.4838	0.0034	1.8168	0.0009
038	CMC	44.813	0.019	10.4883	0.0034	1.8176	0.0009
039	CMC	44.800	0.019	10.4854	0.0034	1.8171	0.0009
040	CMC	44.662	0.019	10.4531	0.0034	1.8115	0.0009
041	CMC	44.752	0.019	10.4742	0.0034	1.8152	0.0009
042	CMC	44.789	0.019	10.4829	0.0034	1.8167	0.0009
043	CMC	44.774	0.019	10.4792	0.0034	1.8160	0.0009
044	CMC	44.759	0.019	10.4759	0.0034	1.8154	0.0009
045	CMC	44.758	0.019	10.4755	0.0034	1.8154	0.0009
046	CMC	44.805	0.019	10.4867	0.0034	1.8173	0.0009
047	CMC	44.775	0.019	10.4796	0.0034	1.8161	0.0009
048	CMC	44.740	0.019	10.4713	0.0034	1.8147	0.0009
049	CMC	44.800	0.019	10.4854	0.0034	1.8171	0.0009
050	CMC	44.758	0.019	10.4755	0.0034	1.8154	0.0009

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

Unit #	Organic substance	^{238}U		^{235}U		^{239}Pu	
		Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
051	CMC	44.793	0.019	10.4838	0.0034	1.8168	0.0009
052	CMC	44.763	0.019	10.4767	0.0034	1.8156	0.0009
053	CMC	44.731	0.019	10.4692	0.0034	1.8143	0.0009
054	CMC	44.848	0.019	10.4966	0.0034	1.8190	0.0009
055	CMC	44.694	0.019	10.4605	0.0034	1.8128	0.0009
056	CMC	44.814	0.019	10.4887	0.0034	1.8177	0.0009
057	CMC	44.749	0.019	10.4734	0.0034	1.8150	0.0009
058	CMC	44.701	0.019	10.4622	0.0034	1.8131	0.0009
059	CMC	44.850	0.019	10.4970	0.0034	1.8191	0.0009
060	CMC	44.706	0.019	10.4634	0.0034	1.8133	0.0009
061	CMC	44.807	0.019	10.4871	0.0034	1.8174	0.0009
062	CMC	44.885	0.019	10.5053	0.0034	1.8205	0.0009
063	CMC	44.733	0.019	10.4697	0.0034	1.8144	0.0009
064	CMC	44.657	0.019	10.4518	0.0034	1.8113	0.0009
065	CMC	44.781	0.019	10.4809	0.0034	1.8163	0.0009
066	CAB/DOP	44.789	0.019	10.4829	0.0034	1.8167	0.0009
067	CMC	44.768	0.019	10.4780	0.0034	1.8158	0.0009
068	CAB/DOP	44.793	0.019	10.4838	0.0034	1.8168	0.0009
069	CMC	44.754	0.019	10.4746	0.0034	1.8152	0.0009
070	CMC	44.758	0.019	10.4755	0.0034	1.8154	0.0009
071	CMC	44.765	0.019	10.4771	0.0034	1.8157	0.0009
072	CMC	44.823	0.019	10.4908	0.0034	1.8180	0.0009
073	CMC	44.664	0.019	10.4535	0.0034	1.8116	0.0009
074	CMC	44.740	0.019	10.4713	0.0034	1.8147	0.0009
075	CMC	44.820	0.019	10.4900	0.0034	1.8179	0.0009
076	CMC	44.839	0.019	10.4945	0.0034	1.8187	0.0009
077	CMC	44.775	0.019	10.4796	0.0034	1.8161	0.0009
078	CMC	44.703	0.019	10.4626	0.0034	1.8131	0.0009
079	CMC	44.837	0.019	10.4941	0.0034	1.8186	0.0009
080	CMC	44.630	0.019	10.4456	0.0034	1.8102	0.0009
081	CMC	44.816	0.019	10.4891	0.0034	1.8177	0.0009
082	CMC	44.869	0.019	10.5016	0.0034	1.8199	0.0009
083	CMC	44.724	0.019	10.4676	0.0034	1.8140	0.0009
084	CMC	44.644	0.019	10.4489	0.0034	1.8108	0.0009
085	CMC	44.758	0.019	10.4755	0.0034	1.8154	0.0009
086	CMC	44.805	0.019	10.4867	0.0034	1.8173	0.0009
087	CMC	44.906	0.019	10.5103	0.0034	1.8214	0.0009
088	CMC	44.593	0.019	10.4369	0.0034	1.8087	0.0009
089	CMC	44.924	0.019	10.5144	0.0034	1.8221	0.0009
090	CMC	44.726	0.019	10.4680	0.0034	1.8141	0.0009
091	CMC	44.676	0.019	10.4564	0.0034	1.8121	0.0009
092	CMC	44.828	0.019	10.4921	0.0034	1.8182	0.0009
093	CMC	44.685	0.019	10.4585	0.0034	1.8124	0.0009
094	CMC	44.875	0.019	10.5028	0.0034	1.8201	0.0009
095	CMC	44.751	0.019	10.4738	0.0034	1.8151	0.0009
096	CMC	44.703	0.019	10.4626	0.0034	1.8131	0.0009
097	CAB/DOP	44.821	0.019	10.4904	0.0034	1.8180	0.0009
098	CAB/DOP	44.789	0.019	10.4829	0.0034	1.8167	0.0009
099	CAB/DOP	44.696	0.019	10.4610	0.0034	1.8129	0.0009
100	CAB/DOP	44.765	0.019	10.4771	0.0034	1.8157	0.0009

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

Unit #	Organic substance	^{238}U		^{235}U		^{239}Pu	
		Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
101	CAB/DOP	44.809	0.019	10.4875	0.0034	1.8175	0.0009
102	CMC	44.749	0.019	10.4734	0.0034	1.8150	0.0009
103	CAB/DOP	44.869	0.019	10.5016	0.0034	1.8199	0.0009
104	CAB/DOP	44.692	0.019	10.4601	0.0034	1.8127	0.0009
105	CAB/DOP	44.685	0.019	10.4585	0.0034	1.8124	0.0009
106	CAB/DOP	44.759	0.019	10.4759	0.0034	1.8154	0.0009
107	CAB/DOP	44.859	0.019	10.4991	0.0034	1.8195	0.0009
108	CAB/DOP	44.671	0.019	10.4551	0.0034	1.8118	0.0009
109	CAB/DOP	44.908	0.019	10.5107	0.0034	1.8215	0.0009
110	CAB/DOP	44.674	0.019	10.4560	0.0034	1.8120	0.0009
111	CAB/DOP	44.844	0.019	10.4958	0.0034	1.8189	0.0009
112	CAB/DOP	44.662	0.019	10.4531	0.0034	1.8115	0.0009
113	CAB/DOP	44.914	0.019	10.5120	0.0034	1.8217	0.0009
114	CAB/DOP	44.602	0.019	10.4390	0.0034	1.8090	0.0009
115	CAB/DOP	44.793	0.019	10.4838	0.0034	1.8168	0.0009
116	CAB/DOP	44.793	0.019	10.4838	0.0034	1.8168	0.0009
117	CAB/DOP	44.782	0.019	10.4813	0.0034	1.8164	0.0009
118	CAB/DOP	44.667	0.019	10.4543	0.0034	1.8117	0.0009
119	CAB/DOP	44.701	0.019	10.4622	0.0034	1.8131	0.0009
120	CAB/DOP	44.782	0.019	10.4813	0.0034	1.8164	0.0009
121	CAB/DOP	44.848	0.019	10.4966	0.0034	1.8190	0.0009
122	CAB/DOP	44.827	0.019	10.4916	0.0034	1.8182	0.0009
123	CAB/DOP	44.704	0.019	10.4630	0.0034	1.8132	0.0009
124	CAB/DOP	44.696	0.019	10.4610	0.0034	1.8129	0.0009
125	CAB/DOP	44.823	0.019	10.4908	0.0034	1.8180	0.0009
126	CAB/DOP	44.669	0.019	10.4547	0.0034	1.8118	0.0009
127	CAB/DOP	44.747	0.019	10.4730	0.0034	1.8149	0.0009
128	CAB/DOP	44.791	0.019	10.4833	0.0034	1.8167	0.0009
129	CAB/DOP	44.809	0.019	10.4875	0.0034	1.8175	0.0009
130	CAB/DOP	44.729	0.019	10.4688	0.0034	1.8142	0.0009
131	CAB/DOP	44.788	0.019	10.4825	0.0034	1.8166	0.0009
132	CAB/DOP	44.774	0.019	10.4792	0.0034	1.8160	0.0009
133	CAB/DOP	44.696	0.019	10.4610	0.0034	1.8129	0.0009
134	CAB/DOP	44.867	0.019	10.5012	0.0034	1.8198	0.0009
135	CAB/DOP	44.851	0.019	10.4974	0.0034	1.8192	0.0009
136	CAB/DOP	44.665	0.019	10.4539	0.0034	1.8116	0.0009
137	CAB/DOP	44.745	0.019	10.4726	0.0034	1.8149	0.0009
138	CAB/DOP	44.740	0.019	10.4713	0.0034	1.8147	0.0009
139	CAB/DOP	44.735	0.019	10.4701	0.0034	1.8144	0.0009
140	CAB/DOP	44.752	0.019	10.4742	0.0034	1.8152	0.0009
141	CAB/DOP	44.766	0.019	10.4775	0.0034	1.8157	0.0009
142	CAB/DOP	44.761	0.019	10.4763	0.0034	1.8155	0.0009
143	CAB/DOP	44.788	0.019	10.4825	0.0034	1.8166	0.0009
144	CMC	44.701	0.019	10.4622	0.0034	1.8131	0.0009
145	CAB/DOP	44.779	0.019	10.4804	0.0034	1.8162	0.0009
146	CAB/DOP	44.745	0.019	10.4726	0.0034	1.8149	0.0009
147	CAB/DOP	44.889	0.019	10.5061	0.0034	1.8207	0.0009
148	CAB/DOP	44.667	0.019	10.4543	0.0034	1.8117	0.0009
149	CMC	44.766	0.019	10.4775	0.0034	1.8157	0.0009
150	CAB/DOP	44.752	0.019	10.4742	0.0034	1.8152	0.0009

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

Unit #	Organic substance	^{238}U		^{235}U		^{239}Pu	
		Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
151	CAB/DOP	44.793	0.019	10.4838	0.0034	1.8168	0.0009
152	CAB/DOP	44.694	0.019	10.4605	0.0034	1.8128	0.0009
153	CAB/DOP	44.793	0.019	10.4838	0.0034	1.8168	0.0009
154	CAB/DOP	44.871	0.019	10.5020	0.0034	1.8200	0.0009
155	CAB/DOP	44.641	0.019	10.4481	0.0034	1.8106	0.0009
156	CAB/DOP	44.781	0.019	10.4809	0.0034	1.8163	0.0009
157	CAB/DOP	44.733	0.019	10.4697	0.0034	1.8144	0.0009
158	CAB/DOP	44.758	0.019	10.4755	0.0034	1.8154	0.0009
159	CAB/DOP	44.724	0.019	10.4676	0.0034	1.8140	0.0009
160	CAB/DOP	44.775	0.019	10.4796	0.0034	1.8161	0.0009
161	CAB/DOP	44.802	0.019	10.4858	0.0034	1.8172	0.0009
162	CAB/DOP	44.797	0.019	10.4846	0.0034	1.8170	0.0009
163	CAB/DOP	44.694	0.019	10.4605	0.0034	1.8128	0.0009
164	CAB/DOP	44.749	0.019	10.4734	0.0034	1.8150	0.0009
165	CAB/DOP	44.834	0.019	10.4933	0.0034	1.8185	0.0009
166	CAB/DOP	44.687	0.019	10.4589	0.0034	1.8125	0.0009
167	CAB/DOP	44.722	0.019	10.4672	0.0034	1.8139	0.0009
168	CAB/DOP	44.727	0.019	10.4684	0.0034	1.8141	0.0009
169	CAB/DOP	44.814	0.019	10.4887	0.0034	1.8177	0.0009
170	CAB/DOP	44.793	0.019	10.4838	0.0034	1.8168	0.0009
171	CAB/DOP	44.685	0.019	10.4585	0.0034	1.8124	0.0009
172	CAB/DOP	44.782	0.019	10.4813	0.0034	1.8164	0.0009
173	CAB/DOP	44.751	0.019	10.4738	0.0034	1.8151	0.0009
174	CAB/DOP	44.772	0.019	10.4788	0.0034	1.8159	0.0009
175	CAB/DOP	44.713	0.019	10.4651	0.0034	1.8136	0.0009
176	CAB/DOP	44.774	0.019	10.4792	0.0034	1.8160	0.0009
177	CAB/DOP	44.713	0.019	10.4651	0.0034	1.8136	0.0009
178	CAB/DOP	44.823	0.019	10.4908	0.0034	1.8180	0.0009
179	CMC	44.667	0.019	10.4543	0.0034	1.8117	0.0009
180	CAB/DOP	44.786	0.019	10.4821	0.0034	1.8165	0.0009
181	CAB/DOP	44.720	0.019	10.4668	0.0034	1.8139	0.0009
182	CAB/DOP	44.665	0.019	10.4539	0.0034	1.8116	0.0009
183	CAB/DOP	44.687	0.019	10.4589	0.0034	1.8125	0.0009
184	CAB/DOP	44.862	0.019	10.4999	0.0034	1.8196	0.0009
185	CAB/DOP	44.687	0.019	10.4589	0.0034	1.8125	0.0009
186	CAB/DOP	44.703	0.019	10.4626	0.0034	1.8131	0.0009
187	CAB/DOP	44.798	0.019	10.4850	0.0034	1.8170	0.0009
188	CAB/DOP	44.687	0.019	10.4589	0.0034	1.8125	0.0009
189	CAB/DOP	44.765	0.019	10.4771	0.0034	1.8157	0.0009
190	CAB/DOP	44.765	0.019	10.4771	0.0034	1.8157	0.0009
191	CAB/DOP	44.758	0.019	10.4755	0.0034	1.8154	0.0009
192	CAB/DOP	44.752	0.019	10.4742	0.0034	1.8152	0.0009
193	CAB/DOP	44.821	0.019	10.4904	0.0034	1.8180	0.0009
194	CAB/DOP	44.697	0.019	10.4614	0.0034	1.8129	0.0009
195	CAB/DOP	44.708	0.019	10.4639	0.0034	1.8134	0.0009
196	CAB/DOP	44.921	0.019	10.5136	0.0034	1.8220	0.0009
197	CAB/DOP	44.625	0.019	10.4444	0.0034	1.8100	0.0009
198	CAB/DOP	44.742	0.019	10.4717	0.0034	1.8147	0.0009
199	CAB/DOP	44.766	0.019	10.4775	0.0034	1.8157	0.0009
200	CAB/DOP	44.779	0.019	10.4804	0.0034	1.8162	0.0009

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

Unit #	Organic substance	^{238}U		^{235}U		^{239}Pu	
		Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
201	CAB/DOP	44.683	0.019	10.4581	0.0034	1.8124	0.0009
202	CAB/DOP	44.759	0.019	10.4759	0.0034	1.8154	0.0009
203	CAB/DOP	44.781	0.019	10.4809	0.0034	1.8163	0.0009
204	CAB/DOP	44.788	0.019	10.4825	0.0034	1.8166	0.0009
205	CAB/DOP	44.717	0.019	10.4659	0.0034	1.8137	0.0009
206	CAB/DOP	44.733	0.019	10.4697	0.0034	1.8144	0.0009
207	CAB/DOP	44.793	0.019	10.4838	0.0034	1.8168	0.0009
208	CAB/DOP	44.646	0.019	10.4493	0.0034	1.8108	0.0009
209	CAB/DOP	44.779	0.019	10.4804	0.0034	1.8162	0.0009
210	CAB/DOP	44.697	0.019	10.4614	0.0034	1.8129	0.0009
211	CAB/DOP	44.786	0.019	10.4821	0.0034	1.8165	0.0009
212	CAB/DOP	44.697	0.019	10.4614	0.0034	1.8129	0.0009
213	CAB/DOP	44.758	0.019	10.4755	0.0034	1.8154	0.0009
214	CAB/DOP	44.740	0.019	10.4713	0.0034	1.8147	0.0009
215	CAB/DOP	44.735	0.019	10.4701	0.0034	1.8144	0.0009
216	CAB/DOP	44.710	0.019	10.4643	0.0034	1.8134	0.0009
217	CAB/DOP	44.795	0.019	10.4842	0.0034	1.8169	0.0009
218	CAB/DOP	44.703	0.019	10.4626	0.0034	1.8131	0.0009
219	CAB/DOP	44.735	0.019	10.4701	0.0034	1.8144	0.0009
220	CAB/DOP	44.743	0.019	10.4721	0.0034	1.8148	0.0009
221	CAB/DOP	44.742	0.019	10.4717	0.0034	1.8147	0.0009
222	CAB/DOP	44.804	0.019	10.4862	0.0034	1.8172	0.0009
223	CAB/DOP	44.745	0.019	10.4726	0.0034	1.8149	0.0009
224	CAB/DOP	44.692	0.019	10.4601	0.0034	1.8127	0.0009
225	CAB/DOP	44.905	0.019	10.5099	0.0034	1.8213	0.0009
226	CAB/DOP	44.697	0.019	10.4614	0.0034	1.8129	0.0009
227	CAB/DOP	44.726	0.019	10.4680	0.0034	1.8141	0.0009
228	CAB/DOP	44.793	0.019	10.4838	0.0034	1.8168	0.0009
229	CAB/DOP	44.706	0.019	10.4634	0.0034	1.8133	0.0009
230	CAB/DOP	44.818	0.019	10.4896	0.0034	1.8178	0.0009
231	CAB/DOP	44.740	0.019	10.4713	0.0034	1.8147	0.0009
232	CAB/DOP	44.685	0.019	10.4585	0.0034	1.8124	0.0009
233	CAB/DOP	44.798	0.019	10.4850	0.0034	1.8170	0.0009
234	CAB/DOP	44.703	0.019	10.4626	0.0034	1.8131	0.0009
235	CAB/DOP	44.813	0.019	10.4883	0.0034	1.8176	0.0009
236	CAB/DOP	44.712	0.019	10.4647	0.0034	1.8135	0.0009
237	CAB/DOP	44.759	0.019	10.4759	0.0034	1.8154	0.0009
238	CAB/DOP	44.795	0.019	10.4842	0.0034	1.8169	0.0009
239	CAB/DOP	44.697	0.019	10.4614	0.0034	1.8129	0.0009
240	CAB/DOP	44.738	0.019	10.4709	0.0034	1.8146	0.0009
241	CMC	44.910	0.019	10.5111	0.0034	1.8215	0.0009
242	CMC	44.648	0.019	10.4498	0.0034	1.8109	0.0009
243	CMC	44.660	0.019	10.4527	0.0034	1.8114	0.0009
244	CMC	44.791	0.019	10.4833	0.0034	1.8167	0.0009
245	CMC	44.774	0.019	10.4792	0.0034	1.8160	0.0009
246	CMC	44.648	0.019	10.4498	0.0034	1.8109	0.0009
247	CMC	44.768	0.019	10.4780	0.0034	1.8158	0.0009
248	CMC	44.733	0.019	10.4697	0.0034	1.8144	0.0009
249	CMC	44.788	0.019	10.4825	0.0034	1.8166	0.0009
250	CMC	44.740	0.019	10.4713	0.0034	1.8147	0.0009

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

Unit #	Organic substance	^{238}U		^{235}U		^{239}Pu	
		Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
251	CMC	44.651	0.019	10.4506	0.0034	1.8111	0.0009
252	CMC	44.751	0.019	10.4738	0.0034	1.8151	0.0009
253	CMC	44.770	0.019	10.4784	0.0034	1.8159	0.0009
254	CMC	44.788	0.019	10.4825	0.0034	1.8166	0.0009
255	CMC	44.735	0.019	10.4701	0.0034	1.8144	0.0009
256	CMC	44.729	0.019	10.4688	0.0034	1.8142	0.0009
257	CMC	44.545	0.019	10.4257	0.0034	1.8067	0.0009
258	CMC	44.779	0.019	10.4804	0.0034	1.8162	0.0009
259	CMC	44.777	0.019	10.4800	0.0034	1.8162	0.0009
260	CMC	44.726	0.019	10.4680	0.0034	1.8141	0.0009
261	CMC	44.765	0.019	10.4771	0.0034	1.8157	0.0009
262	CMC	44.747	0.019	10.4730	0.0034	1.8149	0.0009
263	CMC	44.618	0.019	10.4427	0.0034	1.8097	0.0009
264	CMC	44.841	0.019	10.4950	0.0034	1.8187	0.0009
265	CMC	44.763	0.019	10.4767	0.0034	1.8156	0.0009
266	CMC	44.717	0.019	10.4659	0.0034	1.8137	0.0009
267	CMC	44.781	0.019	10.4809	0.0034	1.8163	0.0009
268	CMC	44.605	0.019	10.4398	0.0034	1.8092	0.0009
269	CMC	44.848	0.019	10.4966	0.0034	1.8190	0.0009
270	CAB/DOP	44.609	0.019	10.4406	0.0034	1.8093	0.0009
271	CMC	44.743	0.019	10.4721	0.0034	1.8148	0.0009
272	CMC	44.724	0.019	10.4676	0.0034	1.8140	0.0009
273	CMC	44.889	0.019	10.5061	0.0034	1.8207	0.0009
274	CMC	44.738	0.019	10.4709	0.0034	1.8146	0.0009
275	CMC	44.820	0.019	10.4900	0.0034	1.8179	0.0009
276	CMC	44.621	0.019	10.4435	0.0034	1.8098	0.0009
277	CMC	44.788	0.019	10.4825	0.0034	1.8166	0.0009
278	CMC	44.836	0.019	10.4937	0.0034	1.8185	0.0009
279	CMC	44.605	0.019	10.4398	0.0034	1.8092	0.0009
280	CMC	44.853	0.019	10.4979	0.0034	1.8193	0.0009
281	CMC	44.726	0.019	10.4680	0.0034	1.8141	0.0009
282	CMC	44.804	0.019	10.4862	0.0034	1.8172	0.0009
283	CMC	44.722	0.019	10.4672	0.0034	1.8139	0.0009
284	CMC	44.775	0.019	10.4796	0.0034	1.8161	0.0009
285	CMC	44.632	0.019	10.4460	0.0034	1.8103	0.0009
286	CMC	44.830	0.019	10.4925	0.0034	1.8183	0.0009
287	CMC	44.639	0.019	10.4477	0.0034	1.8106	0.0009
288	CMC	44.802	0.019	10.4858	0.0034	1.8172	0.0009
289	CAB/DOP	44.710	0.019	10.4643	0.0034	1.8134	0.0009
290	CAB/DOP	44.712	0.019	10.4647	0.0034	1.8135	0.0009
291	CAB/DOP	44.669	0.019	10.4547	0.0034	1.8118	0.0009
292	CAB/DOP	44.687	0.019	10.4589	0.0034	1.8125	0.0009
293	CAB/DOP	44.880	0.019	10.5041	0.0034	1.8203	0.0009
294	CAB/DOP	44.580	0.019	10.4340	0.0034	1.8082	0.0009
295	CAB/DOP	44.756	0.019	10.4751	0.0034	1.8153	0.0009
296	CAB/DOP	44.813	0.019	10.4883	0.0034	1.8176	0.0009
297	CAB/DOP	44.641	0.019	10.4481	0.0034	1.8106	0.0009
298	CAB/DOP	44.729	0.019	10.4688	0.0034	1.8142	0.0009
299	CAB/DOP	44.681	0.019	10.4576	0.0034	1.8123	0.0009
300	CAB/DOP	44.731	0.019	10.4692	0.0034	1.8143	0.0009

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

Unit #	Organic substance	^{238}U		^{235}U		^{239}Pu	
		Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
301	CAB/DOP	44.736	0.019	10.4705	0.0034	1.8145	0.0009
302	CAB/DOP	44.745	0.019	10.4726	0.0034	1.8149	0.0009
303	CAB/DOP	44.763	0.019	10.4767	0.0034	1.8156	0.0009
304	CAB/DOP	44.727	0.019	10.4684	0.0034	1.8141	0.0009
305	CAB/DOP	44.637	0.019	10.4473	0.0034	1.8105	0.0009
306	CAB/DOP	44.850	0.019	10.4970	0.0034	1.8191	0.0009
307	CAB/DOP	44.706	0.019	10.4634	0.0034	1.8133	0.0009
308	CAB/DOP	44.738	0.019	10.4709	0.0034	1.8146	0.0009
309	CAB/DOP	44.602	0.019	10.4390	0.0034	1.8090	0.0009
310	CAB/DOP	44.793	0.019	10.4838	0.0034	1.8168	0.0009
311	CAB/DOP	44.774	0.019	10.4792	0.0034	1.8160	0.0009
312	CAB/DOP	44.591	0.019	10.4365	0.0034	1.8086	0.0009
313	CAB/DOP	44.665	0.019	10.4539	0.0034	1.8116	0.0009
314	CAB/DOP	44.768	0.019	10.4780	0.0034	1.8158	0.0009
315	CAB/DOP	44.731	0.019	10.4692	0.0034	1.8143	0.0009
316	CAB/DOP	44.729	0.019	10.4688	0.0034	1.8142	0.0009
317	CAB/DOP	44.678	0.019	10.4568	0.0034	1.8121	0.0009
318	CAB/DOP	44.720	0.019	10.4668	0.0034	1.8139	0.0009
319	CAB/DOP	44.651	0.019	10.4506	0.0034	1.8111	0.0009
320	CAB/DOP	44.880	0.019	10.5041	0.0034	1.8203	0.0009
321	CAB/DOP	44.628	0.019	10.4452	0.0034	1.8101	0.0009
322	CAB/DOP	44.751	0.019	10.4738	0.0034	1.8151	0.0009
323	CAB/DOP	44.848	0.019	10.4966	0.0034	1.8190	0.0009
324	CAB/DOP	44.609	0.019	10.4406	0.0034	1.8093	0.0009
325	CAB/DOP	44.827	0.019	10.4916	0.0034	1.8182	0.0009
326	CAB/DOP	44.689	0.019	10.4593	0.0034	1.8126	0.0009
327	CAB/DOP	44.612	0.019	10.4415	0.0034	1.8095	0.0009
328	CAB/DOP	44.841	0.019	10.4950	0.0034	1.8187	0.0009
329	CAB/DOP	44.722	0.019	10.4672	0.0034	1.8139	0.0009
330	CAB/DOP	44.704	0.019	10.4630	0.0034	1.8132	0.0009
331	CAB/DOP	44.648	0.019	10.4498	0.0034	1.8109	0.0009
332	CAB/DOP	44.639	0.019	10.4477	0.0034	1.8106	0.0009
333	CAB/DOP	44.931	0.019	10.5161	0.0034	1.8224	0.0009
334	CAB/DOP	44.559	0.019	10.4290	0.0034	1.8073	0.0009
335	CMC	44.818	0.019	10.4896	0.0034	1.8178	0.0009
336[3]	N.A	N.A	N.A	N.A	N.A	N.A	N.A
337	CAB/DOB	44.715	0.019	10.4655	0.0034	1.8136	0.0009
338[3]	N.A	N.A	N.A	N.A	N.A	N.A	N.A
339	CAB/DOP	44.720	0.019	10.4668	0.0034	1.8139	0.0009
340	CAB/DOP	44.614	0.019	10.4419	0.0034	1.8095	0.0009
341	CMC	44.836	0.019	10.4937	0.0034	1.8185	0.0009
342	CAB/DOP	44.689	0.019	10.4593	0.0034	1.8126	0.0009
343	CAB/DOP	44.621	0.019	10.4435	0.0034	1.8098	0.0009
344	CAB/DOP	44.846	0.019	10.4962	0.0034	1.8190	0.0009
345	CAB/DOP	44.724	0.019	10.4676	0.0034	1.8140	0.0009
346	CAB/DOP	44.692	0.019	10.4601	0.0034	1.8127	0.0009
347	CAB/DOP	44.846	0.019	10.4962	0.0034	1.8190	0.0009
348	CMC	44.623	0.019	10.4440	0.0034	1.8099	0.0009
349	CAB/DOP	44.793	0.019	10.4838	0.0034	1.8168	0.0009
350	CAB/DOP	44.570	0.019	10.4315	0.0034	1.8078	0.0009

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

Unit #	Organic substance	^{238}U		^{235}U		^{239}Pu	
		Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
351	CAB/DOP	44.921	0.019	10.5136	0.0034	1.8220	0.0009
352	CAB/DOP	44.511	0.019	10.4178	0.0034	1.8054	0.0009
353	CAB/DOP	44.910	0.019	10.5111	0.0034	1.8215	0.0009
354	CAB/DOP	44.632	0.019	10.4460	0.0034	1.8103	0.0009
355	CAB/DOP	44.774	0.019	10.4792	0.0034	1.8160	0.0009
356	CAB/DOP	44.701	0.019	10.4622	0.0034	1.8131	0.0009
357	CAB/DOP	44.717	0.019	10.4659	0.0034	1.8137	0.0009
358	CAB/DOP	44.625	0.019	10.4444	0.0034	1.8100	0.0009
359	CAB/DOP	44.820	0.019	10.4900	0.0034	1.8179	0.0009
360	CAB/DOP	44.644	0.019	10.4489	0.0034	1.8108	0.0009
361	CAB/DOP	44.850	0.019	10.4970	0.0034	1.8191	0.0009
362	CAB/DOP	44.596	0.019	10.4377	0.0034	1.8088	0.0009
363	CAB/DOP	44.797	0.019	10.4846	0.0034	1.8170	0.0009
364	CAB/DOP	44.683	0.019	10.4581	0.0034	1.8124	0.0009
365	CAB/DOP	44.834	0.019	10.4933	0.0034	1.8185	0.0009
366	CAB/DOP	44.570	0.019	10.4315	0.0034	1.8078	0.0009
367	CAB/DOP	44.864	0.019	10.5003	0.0034	1.8197	0.0009
368	CAB/DOP	44.731	0.019	10.4692	0.0034	1.8143	0.0009
369	CAB/DOP	44.570	0.019	10.4315	0.0034	1.8078	0.0009
370	CAB/DOP	44.740	0.019	10.4713	0.0034	1.8147	0.0009
371	CAB/DOP	44.821	0.019	10.4904	0.0034	1.8180	0.0009
372	CAB/DOP	44.651	0.019	10.4506	0.0034	1.8111	0.0009
373	CAB/DOP	44.836	0.019	10.4937	0.0034	1.8185	0.0009
374	CAB/DOP	44.697	0.019	10.4614	0.0034	1.8129	0.0009
375	CAB/DOP	44.722	0.019	10.4672	0.0034	1.8139	0.0009
376[3]	N.A	N.A	N.A	N.A	N.A	N.A	N.A
377	CAB/DOP	44.759	0.019	10.4759	0.0034	1.8154	0.0009
378[3]	N.A	N.A	N.A	N.A	N.A	N.A	N.A
379	CAB/DOP	44.644	0.019	10.4489	0.0034	1.8108	0.0009
380	CAB/DOP	44.798	0.019	10.4850	0.0034	1.8170	0.0009
381	CAB/DOP	44.712	0.019	10.4647	0.0034	1.8135	0.0009
382	CAB/DOP	44.749	0.019	10.4734	0.0034	1.8150	0.0009
383	CAB/DOP	44.694	0.019	10.4605	0.0034	1.8128	0.0009
384	CAB/DOP	44.743	0.019	10.4721	0.0034	1.8148	0.0009
385	CMC	44.782	0.019	10.4813	0.0034	1.8164	0.0009
386	CMC	44.729	0.019	10.4688	0.0034	1.8142	0.0009
387	CMC	44.676	0.019	10.4564	0.0034	1.8121	0.0009
388	CMC	44.681	0.019	10.4576	0.0034	1.8123	0.0009
389	CMC	44.784	0.019	10.4817	0.0034	1.8164	0.0009
390	CAB/DOP	44.611	0.019	10.4410	0.0034	1.8094	0.0009
391	CMC	44.836	0.019	10.4937	0.0034	1.8185	0.0009
392	CMC	44.774	0.019	10.4792	0.0034	1.8160	0.0009
393	CMC	44.678	0.019	10.4568	0.0034	1.8121	0.0009
394	CMC	44.733	0.019	10.4697	0.0034	1.8144	0.0009
395	CMC	44.784	0.019	10.4817	0.0034	1.8164	0.0009
396	CMC	44.634	0.019	10.4464	0.0034	1.8103	0.0009
397	CMC	44.834	0.019	10.4933	0.0034	1.8185	0.0009
398	CMC	44.717	0.019	10.4659	0.0034	1.8137	0.0009
399	CMC	44.758	0.019	10.4755	0.0034	1.8154	0.0009
400	CMC	44.584	0.019	10.4348	0.0034	1.8083	0.0009

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

Unit #	Organic substance	^{238}U		^{235}U		^{239}Pu	
		Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
401	CMC	44.857	0.019	10.4987	0.0034	1.8194	0.0009
402	CMC	44.740	0.019	10.4713	0.0034	1.8147	0.0009
403	CMC	44.655	0.019	10.4514	0.0034	1.8112	0.0009
404	CMC	44.747	0.019	10.4730	0.0034	1.8149	0.0009
405	CMC	44.625	0.019	10.4444	0.0034	1.8100	0.0009
406	CMC	44.827	0.019	10.4916	0.0034	1.8182	0.0009
407	CMC	44.779	0.019	10.4804	0.0034	1.8162	0.0009
408	CMC	44.609	0.019	10.4406	0.0034	1.8093	0.0009
409	CMC	44.860	0.019	10.4995	0.0034	1.8195	0.0009
410	CMC	44.727	0.019	10.4684	0.0034	1.8141	0.0009
411	CMC	44.612	0.019	10.4415	0.0034	1.8095	0.0009
412	CMC	44.821	0.019	10.4904	0.0034	1.8180	0.0009
413	CMC	44.779	0.019	10.4804	0.0034	1.8162	0.0009
414	CMC	44.527	0.019	10.4216	0.0034	1.8060	0.0009
415	CMC	44.857	0.019	10.4987	0.0034	1.8194	0.0009
416	CMC	44.595	0.019	10.4373	0.0034	1.8088	0.0009
417	CMC	44.862	0.019	10.4999	0.0034	1.8196	0.0009
418	CMC	44.733	0.019	10.4697	0.0034	1.8144	0.0009
419	CMC	44.690	0.019	10.4597	0.0034	1.8126	0.0009
420	CMC	44.586	0.019	10.4352	0.0034	1.8084	0.0009
421	CMC	44.777	0.019	10.4800	0.0034	1.8162	0.0009
422	CMC	44.850	0.019	10.4970	0.0034	1.8191	0.0009
423	CMC	44.550	0.019	10.4270	0.0034	1.8070	0.0009
424	CAB/DOP	44.701	0.019	10.4622	0.0034	1.8131	0.0009
425	CMC	44.726	0.019	10.4680	0.0034	1.8141	0.0009
426	CMC	44.850	0.019	10.4970	0.0034	1.8191	0.0009
427	CMC	44.598	0.019	10.4381	0.0034	1.8089	0.0009
428	CMC	44.880	0.019	10.5041	0.0034	1.8203	0.0009
429	CAB/DOP	44.632	0.019	10.4460	0.0034	1.8103	0.0009
430	CMC	44.743	0.019	10.4721	0.0034	1.8148	0.0009
431	CMC	44.699	0.019	10.4618	0.0034	1.8130	0.0009
432	CMC	44.630	0.019	10.4456	0.0034	1.8102	0.0009
433	CMC	44.848	0.019	10.4966	0.0034	1.8190	0.0009
434	CMC	44.568	0.019	10.4311	0.0034	1.8077	0.0009
435	CMC	44.742	0.019	10.4717	0.0034	1.8147	0.0009
436	CMC	44.658	0.019	10.4522	0.0034	1.8113	0.0009
437	CMC	44.653	0.019	10.4510	0.0034	1.8111	0.0009
438	CMC	44.735	0.019	10.4701	0.0034	1.8144	0.0009
439	CMC	44.650	0.019	10.4502	0.0034	1.8110	0.0009
440	CMC	44.775	0.019	10.4796	0.0034	1.8161	0.0009
441	CMC	44.715	0.019	10.4655	0.0034	1.8136	0.0009
442	CMC	44.697	0.019	10.4614	0.0034	1.8129	0.0009
443	CMC	44.722	0.019	10.4672	0.0034	1.8139	0.0009
444	CMC	44.761	0.019	10.4763	0.0034	1.8155	0.0009
445	CMC	44.701	0.019	10.4622	0.0034	1.8131	0.0009
446	CMC	44.580	0.019	10.4340	0.0034	1.8082	0.0009
447	CMC	44.699	0.019	10.4618	0.0034	1.8130	0.0009
448	CMC	44.708	0.019	10.4639	0.0034	1.8134	0.0009
449	CMC	44.754	0.019	10.4746	0.0034	1.8152	0.0009
450	CMC	44.653	0.019	10.4510	0.0034	1.8111	0.0009

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

Unit #	Organic substance	^{238}U		^{235}U		^{239}Pu	
		Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
451	CMC	44.660	0.019	10.4527	0.0034	1.8114	0.0009
452	CMC	44.729	0.019	10.4688	0.0034	1.8142	0.0009
453	CMC	44.708	0.019	10.4639	0.0034	1.8134	0.0009
454	CMC	44.804	0.019	10.4862	0.0034	1.8172	0.0009
455	CMC	44.554	0.019	10.4278	0.0034	1.8071	0.0009
456	CMC	44.781	0.019	10.4809	0.0034	1.8163	0.0009
457	CMC	44.727	0.019	10.4684	0.0034	1.8141	0.0009
458	CMC	44.664	0.019	10.4535	0.0034	1.8116	0.0009
459	CMC	44.660	0.019	10.4527	0.0034	1.8114	0.0009
460	CMC	44.823	0.019	10.4908	0.0034	1.8180	0.0009
461	CMC	44.735	0.019	10.4701	0.0034	1.8144	0.0009
462	CMC	44.664	0.019	10.4535	0.0034	1.8116	0.0009
463	CMC	44.701	0.019	10.4622	0.0034	1.8131	0.0009
464	CMC	44.738	0.019	10.4709	0.0034	1.8146	0.0009
465	CMC	44.630	0.019	10.4456	0.0034	1.8102	0.0009
466	CMC	44.660	0.019	10.4527	0.0034	1.8114	0.0009
467	CMC	44.662	0.019	10.4531	0.0034	1.8115	0.0009
468	CAB/DOP	44.712	0.019	10.4647	0.0034	1.8135	0.0009
469	CMC	44.625	0.019	10.4444	0.0034	1.8100	0.0009
470	CMC	44.720	0.019	10.4668	0.0034	1.8139	0.0009
471	CMC	44.789	0.019	10.4829	0.0034	1.8167	0.0009
472	CMC	44.689	0.019	10.4593	0.0034	1.8126	0.0009
473	CMC	44.648	0.019	10.4498	0.0034	1.8109	0.0009
474	CMC	44.719	0.019	10.4663	0.0034	1.8138	0.0009
475	CMC	44.751	0.019	10.4738	0.0034	1.8151	0.0009
476	CMC	44.690	0.019	10.4597	0.0034	1.8126	0.0009
477	CMC	44.678	0.019	10.4568	0.0034	1.8121	0.0009
478	CMC	44.607	0.019	10.4402	0.0034	1.8093	0.0009
479	CMC	44.671	0.019	10.4551	0.0034	1.8118	0.0009
480	CMC	44.887	0.019	10.5057	0.0034	1.8206	0.0009
481	CAB/DOP	44.674	0.019	10.4560	0.0034	1.8120	0.0009
482	CAB/DOP	44.635	0.019	10.4469	0.0034	1.8104	0.0009
483	CAB/DOP	44.802	0.019	10.4858	0.0034	1.8172	0.0009
484	CAB/DOP	44.665	0.019	10.4539	0.0034	1.8116	0.0009
485	CAB/DOP	44.850	0.019	10.4970	0.0034	1.8191	0.0009
486	CAB/DOP	44.628	0.019	10.4452	0.0034	1.8101	0.0009
487	CAB/DOP	44.766	0.019	10.4775	0.0034	1.8157	0.0009
488	CAB/DOP	44.650	0.019	10.4502	0.0034	1.8110	0.0009
489	CAB/DOP	44.869	0.019	10.5016	0.0034	1.8199	0.0009
490	CAB/DOP	44.754	0.019	10.4746	0.0034	1.8152	0.0009
491	CAB/DOP	44.674	0.019	10.4560	0.0034	1.8120	0.0009
492	CAB/DOP	44.742	0.019	10.4717	0.0034	1.8147	0.0009
493	CAB/DOP	44.770	0.019	10.4784	0.0034	1.8159	0.0009
494	CAB/DOP	44.775	0.019	10.4796	0.0034	1.8161	0.0009
495	CAB/DOP	44.648	0.019	10.4498	0.0034	1.8109	0.0009
496	CAB/DOP	44.655	0.019	10.4514	0.0034	1.8112	0.0009
497	CAB/DOP	44.743	0.019	10.4721	0.0034	1.8148	0.0009
498	CAB/DOP	44.749	0.019	10.4734	0.0034	1.8150	0.0009
499	CAB/DOP	44.690	0.019	10.4597	0.0034	1.8126	0.0009
500	CAB/DOP	44.830	0.019	10.4925	0.0034	1.8183	0.0009

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

Unit #	Organic substance	^{238}U		^{235}U		^{239}Pu	
		Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
501	CAB/DOP	44.582	0.019	10.4344	0.0034	1.8083	0.0009
502	CAB/DOP	44.802	0.019	10.4858	0.0034	1.8172	0.0009
503	CMC	44.694	0.019	10.4605	0.0034	1.8128	0.0009
504	CAB/DOP	44.720	0.019	10.4668	0.0034	1.8139	0.0009
505	CAB/DOP	44.687	0.019	10.4589	0.0034	1.8125	0.0009
506	CAB/DOP	44.742	0.019	10.4717	0.0034	1.8147	0.0009
507	CMC	44.657	0.019	10.4518	0.0034	1.8113	0.0009
508	CAB/DOP	44.554	0.019	10.4278	0.0034	1.8071	0.0009
509	CAB/DOP	44.704	0.019	10.4630	0.0034	1.8132	0.0009
510	CAB/DOP	44.855	0.019	10.4983	0.0034	1.8193	0.0009
511	CAB/DOP	44.704	0.019	10.4630	0.0034	1.8132	0.0009
512	CAB/DOP	44.657	0.019	10.4518	0.0034	1.8113	0.0009
513	CAB/DOP	44.667	0.019	10.4543	0.0034	1.8117	0.0009
514	CAB/DOP	44.680	0.019	10.4572	0.0034	1.8122	0.0009
515	CAB/DOP	44.701	0.019	10.4622	0.0034	1.8131	0.0009
516	CAB/DOP	44.727	0.019	10.4684	0.0034	1.8141	0.0009
517	CAB/DOP	44.655	0.019	10.4514	0.0034	1.8112	0.0009
518	CAB/DOP	44.742	0.019	10.4717	0.0034	1.8147	0.0009
519	CAB/DOP	44.729	0.019	10.4688	0.0034	1.8142	0.0009
520	CAB/DOP	44.710	0.019	10.4643	0.0034	1.8134	0.0009
521	CAB/DOP	44.667	0.019	10.4543	0.0034	1.8117	0.0009
522	CAB/DOP	44.619	0.019	10.4431	0.0034	1.8098	0.0009
523	CAB/DOP	44.660	0.019	10.4527	0.0034	1.8114	0.0009
524	CAB/DOP	44.800	0.019	10.4854	0.0034	1.8171	0.0009
525	CAB/DOP	44.646	0.019	10.4493	0.0034	1.8108	0.0009
526	CAB/DOP	44.708	0.019	10.4639	0.0034	1.8134	0.0009
527	CAB/DOP	44.692	0.019	10.4601	0.0034	1.8127	0.0009
528	CAB/DOP	44.642	0.019	10.4485	0.0034	1.8107	0.0009
529	CAB/DOP	44.791	0.019	10.4833	0.0034	1.8167	0.0009
530	CAB/DOP	44.692	0.019	10.4601	0.0034	1.8127	0.0009
531	CAB/DOP	44.564	0.019	10.4303	0.0034	1.8075	0.0009
532	CAB/DOP	44.814	0.019	10.4887	0.0034	1.8177	0.0009
533	CAB/DOP	44.687	0.019	10.4589	0.0034	1.8125	0.0009
534	CAB/DOP	44.676	0.019	10.4564	0.0034	1.8121	0.0009
535	CAB/DOP	44.664	0.019	10.4535	0.0034	1.8116	0.0009
536	CAB/DOP	44.561	0.019	10.4294	0.0034	1.8074	0.0009
537	CAB/DOP	44.869	0.019	10.5016	0.0034	1.8199	0.0009
538	CAB/DOP	44.517	0.019	10.4191	0.0034	1.8056	0.0009
539	CAB/DOP	44.740	0.019	10.4713	0.0034	1.8147	0.0009
540	CAB/DOP	44.804	0.019	10.4862	0.0034	1.8172	0.0009
541	CAB/DOP	44.641	0.019	10.4481	0.0034	1.8106	0.0009
542	CAB/DOP	44.648	0.019	10.4498	0.0034	1.8109	0.0009
543	CAB/DOP	44.681	0.019	10.4576	0.0034	1.8123	0.0009
544	CAB/DOP	44.738	0.019	10.4709	0.0034	1.8146	0.0009
545	CAB/DOP	44.665	0.019	10.4539	0.0034	1.8116	0.0009
546	CAB/DOP	44.696	0.019	10.4610	0.0034	1.8129	0.0009
547	CAB/DOP	44.591	0.019	10.4365	0.0034	1.8086	0.0009
548	CAB/DOP	44.729	0.019	10.4688	0.0034	1.8142	0.0009
549	CAB/DOP	44.740	0.019	10.4713	0.0034	1.8147	0.0009
550	CAB/DOP	44.681	0.019	10.4576	0.0034	1.8123	0.0009

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

Unit #	Organic substance	^{238}U		^{235}U		^{239}Pu	
		Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
551	CAB/DOP	44.680	0.019	10.4572	0.0034	1.8122	0.0009
552	CAB/DOP	44.639	0.019	10.4477	0.0034	1.8106	0.0009
553	CAB/DOP	44.825	0.019	10.4912	0.0034	1.8181	0.0009
554	CAB/DOP	44.635	0.019	10.4469	0.0034	1.8104	0.0009
555	CAB/DOP	44.635	0.019	10.4469	0.0034	1.8104	0.0009
556	CAB/DOP	44.751	0.019	10.4738	0.0034	1.8151	0.0009
557	CAB/DOP	44.545	0.019	10.4257	0.0034	1.8067	0.0009
558	CAB/DOP	44.846	0.019	10.4962	0.0034	1.8190	0.0009
559	CAB/DOP	44.676	0.019	10.4564	0.0034	1.8121	0.0009
560	CAB/DOP	44.559	0.019	10.4290	0.0034	1.8073	0.0009
561	CAB/DOP	44.692	0.019	10.4601	0.0034	1.8127	0.0009
562	CAB/DOP	44.735	0.019	10.4701	0.0034	1.8144	0.0009
563	CAB/DOP	44.658	0.019	10.4522	0.0034	1.8113	0.0009
564	CAB/DOP	44.747	0.019	10.4730	0.0034	1.8149	0.0009
565	CAB/DOP	44.589	0.019	10.4361	0.0034	1.8085	0.0009
566	CAB/DOP	44.809	0.019	10.4875	0.0034	1.8175	0.0009
567	CAB/DOP	44.660	0.019	10.4527	0.0034	1.8114	0.0009
568	CAB/DOP	44.657	0.019	10.4518	0.0034	1.8113	0.0009
569	CAB/DOP	44.618	0.019	10.4427	0.0034	1.8097	0.0009
570	CAB/DOP	44.632	0.019	10.4460	0.0034	1.8103	0.0009
571	CAB/DOP	44.745	0.019	10.4726	0.0034	1.8149	0.0009
572	CAB/DOP	44.690	0.019	10.4597	0.0034	1.8126	0.0009
573	CAB/DOP	44.639	0.019	10.4477	0.0034	1.8106	0.0009
574	CAB/DOP	44.685	0.019	10.4585	0.0034	1.8124	0.0009
575	CAB/DOP	44.673	0.019	10.4556	0.0034	1.8119	0.0009
576	CAB/DOP	44.680	0.019	10.4572	0.0034	1.8122	0.0009
577	CAB/DOP	44.789	0.019	10.4829	0.0034	1.8167	0.0009
578	CAB/DOP	44.524	0.019	10.4207	0.0034	1.8059	0.0009
579	CAB/DOP	44.795	0.019	10.4842	0.0034	1.8169	0.0009
580	CAB/DOP	44.681	0.019	10.4576	0.0034	1.8123	0.0009
581	CAB/DOP	44.642	0.019	10.4485	0.0034	1.8107	0.0009
582	CAB/DOP	44.729	0.019	10.4688	0.0034	1.8142	0.0009
583	CAB/DOP	44.593	0.019	10.4369	0.0034	1.8087	0.0009
584	CAB/DOP	44.782	0.019	10.4813	0.0034	1.8164	0.0009
585[3]	N.A	N.A	N.A	N.A	N.A	N.A	N.A
586	CAB/DOP	44.671	0.019	10.4551	0.0034	1.8118	0.0009
587	CAB/DOP	44.678	0.019	10.4568	0.0034	1.8121	0.0009
588	CAB/DOP	44.628	0.019	10.4452	0.0034	1.8101	0.0009
589	CAB/DOP	44.568	0.019	10.4311	0.0034	1.8077	0.0009
590	CAB/DOP	44.797	0.019	10.4846	0.0034	1.8170	0.0009
591	CAB/DOP	44.719	0.019	10.4663	0.0034	1.8138	0.0009
592	CAB/DOP	44.719	0.019	10.4663	0.0034	1.8138	0.0009
593	CAB/DOP	44.665	0.019	10.4539	0.0034	1.8116	0.0009
594	CAB/DOP	44.660	0.019	10.4527	0.0034	1.8114	0.0009
595	CAB/DOP	44.632	0.019	10.4460	0.0034	1.8103	0.0009
596	CAB/DOP	44.586	0.019	10.4352	0.0034	1.8084	0.0009
597	CMC	44.674	0.019	10.4560	0.0034	1.8120	0.0009
598	CAB/DOP	44.751	0.019	10.4738	0.0034	1.8151	0.0009
599	CAB/DOP	44.793	0.019	10.4838	0.0034	1.8168	0.0009
600	CAB/DOP	44.616	0.019	10.4423	0.0034	1.8096	0.0009

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

Unit #	Organic substance	^{238}U		^{235}U		^{239}Pu	
		Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
601	CAB/DOP	44.706	0.019	10.4634	0.0034	1.8133	0.0009
602	CAB/DOP	44.582	0.019	10.4344	0.0034	1.8083	0.0009
603	CAB/DOP	44.798	0.019	10.4850	0.0034	1.8170	0.0009
604	CAB/DOP	44.639	0.019	10.4477	0.0034	1.8106	0.0009
605	CAB/DOP	44.766	0.019	10.4775	0.0034	1.8157	0.0009
606	CAB/DOP	44.646	0.019	10.4493	0.0034	1.8108	0.0009
607	CAB/DOP	44.683	0.019	10.4581	0.0034	1.8124	0.0009
608	CAB/DOP	44.696	0.019	10.4610	0.0034	1.8129	0.0009
609	CAB/DOP	44.678	0.019	10.4568	0.0034	1.8121	0.0009
610	CAB/DOP	44.517	0.019	10.4191	0.0034	1.8056	0.0009
611	CAB/DOP	44.798	0.019	10.4850	0.0034	1.8170	0.0009
612	CAB/DOP	44.662	0.019	10.4531	0.0034	1.8115	0.0009
613	CAB/DOP	44.724	0.019	10.4676	0.0034	1.8140	0.0009
614	CAB/DOP	44.573	0.019	10.4323	0.0034	1.8079	0.0009
615	CAB/DOP	44.738	0.019	10.4709	0.0034	1.8146	0.0009
616	CAB/DOP	44.724	0.019	10.4676	0.0034	1.8140	0.0009
617	CAB/DOP	44.628	0.019	10.4452	0.0034	1.8101	0.0009
618	CAB/DOP	44.681	0.019	10.4576	0.0034	1.8123	0.0009
619	CAB/DOP	44.664	0.019	10.4535	0.0034	1.8116	0.0009
620	CAB/DOP	44.671	0.019	10.4551	0.0034	1.8118	0.0009
621	CAB/DOP	44.665	0.019	10.4539	0.0034	1.8116	0.0009
622	CAB/DOP	44.720	0.019	10.4668	0.0034	1.8139	0.0009
623	CAB/DOP	44.588	0.019	10.4357	0.0034	1.8085	0.0009
624	CAB/DOP	44.680	0.019	10.4572	0.0034	1.8122	0.0009
625	CAB/DOP	44.614	0.019	10.4419	0.0034	1.8095	0.0009
626	CAB/DOP	44.651	0.019	10.4506	0.0034	1.8111	0.0009
627	CAB/DOP	44.699	0.019	10.4618	0.0034	1.8130	0.0009
628	CAB/DOP	44.648	0.019	10.4498	0.0034	1.8109	0.0009
629	CAB/DOP	44.712	0.019	10.4647	0.0034	1.8135	0.0009
630	CAB/DOP	44.644	0.019	10.4489	0.0034	1.8108	0.0009
631	CAB/DOP	44.765	0.019	10.4771	0.0034	1.8157	0.0009
632	CAB/DOP	44.665	0.019	10.4539	0.0034	1.8116	0.0009
633	CAB/DOP	44.621	0.019	10.4435	0.0034	1.8098	0.0009
634	CAB/DOP	44.704	0.019	10.4630	0.0034	1.8132	0.0009
635	CAB/DOP	44.735	0.019	10.4701	0.0034	1.8144	0.0009
636	CAB/DOP	44.710	0.019	10.4643	0.0034	1.8134	0.0009
637	CMC	44.570	0.019	10.4315	0.0034	1.8078	0.0009
638	CAB/DOP	44.756	0.019	10.4751	0.0034	1.8153	0.0009
639	CAB/DOP	44.651	0.019	10.4506	0.0034	1.8111	0.0009
640	CAB/DOP	44.680	0.019	10.4572	0.0034	1.8122	0.0009
641	CAB/DOP	44.641	0.019	10.4481	0.0034	1.8106	0.0009
642	CAB/DOP	44.729	0.019	10.4688	0.0034	1.8142	0.0009
643	CAB/DOP	44.644	0.019	10.4489	0.0034	1.8108	0.0009
644	CAB/DOP	44.616	0.019	10.4423	0.0034	1.8096	0.0009
645	CAB/DOP	44.642	0.019	10.4485	0.0034	1.8107	0.0009
646	CAB/DOP	44.832	0.019	10.4929	0.0034	1.8184	0.0009
647	CAB/DOP	44.662	0.019	10.4531	0.0034	1.8115	0.0009
648	CAB/DOP	44.545	0.019	10.4257	0.0034	1.8067	0.0009
649	CAB/DOP	44.805	0.019	10.4867	0.0034	1.8173	0.0009
650	CAB/DOP	44.712	0.019	10.4647	0.0034	1.8135	0.0009

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

Unit #	Organic substance	^{238}U		^{235}U		^{239}Pu	
		Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
651	CAB/DOP	44.634	0.019	10.4464	0.0034	1.8103	0.0009
652	CAB/DOP	44.605	0.019	10.4398	0.0034	1.8092	0.0009
653	CAB/DOP	44.813	0.019	10.4883	0.0034	1.8176	0.0009
654	CMC	44.665	0.019	10.4539	0.0034	1.8116	0.0009
655	CAB/DOP	44.634	0.019	10.4464	0.0034	1.8103	0.0009
656	CAB/DOP	44.735	0.019	10.4701	0.0034	1.8144	0.0009
657	CAB/DOP	44.627	0.019	10.4448	0.0034	1.8101	0.0009
658	CAB/DOP	44.727	0.019	10.4684	0.0034	1.8141	0.0009
659	CAB/DOP	44.703	0.019	10.4626	0.0034	1.8131	0.0009
660	CAB/DOP	44.575	0.019	10.4328	0.0034	1.8080	0.0009
661	CAB/DOP	44.589	0.019	10.4361	0.0034	1.8085	0.0009
662	CAB/DOP	44.765	0.019	10.4771	0.0034	1.8157	0.0009
663	CAB/DOP	44.710	0.019	10.4643	0.0034	1.8134	0.0009
664	CAB/DOP	44.644	0.019	10.4489	0.0034	1.8108	0.0009
665	CAB/DOP	44.719	0.019	10.4663	0.0034	1.8138	0.0009
666	CAB/DOP	44.635	0.019	10.4469	0.0034	1.8104	0.0009
667	CAB/DOP	44.777	0.019	10.4800	0.0034	1.8162	0.0009
668	CAB/DOP	44.501	0.019	10.4153	0.0034	1.8050	0.0009
669	CAB/DOP	44.850	0.019	10.4970	0.0034	1.8191	0.0009
670	CAB/DOP	44.692	0.019	10.4601	0.0034	1.8127	0.0009
671	CAB/DOP	44.692	0.019	10.4601	0.0034	1.8127	0.0009
672	CAB/DOP	44.579	0.019	10.4336	0.0034	1.8081	0.0009
673	CMC	44.731	0.019	10.4692	0.0034	1.8143	0.0009
674	CMC	44.662	0.019	10.4531	0.0034	1.8115	0.0009
675	CMC	44.554	0.019	10.4278	0.0034	1.8071	0.0009
676	CMC	44.703	0.019	10.4626	0.0034	1.8131	0.0009
677	CMC	44.628	0.019	10.4452	0.0034	1.8101	0.0009
678	CMC	44.828	0.019	10.4921	0.0034	1.8182	0.0009
679	CMC	44.534	0.019	10.4232	0.0034	1.8063	0.0009
680	CMC	44.836	0.019	10.4937	0.0034	1.8185	0.0009
681	CMC	44.605	0.019	10.4398	0.0034	1.8092	0.0009
682	CMC	44.660	0.019	10.4527	0.0034	1.8114	0.0009
683	CMC	44.635	0.019	10.4469	0.0034	1.8104	0.0009
684	CMC	44.788	0.019	10.4825	0.0034	1.8166	0.0009
685	CMC	44.650	0.019	10.4502	0.0034	1.8110	0.0009
686	CMC	44.680	0.019	10.4572	0.0034	1.8122	0.0009
687	CMC	44.669	0.019	10.4547	0.0034	1.8118	0.0009
688	CMC	44.657	0.019	10.4518	0.0034	1.8113	0.0009
689	CMC	44.763	0.019	10.4767	0.0034	1.8156	0.0009
690	CMC	44.557	0.019	10.4286	0.0034	1.8073	0.0009
691	CMC	44.655	0.019	10.4514	0.0034	1.8112	0.0009
692	CMC	44.712	0.019	10.4647	0.0034	1.8135	0.0009
693	CMC	44.634	0.019	10.4464	0.0034	1.8103	0.0009
694	CMC	44.726	0.019	10.4680	0.0034	1.8141	0.0009
695	CMC	44.642	0.019	10.4485	0.0034	1.8107	0.0009
696	CMC	44.804	0.019	10.4862	0.0034	1.8172	0.0009
697	CMC	44.634	0.019	10.4464	0.0034	1.8103	0.0009
698	CMC	44.614	0.019	10.4419	0.0034	1.8095	0.0009
699	CMC	44.646	0.019	10.4493	0.0034	1.8108	0.0009
700	CMC	44.641	0.019	10.4481	0.0034	1.8106	0.0009

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

Unit #	Organic substance	^{238}U		^{235}U		^{239}Pu	
		Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
701	CMC	44.710	0.019	10.4643	0.0034	1.8134	0.0009
702	CMC	44.821	0.019	10.4904	0.0034	1.8180	0.0009
703	CMC	44.619	0.019	10.4431	0.0034	1.8098	0.0009
704	CMC	44.759	0.019	10.4759	0.0034	1.8154	0.0009
705	CMC	44.513	0.019	10.4182	0.0034	1.8055	0.0009
706	CMC	44.738	0.019	10.4709	0.0034	1.8146	0.0009
707	CMC	44.696	0.019	10.4610	0.0034	1.8129	0.0009
708	CMC	44.664	0.019	10.4535	0.0034	1.8116	0.0009
709	CMC	44.621	0.019	10.4435	0.0034	1.8098	0.0009
710	CMC	44.651	0.019	10.4506	0.0034	1.8111	0.0009
711	CMC	44.855	0.019	10.4983	0.0034	1.8193	0.0009
712	CMC	44.694	0.019	10.4605	0.0034	1.8128	0.0009
713	CMC	44.520	0.019	10.4199	0.0034	1.8057	0.0009
714	CMC	44.673	0.019	10.4556	0.0034	1.8119	0.0009
715	CAB/DOP	44.662	0.019	10.4531	0.0034	1.8115	0.0009
716	CAB/DOP	44.804	0.019	10.4862	0.0034	1.8172	0.0009
717	CMC	44.591	0.019	10.4365	0.0034	1.8086	0.0009
718	CAB/DOP	44.717	0.019	10.4659	0.0034	1.8137	0.0009
719	CMC	44.634	0.019	10.4464	0.0034	1.8103	0.0009
720	CMC	44.662	0.019	10.4531	0.0034	1.8115	0.0009
721	CAB/DOP	44.706	0.019	10.4634	0.0034	1.8133	0.0009
722	CAB/DOP	44.690	0.019	10.4597	0.0034	1.8126	0.0009
723	CAB/DOP	44.727	0.019	10.4684	0.0034	1.8141	0.0009
724	CAB/DOP	44.598	0.019	10.4381	0.0034	1.8089	0.0009
725	CAB/DOP	44.680	0.019	10.4572	0.0034	1.8122	0.0009
726	CAB/DOP	44.612	0.019	10.4415	0.0034	1.8095	0.0009
727	CAB/DOP	44.664	0.019	10.4535	0.0034	1.8116	0.0009
728	CAB/DOP	44.761	0.019	10.4763	0.0034	1.8155	0.0009
729	CAB/DOP	44.559	0.019	10.4290	0.0034	1.8073	0.0009
730	CAB/DOP	44.685	0.019	10.4585	0.0034	1.8124	0.0009
731	CAB/DOP	44.798	0.019	10.4850	0.0034	1.8170	0.0009
732	CAB/DOP	44.706	0.019	10.4634	0.0034	1.8133	0.0009
733	CAB/DOP	44.689	0.019	10.4593	0.0034	1.8126	0.0009
734	CAB/DOP	44.612	0.019	10.4415	0.0034	1.8095	0.0009
735	CAB/DOP	44.577	0.019	10.4332	0.0034	1.8080	0.0009
736	CAB/DOP	44.855	0.019	10.4983	0.0034	1.8193	0.0009
737	CAB/DOP	44.524	0.019	10.4207	0.0034	1.8059	0.0009
738	CAB/DOP	44.804	0.019	10.4862	0.0034	1.8172	0.0009
739	CAB/DOP	44.580	0.019	10.4340	0.0034	1.8082	0.0009
740	CAB/DOP	44.692	0.019	10.4601	0.0034	1.8127	0.0009
741	CAB/DOP	44.715	0.019	10.4655	0.0034	1.8136	0.0009
742	CAB/DOP	44.598	0.019	10.4381	0.0034	1.8089	0.0009
743	CAB/DOP	44.697	0.019	10.4614	0.0034	1.8129	0.0009
744	CMC	44.641	0.019	10.4481	0.0034	1.8106	0.0009
745	CAB/DOP	44.749	0.019	10.4734	0.0034	1.8150	0.0009
746	CAB/DOP	44.540	0.019	10.4245	0.0034	1.8065	0.0009
747	CAB/DOP	44.696	0.019	10.4610	0.0034	1.8129	0.0009
748	CAB/DOP	44.765	0.019	10.4771	0.0034	1.8157	0.0009
749	CAB/DOP	44.667	0.019	10.4543	0.0034	1.8117	0.0009
750	CAB/DOP	44.685	0.019	10.4585	0.0034	1.8124	0.0009

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

Unit #	Organic substance	^{238}U		^{235}U		^{239}Pu	
		Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
751	CAB/DOP	44.648	0.019	10.4498	0.0034	1.8109	0.0009
752	CAB/DOP	44.557	0.019	10.4286	0.0034	1.8073	0.0009
753	CAB/DOP	44.678	0.019	10.4568	0.0034	1.8121	0.0009
754	CAB/DOP	44.869	0.019	10.5016	0.0034	1.8199	0.0009
755	CAB/DOP	44.607	0.019	10.4402	0.0034	1.8093	0.0009
756	CAB/DOP	44.727	0.019	10.4684	0.0034	1.8141	0.0009
757	CAB/DOP	44.667	0.019	10.4543	0.0034	1.8117	0.0009
758	CAB/DOP	44.623	0.019	10.4440	0.0034	1.8099	0.0009
759	CAB/DOP	44.685	0.019	10.4585	0.0034	1.8124	0.0009
760	CAB/DOP	44.683	0.019	10.4581	0.0034	1.8124	0.0009
761	CAB/DOP	44.536	0.019	10.4236	0.0034	1.8064	0.0009
762	CAB/DOP	44.797	0.019	10.4846	0.0034	1.8170	0.0009
763	CAB/DOP	44.722	0.019	10.4672	0.0034	1.8139	0.0009
764	CAB/DOP	44.635	0.019	10.4469	0.0034	1.8104	0.0009
765	CAB/DOP	44.699	0.019	10.4618	0.0034	1.8130	0.0009
766	CAB/DOP	44.577	0.019	10.4332	0.0034	1.8080	0.0009
767	CAB/DOP	44.690	0.019	10.4597	0.0034	1.8126	0.0009
768	CAB/DOP	44.634	0.019	10.4464	0.0034	1.8103	0.0009
769	CMC	44.797	0.019	10.4846	0.0034	1.8170	0.0009
770	CMC	44.662	0.019	10.4531	0.0034	1.8115	0.0009
771	CMC	44.761	0.019	10.4763	0.0034	1.8155	0.0009
772	CMC	44.657	0.019	10.4518	0.0034	1.8113	0.0009
773	CMC	44.848	0.019	10.4966	0.0034	1.8190	0.0009
774	CMC	44.540	0.019	10.4245	0.0034	1.8065	0.0009
775	CMC	44.768	0.019	10.4780	0.0034	1.8158	0.0009
776	CMC	44.683	0.019	10.4581	0.0034	1.8124	0.0009
777	CMC	44.805	0.019	10.4867	0.0034	1.8173	0.0009
778	CMC	44.605	0.019	10.4398	0.0034	1.8092	0.0009
779	CMC	44.816	0.019	10.4891	0.0034	1.8177	0.0009
780	CMC	44.660	0.019	10.4527	0.0034	1.8114	0.0009
781	CMC	44.632	0.019	10.4460	0.0034	1.8103	0.0009
782	CMC	44.738	0.019	10.4709	0.0034	1.8146	0.0009
783	CMC	44.889	0.019	10.5061	0.0034	1.8207	0.0009
784	CMC	44.657	0.019	10.4518	0.0034	1.8113	0.0009
785	CMC	44.745	0.019	10.4726	0.0034	1.8149	0.0009
786	CMC	44.611	0.019	10.4410	0.0034	1.8094	0.0009
787	CMC	44.696	0.019	10.4610	0.0034	1.8129	0.0009
788	CMC	44.719	0.019	10.4663	0.0034	1.8138	0.0009
789	CMC	44.621	0.019	10.4435	0.0034	1.8098	0.0009
790	CMC	44.864	0.019	10.5003	0.0034	1.8197	0.0009
791	CMC	44.628	0.019	10.4452	0.0034	1.8101	0.0009
792	CMC	44.678	0.019	10.4568	0.0034	1.8121	0.0009
793	CMC	44.621	0.019	10.4435	0.0034	1.8098	0.0009
794	CMC	44.774	0.019	10.4792	0.0034	1.8160	0.0009
795	CMC	44.696	0.019	10.4610	0.0034	1.8129	0.0009
796	CMC	44.632	0.019	10.4460	0.0034	1.8103	0.0009
797	CMC	44.749	0.019	10.4734	0.0034	1.8150	0.0009
798	CAB/DOP	44.717	0.019	10.4659	0.0034	1.8137	0.0009
799	CMC	44.573	0.019	10.4323	0.0034	1.8079	0.0009
800	CMC	44.789	0.019	10.4829	0.0034	1.8167	0.0009

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

Unit #	Organic substance	^{238}U		^{235}U		^{239}Pu	
		Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
801	CMC	44.657	0.019	10.4518	0.0034	1.8113	0.0009
802	CMC	44.690	0.019	10.4597	0.0034	1.8126	0.0009
803	CMC	44.697	0.019	10.4614	0.0034	1.8129	0.0009
804	CMC	44.669	0.019	10.4547	0.0034	1.8118	0.0009
805	CMC	44.690	0.019	10.4597	0.0034	1.8126	0.0009
806	CMC	44.653	0.019	10.4510	0.0034	1.8111	0.0009
807	CMC	44.708	0.019	10.4639	0.0034	1.8134	0.0009
808	CMC	44.720	0.019	10.4668	0.0034	1.8139	0.0009
809	CMC	44.627	0.019	10.4448	0.0034	1.8101	0.0009
810	CMC	44.743	0.019	10.4721	0.0034	1.8148	0.0009
811	CMC	44.729	0.019	10.4688	0.0034	1.8142	0.0009
812	CMC	44.593	0.019	10.4369	0.0034	1.8087	0.0009
813	CMC	44.704	0.019	10.4630	0.0034	1.8132	0.0009
814	CMC	44.678	0.019	10.4568	0.0034	1.8121	0.0009
815	CAB/DOP	44.697	0.019	10.4614	0.0034	1.8129	0.0009
816	CMC	44.697	0.019	10.4614	0.0034	1.8129	0.0009
817 [4]	No coating	44.589	0.019	10.4361	0.0034	1.8085	0.0009
818	CMC	44.805	0.019	10.4867	0.0034	1.8173	0.0009
819[4]	No coating	44.545	0.019	10.4257	0.0034	1.8067	0.0009
820	CMC	44.704	0.019	10.4630	0.0034	1.8132	0.0009
821	CMC	44.603	0.019	10.4394	0.0034	1.8091	0.0009
822	CMC	44.772	0.019	10.4788	0.0034	1.8159	0.0009
823	CMC	44.611	0.019	10.4410	0.0034	1.8094	0.0009
824	CMC	44.580	0.019	10.4340	0.0034	1.8082	0.0009
825[4]	No coating	44.880	0.019	10.5041	0.0034	1.8203	0.0009
826	CMC	44.697	0.019	10.4614	0.0034	1.8129	0.0009
827[4]	No coating	44.611	0.019	10.4410	0.0034	1.8094	0.0009
828[4]	No coating	44.614	0.019	10.4419	0.0034	1.8095	0.0009
829[4]	No coating	44.678	0.019	10.4568	0.0034	1.8121	0.0009
830[4]	No coating	44.685	0.019	10.4585	0.0034	1.8124	0.0009
831[4]	No coating	44.648	0.019	10.4498	0.0034	1.8109	0.0009
832[4]	No coating	44.557	0.019	10.4286	0.0034	1.8073	0.0009
833	CMC	44.742	0.019	10.4717	0.0034	1.8147	0.0009
834[4]	No coating	44.627	0.019	10.4448	0.0034	1.8101	0.0009
835[4]	No coating	44.719	0.019	10.4663	0.0034	1.8138	0.0009
836[4]	No coating	44.712	0.019	10.4647	0.0034	1.8135	0.0009
837[4]	No coating	44.563	0.019	10.4299	0.0034	1.8075	0.0009
838[4]	No coating	44.816	0.019	10.4891	0.0034	1.8177	0.0009
839	CMC	44.715	0.019	10.4655	0.0034	1.8136	0.0009
840	CMC	44.641	0.019	10.4481	0.0034	1.8106	0.0009
841	CMC	44.609	0.019	10.4406	0.0034	1.8093	0.0009
842	CMC	44.703	0.019	10.4626	0.0034	1.8131	0.0009
843	CMC	44.697	0.019	10.4614	0.0034	1.8129	0.0009
844	CMC	44.580	0.019	10.4340	0.0034	1.8082	0.0009
845	CMC	44.642	0.019	10.4485	0.0034	1.8107	0.0009
846	CMC	44.752	0.019	10.4742	0.0034	1.8152	0.0009
847	CMC	44.671	0.019	10.4551	0.0034	1.8118	0.0009
848	CMC	44.623	0.019	10.4440	0.0034	1.8099	0.0009
849	CMC	44.692	0.019	10.4601	0.0034	1.8127	0.0009
850	CMC	44.722	0.019	10.4672	0.0034	1.8139	0.0009

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

Unit #	Organic substance	^{238}U		^{235}U		^{239}Pu	
		Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
851	CMC	44.593	0.019	10.4369	0.0034	1.8087	0.0009
852	CMC	44.658	0.019	10.4522	0.0034	1.8113	0.0009
853	CMC	44.726	0.019	10.4680	0.0034	1.8141	0.0009
854	CMC	44.612	0.019	10.4415	0.0034	1.8095	0.0009
855	CMC	44.722	0.019	10.4672	0.0034	1.8139	0.0009
856	CMC	44.543	0.019	10.4253	0.0034	1.8067	0.0009
857	CMC	44.802	0.019	10.4858	0.0034	1.8172	0.0009
858	CMC	44.634	0.019	10.4464	0.0034	1.8103	0.0009
859	CMC	44.644	0.019	10.4489	0.0034	1.8108	0.0009
860	CMC	44.715	0.019	10.4655	0.0034	1.8136	0.0009
861	CMC	44.683	0.019	10.4581	0.0034	1.8124	0.0009
862	CMC	44.637	0.019	10.4473	0.0034	1.8105	0.0009
863	CMC	44.586	0.019	10.4352	0.0034	1.8084	0.0009
864	CMC	44.747	0.019	10.4730	0.0034	1.8149	0.0009
865	CAB/DOP	44.756	0.019	10.4751	0.0034	1.8153	0.0009
866	CMC	44.584	0.019	10.4348	0.0034	1.8083	0.0009
867	CAB/DOP	44.722	0.019	10.4672	0.0034	1.8139	0.0009
868	CAB/DOP	44.600	0.019	10.4386	0.0034	1.8090	0.0009
869	CAB/DOP	44.674	0.019	10.4560	0.0034	1.8120	0.0009
870	CAB/DOP	44.674	0.019	10.4560	0.0034	1.8120	0.0009
871	CAB/DOP	44.641	0.019	10.4481	0.0034	1.8106	0.0009
872	CAB/DOP	44.687	0.019	10.4589	0.0034	1.8125	0.0009
873	CAB/DOP	44.552	0.019	10.4274	0.0034	1.8070	0.0009
874	CAB/DOP	44.788	0.019	10.4825	0.0034	1.8166	0.0009
875	CAB/DOP	44.681	0.019	10.4576	0.0034	1.8123	0.0009
876	CAB/DOP	44.526	0.019	10.4211	0.0034	1.8060	0.0009
877	CAB/DOP	44.655	0.019	10.4514	0.0034	1.8112	0.0009
878	CAB/DOP	44.759	0.019	10.4759	0.0034	1.8154	0.0009
879	CAB/DOP	44.685	0.019	10.4585	0.0034	1.8124	0.0009
880	CAB/DOP	44.715	0.019	10.4655	0.0034	1.8136	0.0009
881	CAB/DOP	44.588	0.019	10.4357	0.0034	1.8085	0.0009
882	CAB/DOP	44.797	0.019	10.4846	0.0034	1.8170	0.0009
883	CMC	44.529	0.019	10.4220	0.0034	1.8061	0.0009
884	CAB/DOP	44.665	0.019	10.4539	0.0034	1.8116	0.0009
885	CAB/DOP	44.664	0.019	10.4535	0.0034	1.8116	0.0009
886	CAB/DOP	44.655	0.019	10.4514	0.0034	1.8112	0.0009
887	CAB/DOP	44.703	0.019	10.4626	0.0034	1.8131	0.0009
888	CAB/DOP	44.650	0.019	10.4502	0.0034	1.8110	0.0009
889	CMC	44.627	0.019	10.4448	0.0034	1.8101	0.0009
890	CMC	44.664	0.019	10.4535	0.0034	1.8116	0.0009
891	CMC	44.639	0.019	10.4477	0.0034	1.8106	0.0009
892	CMC	44.657	0.019	10.4518	0.0034	1.8113	0.0009
893	CMC	44.671	0.019	10.4551	0.0034	1.8118	0.0009
894	CMC	44.676	0.019	10.4564	0.0034	1.8121	0.0009
895	CMC	44.623	0.019	10.4440	0.0034	1.8099	0.0009
896	CMC	44.743	0.019	10.4721	0.0034	1.8148	0.0009
897	CAB/DOP	44.690	0.019	10.4597	0.0034	1.8126	0.0009
898	CMC	44.625	0.019	10.4444	0.0034	1.8100	0.0009
899	CAB/DOP	44.751	0.019	10.4738	0.0034	1.8151	0.0009
900	CAB/DOP	44.550	0.019	10.4270	0.0034	1.8070	0.0009

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

Unit #	Organic substance	^{238}U		^{235}U		^{239}Pu	
		Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
901	CMC	44.683	0.019	10.4581	0.0034	1.8124	0.0009
902	CAB/DOP	44.660	0.019	10.4527	0.0034	1.8114	0.0009
903	CMC	44.696	0.019	10.4610	0.0034	1.8129	0.0009
904	CMC	44.596	0.019	10.4377	0.0034	1.8088	0.0009
905	CAB/DOP	44.687	0.019	10.4589	0.0034	1.8125	0.0009
906	CAB/DOP	44.660	0.019	10.4527	0.0034	1.8114	0.0009
907	CAB/DOP	44.712	0.019	10.4647	0.0034	1.8135	0.0009
908	CAB/DOP	44.674	0.019	10.4560	0.0034	1.8120	0.0009
909	CAB/DOP	44.561	0.019	10.4294	0.0034	1.8074	0.0009
910	CAB/DOP	44.830	0.019	10.4925	0.0034	1.8183	0.0009
911	CMC	44.637	0.019	10.4473	0.0034	1.8105	0.0009
912	CMC	44.623	0.019	10.4440	0.0034	1.8099	0.0009
913	CMC	44.651	0.019	10.4506	0.0034	1.8111	0.0009
914	CMC	44.563	0.019	10.4299	0.0034	1.8075	0.0009
915	CMC	44.678	0.019	10.4568	0.0034	1.8121	0.0009
916	CMC	44.751	0.019	10.4738	0.0034	1.8151	0.0009
917	CMC	44.554	0.019	10.4278	0.0034	1.8071	0.0009
918	CMC	44.650	0.019	10.4502	0.0034	1.8110	0.0009
919	CMC	44.655	0.019	10.4514	0.0034	1.8112	0.0009
920	CMC	44.754	0.019	10.4746	0.0034	1.8152	0.0009
921	CMC	44.586	0.019	10.4352	0.0034	1.8084	0.0009
922	CMC	44.655	0.019	10.4514	0.0034	1.8112	0.0009
923	CMC	44.627	0.019	10.4448	0.0034	1.8101	0.0009
924	CMC	44.800	0.019	10.4854	0.0034	1.8171	0.0009
925	CMC	44.499	0.019	10.4149	0.0034	1.8049	0.0009
926	CMC	44.774	0.019	10.4792	0.0034	1.8160	0.0009
927	CMC	44.713	0.019	10.4651	0.0034	1.8136	0.0009
928	CMC	44.591	0.019	10.4365	0.0034	1.8086	0.0009
929	CAB/DOP	44.697	0.019	10.4614	0.0034	1.8129	0.0009
930	CMC	44.625	0.019	10.4444	0.0034	1.8100	0.0009
931	CMC	44.708	0.019	10.4639	0.0034	1.8134	0.0009
932	CMC	44.518	0.019	10.4195	0.0034	1.8057	0.0009
933	CMC	44.749	0.019	10.4734	0.0034	1.8150	0.0009
934	CMC	44.639	0.019	10.4477	0.0034	1.8106	0.0009
935	CMC	44.708	0.019	10.4639	0.0034	1.8134	0.0009
936	CMC	44.738	0.019	10.4709	0.0034	1.8146	0.0009
937	CMC	44.579	0.019	10.4336	0.0034	1.8081	0.0009
938	CMC	44.660	0.019	10.4527	0.0034	1.8114	0.0009
939	CMC	44.618	0.019	10.4427	0.0034	1.8097	0.0009
940	CMC	44.685	0.019	10.4585	0.0034	1.8124	0.0009
941	CMC	44.605	0.019	10.4398	0.0034	1.8092	0.0009
942	CMC	44.632	0.019	10.4460	0.0034	1.8103	0.0009
943	CMC	44.703	0.019	10.4626	0.0034	1.8131	0.0009
944	CMC	44.642	0.019	10.4485	0.0034	1.8107	0.0009
945	CMC	44.685	0.019	10.4585	0.0034	1.8124	0.0009
946	CAB/DOP	44.740	0.019	10.4713	0.0034	1.8147	0.0009
947	CMC	44.504	0.019	10.4162	0.0034	1.8051	0.0009
948	CMC	44.664	0.019	10.4535	0.0034	1.8116	0.0009
949	CMC	44.669	0.019	10.4547	0.0034	1.8118	0.0009
950	CMC	44.696	0.019	10.4610	0.0034	1.8129	0.0009

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

Unit #	Organic substance	^{238}U		^{235}U		^{239}Pu	
		Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
951	CMC	44.628	0.019	10.4452	0.0034	1.8101	0.0009
952	CMC	44.669	0.019	10.4547	0.0034	1.8118	0.0009
953	CMC	44.662	0.019	10.4531	0.0034	1.8115	0.0009
954	CMC	44.673	0.019	10.4556	0.0034	1.8119	0.0009
955	CMC	44.642	0.019	10.4485	0.0034	1.8107	0.0009
956	CMC	44.602	0.019	10.4390	0.0034	1.8090	0.0009
957	CMC	44.671	0.019	10.4551	0.0034	1.8118	0.0009
958	CMC	44.658	0.019	10.4522	0.0034	1.8113	0.0009
959	CMC	44.552	0.019	10.4274	0.0034	1.8070	0.0009
960	CMC	44.697	0.019	10.4614	0.0034	1.8129	0.0009
961	CAB/DOP	44.712	0.019	10.4647	0.0034	1.8135	0.0009
962	CAB/DOP	44.497	0.019	10.4145	0.0034	1.8048	0.0009
963	CAB/DOP	44.731	0.019	10.4692	0.0034	1.8143	0.0009
964	CAB/DOP	44.460	0.019	10.4058	0.0034	1.8033	0.0009
965	CAB/DOP	44.630	0.019	10.4456	0.0034	1.8102	0.0009
966	CAB/DOP	44.689	0.019	10.4593	0.0034	1.8126	0.0009
967	CAB/DOP	44.612	0.019	10.4415	0.0034	1.8095	0.0009
968	CAB/DOP	44.630	0.019	10.4456	0.0034	1.8102	0.0009
969	CAB/DOP	44.579	0.019	10.4336	0.0034	1.8081	0.0009
970	CAB/DOP	44.646	0.019	10.4493	0.0034	1.8108	0.0009
971	CAB/DOP	44.630	0.019	10.4456	0.0034	1.8102	0.0009
972	CAB/DOP	44.513	0.019	10.4182	0.0034	1.8055	0.0009
973	CAB/DOP	44.694	0.019	10.4605	0.0034	1.8128	0.0009
974	CAB/DOP	44.627	0.019	10.4448	0.0034	1.8101	0.0009
975	CAB/DOP	44.607	0.019	10.4402	0.0034	1.8093	0.0009
976	CAB/DOP	44.650	0.019	10.4502	0.0034	1.8110	0.0009
977	CAB/DOP	44.517	0.019	10.4191	0.0034	1.8056	0.0009
978	CAB/DOP	44.676	0.019	10.4564	0.0034	1.8121	0.0009
979	CAB/DOP	44.641	0.019	10.4481	0.0034	1.8106	0.0009
980	CAB/DOP	44.582	0.019	10.4344	0.0034	1.8083	0.0009
981	CAB/DOP	44.651	0.019	10.4506	0.0034	1.8111	0.0009
982	CAB/DOP	44.572	0.019	10.4319	0.0034	1.8078	0.0009
983	CAB/DOP	44.680	0.019	10.4572	0.0034	1.8122	0.0009
984	CAB/DOP	44.602	0.019	10.4390	0.0034	1.8090	0.0009
985	CAB/DOP	44.625	0.019	10.4444	0.0034	1.8100	0.0009
986	CAB/DOP	44.609	0.019	10.4406	0.0034	1.8093	0.0009
987	CAB/DOP	44.510	0.019	10.4174	0.0034	1.8053	0.0009
988	CAB/DOP	44.779	0.019	10.4804	0.0034	1.8162	0.0009
989	CAB/DOP	44.543	0.019	10.4253	0.0034	1.8067	0.0009
990	CAB/DOP	44.653	0.019	10.4510	0.0034	1.8111	0.0009
991	CAB/DOP	44.517	0.019	10.4191	0.0034	1.8056	0.0009
992	CAB/DOP	44.745	0.019	10.4726	0.0034	1.8149	0.0009
993	CAB/DOP	44.501	0.019	10.4153	0.0034	1.8050	0.0009
994	CAB/DOP	44.722	0.019	10.4672	0.0034	1.8139	0.0009
995	CAB/DOP	44.637	0.019	10.4473	0.0034	1.8105	0.0009
996	CAB/DOP	44.534	0.019	10.4232	0.0034	1.8063	0.0009
997	CAB/DOP	44.719	0.019	10.4663	0.0034	1.8138	0.0009
998	CAB/DOP	44.572	0.019	10.4319	0.0034	1.8078	0.0009
999	CAB/DOP	44.614	0.019	10.4419	0.0034	1.8095	0.0009
1000	CAB/DOP	44.678	0.019	10.4568	0.0034	1.8121	0.0009

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

Unit #	Organic substance	^{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	CAB/DOP	44.506	0.019	10.4166	0.0034	1.8052	0.0009
1002	CMC	44.687	0.019	10.4589	0.0034	1.8125	0.0009
1003	CAB/DOP	44.508	0.019	10.4170	0.0034	1.8052	0.0009
1004	CAB/DOP	44.712	0.019	10.4647	0.0034	1.8135	0.0009
1005	CAB/DOP	44.598	0.019	10.4381	0.0034	1.8089	0.0009
1006	CAB/DOP	44.602	0.019	10.4390	0.0034	1.8090	0.0009
1007	CAB/DOP	44.625	0.019	10.4444	0.0034	1.8100	0.0009
1008	CAB/DOP	44.425	0.019	10.3975	0.0034	1.8019	0.0009

[1] The certified values are traceable to the values on the respective metal certificates (EC NRM 101, NBL CRM 116-A and CETAMA MP2). The reference date for the mass of ^{238}U, ^{235}U and ^{239}Pu per vial is November 1, 2018.
[2] The 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.
[3] 5 vials were excluded excluded from the certification process based on barcode failure and because of splashing during dispensing or before drying.
[4] 14 vials are reserved for experimental purposes without coating.
The atomic masses of radionuclides were obtained from Wang et al. (The AME 2016 atomic mass evaluation (II). Tables, Graphs and References, Chinese Physics C, Vol. 41, No. 3, 2017).
The half-lives of radionuclides were obtained from DDEP-BIPM (Table of radionuclides) and R. Wellum et al. (A new evaluation of the half-life of ^{241}Pu, J. Anal. At. Spectrom., 24, 801-807, 2009).

The Nuclear Material Catalogue can be found on the Science Hub:
https://ec.europa.eu/jrc/sites/jrcsh/files/nuclear_catalogue_2019.pdf

European Commission – Joint Research Centre
Directorate G – Nuclear Safety and Security
G.2 – Standards for Nuclear Safety, Security and Safeguards Unit
Retieseweg 111, B - 2440 Geel (Belgium)

Annex 2 The certificate of EC NRM 101 uranium metal

Certified Nuclear Reference Material

Certificate of Analysis

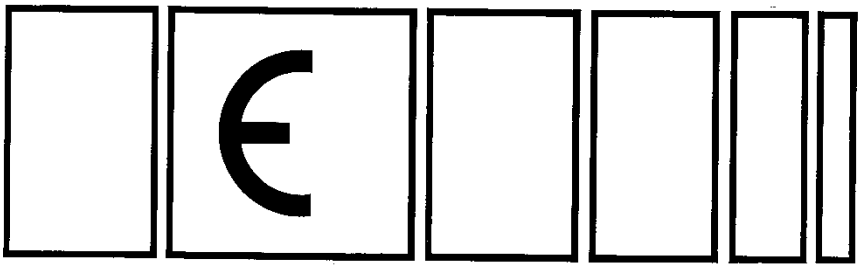
EC NUCLEAR REFERENCE MATERIAL NO. 101

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 isotopic composition of EC NRM 101

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)	0.0072593		+/- 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 4 The certificate of NBL PO CRM 116-A uranium metal

New Brunswick Laboratory
U.S. Department of Energy

Certificate of Analysis
CRM 116-A
Uranium (enriched) Metal Assay and Isotopic Standard

Certified Property Values

Amount Content	Value	Expanded[1] Uncertainty	Isotope-Amount Ratio	Value	Expanded[1] Uncertainty
g U•g^{-1} metal	0.99945	0.00014	$n(^{233}U)/n(^{235}U)$	0.0000003863	0.0000000086
			$n(^{234}U)/n(^{235}U)$	0.0115836	0.0000097
Molar Mass	Value	Expanded[1] Uncertainty	$n(^{236}U)/n(^{235}U)$	0.0094713	0.0000077
g•mol^{-1}	235.18572	0.00011	$n(^{238}U)/n(^{235}U)$	0.051277	0.000041
Isotope-Amount Fraction (•100)	Value	Expanded[1] Uncertainty	Isotope Mass Fraction (•100)	Value	Expanded[1] Uncertainty
$n(^{233}U)/n(U)$	0.00003603	0.00000080	$m(^{233}U)/m(U)$	0.00003570	0.00000079
$n(^{234}U)/n(U)$	1.08023	0.00089	$m(^{234}U)/m(U)$	1.07497	0.00088
$n(^{235}U)/n(U)$	93.2547	0.0038	$m(^{235}U)/m(U)$	93.1985	0.0038
$n(^{236}U)/n(U)$	0.88324	0.00071	$m(^{236}U)/m(U)$	0.88647	0.00071
$n(^{238}U)/n(U)$	4.7818	0.0036	$m(^{238}U)/m(U)$	4.8401	0.0037

[1] Expanded uncertainties for certified property values have a coverage factor of approximately 2.0 with the exception of the amount content value which has a coverage factor of 2.4 and the ^{233}U values which have a coverage factor of 3.3 for isotope amount ratio, isotope-amount fraction, and isotope mass fraction.

Notes:

Certified Reference Material 116-A (CRM 116-A) is a uranium amount content and isotope-amount ratio standard intended for use in calibration of and/or quality control for uranium analysis methods. Each unit of CRM 116-A consists of a metal piece with a mass of approximately 1.1 grams. This CRM is not characterized for total quantity of material which may be somewhat greater or less than the nominal mass (between 1.0 g and 1.2 g).

CRM 116-A is a radioactive material and should be handled and stored under proper radiologically-controlled conditions at all times.

October 31, 2013
Steven Bakhtiar
Laboratory Director

Page 1 of 3

New Brunswick Laboratory
Argonne, Illinois
www.science.energy.gov/nbl

CRM 116-A units do not have an expiration date. To maintain the integrity of an unused unit, it should remain in the original packaging and should be stored in a dry, temperature controlled location.

Measurements for uranium amount content and isotope-amount ratios were performed on metal samples with a mass of 1.1 gram or greater. The homogeneity of uranium amount content or isotopic composition has not been assessed for metal pieces smaller than 1.1 gram. Prior to use, surface oxide must be removed to ensure accurate uranium amount content values. A suggested procedure is provided below.

Suggested Preparation Procedure for Achieving Accurate Mass and Amount Content Values

1. Cover the uranium metal sample in 8 $mol \cdot L^{-1}$ nitric acid for 10-20 minutes to remove all visible surface oxides.
2. To minimize oxidation of the sample and ensure an accurate determination of uranium metal mass, the following steps should be performed immediately following Step 1.
   2.1 Thoroughly rinse the metal piece with distilled, deionized water.
   2.2 Remove excess water by thoroughly rinsing the metal piece with pure acetone.
   2.3 Allow the acetone to evaporate (30 – 60 seconds is typically sufficient).
   2.4 Perform a weighing of sufficient accuracy and precision for user's need.

Description:

The CRM 116-A metal pieces are machined metal cylinders. The stock material for the CRM was obtained from a single casting of a HEU right-annular cylinder of metal. Several wedges of material were cut from the annular cylinder and machined into rods which were stamped into narrow-diameter rods. The rods were then machined to shape and cut into the individual 1.1-gram metal cylinders that comprise each CRM 116-A unit.

Uranium amount content for CRM 116-A was determined by the NBL High Precision Titrimetric method using CRM 99 Potassium Dichromate Oxidimetric Standard as the titrant. The CRM 112-A Uranium Metal Assay and Isotopic Standard was used as a control to verify performance of the measurement system. Traceability of the measurements is primarily established by direct determination of uranium amount content based on the titration of uranium using CRM 99 Potassium Dichromate Oxidimetric Standard. CRM 99 was calibrated against CRM 112-A which, in turn, was originally provided by the National Bureau of Standards (now known as the National Institute of Standards and Technology) as SRM 960.

A detailed thermal ionization mass spectrometry measurement campaign was performed on CRM 116-A to determine uranium isotope-amount ratios and uncertainties. Mass discrimination calibrations were performed on a sample turret basis using multiple measurements of NBL Uranium Isotopic Standards U900 and U930-D. Analyses of CRM U970 Uranium Isotopic Standard were performed to verify that mass spectrometric measurements were in control. Traceability of the isotope-amount ratio measurements for CRM 116-A was established by calibration of the mass spectrometers using combined measurements of CRMs U900 and U930-D Uranium Isotopic Standards. CRM 900 was originally provided by the National Bureau of Standards (now known as the National Institute of Standards and Technology) as SRM U900. U930-D is directly traceable to National Bureau of Standards SRM U930 Uranium Isotopic Standard.

Measurement Uncertainty:

Reported numerical uncertainties for values are expressed as expanded uncertainties ($U = k \cdot u_c$) at the 95% level of confidence, where the expanded uncertainty (U) is the product of the combined standard uncertainty (u_c) and a coverage factor (k). The last figure in reported values and uncertainties is provided for information purposes and is not intended to convey a significant degree of reliability. The isotope-amount and weight fraction values and uncertainties are provided primarily for information purposes. To assure proper uncertainty propagation, it is recommended that isotope-amount ratios and associated uncertainties be used for calculations incorporating CRM 116-A values.

Uncertainties were determined according to the protocols outlined in JCGM 100:2008 *Guide to the Expression of Uncertainty in Measurement*. The combined standard uncertainties for attribute values consist of Type A and Type B components. The Type A uncertainty components for amount content is derived from the standard deviation of high precision titrations performed on 1.1 g U metal samples and the standard uncertainty for the primary analytical amount content measurements, which utilized 3-g U metal samples. The Type B component is the combined standard uncertainty of the CRM 99 oxidimetric standard. The Type A components for isotope-amount ratios are derived from standard deviations associated with isotopic ratio measurements of the samples and the $n(^{238}U)/n(^{235}U)$ ratio of NBL CRMs U900 and U930-D. Type B components are based on the combined standard uncertainties for the $n(^{238}U)/n(^{235}U)$ ratios of CRMs U900 and U930-D and components to account for additional sources of uncertainty associated with background corrections and analytical biases. Isotope mass fractions incorporate an additional Type B component associated with the uncertainty of the atomic mass for the U isotopes. The coverage factor (k) for each expanded uncertainty is based on the effective degrees of freedom for that quantity and is the Student's t-factor necessary to provide a 95% level of confidence ($k \approx 2.0$ for the values cited in this certificate except for the amount content value with $k = 2.4$ and the ^{233}U isotope amount ratio, amount fraction, and mass fraction which have coverage factors of $k = 3.3$). A more detailed explanation of measurement uncertainty can be obtained upon request from NBL.

References:

Bureau International des Poids et Measures (BIPM), Evaluation of Measurement Data - Guide to the Expression of Uncertainty in Measurement, JCGM 100: 2008.

Annex 5 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

Rodrigue

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
30207 BAGNOLS SUR CEZE CEDEX
Téléphone 04.66.79.69.88 - Télécopie 04.66.79.69.89

Annex 6 The certificate of plutonium isotope abundances of CETAMA MP2

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·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 7 The certificate of uranium amount content and isotope abundances of CETAMA MP2

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

CERTIFICATE of a reference measurement

IM/MeaC/06/06-MP2
6 March 2006

1. Applicant: DEN/DRCP CETAMA
CEA/VALRHO/Marcoule - B.P. 17171
30207 BAGNOLS-SUR-CEZE cedex

2. Sample Identification:
- MP2 – uranium fraction
- chemical form: in 4 M HNO_3 solution
- IM sample registration number: IM-NUCLEAR-2006-02-00700

3. Measurands:
- Element amount content: **2.798 6(25) µmol (U)·g^{-1}**
657.99(58) µg (U)·g^{-1}
- Isotopic composition

isotope amount ratio(s)	
$n(^{233}U)/n(^{235}U)$	N/A (spiked with ^{233}U)
$n(^{234}U)/n(^{235}U)$	0.009 005 0(38)
$n(^{236}U)/n(^{235}U)$	0.082 571(28)
$n(^{238}U)/n(^{235}U)$	N/A (set to ^{238}U=0)

amount fraction (·100)		mass fraction (·100)	
$n(^{233}U)/n(U)$	N/A	$m(^{233}U)/m(U)$	N/A
$n(^{234}U)/n(U)$	0.8 249 5(36)	$m(^{234}U)/m(U)$	0.8 212 0(35)
$n(^{235}U)/n(U)$	91.610 7(22)	$m(^{235}U)/m(U)$	91.584 4(22)
$n(^{236}U)/n(U)$	7.564 4(24)	$m(^{236}U)/m(U)$	7.594 4(24)
$n(^{238}U)/n(U)$	N/A	$m(^{238}U)/m(U)$	N/A

molar mass: 235.111 416(26) g·mol^{-1}

Retieseweg, B-2440 Geel, BelgiumTel.: +32-(0)14-571 211 • Fax: +32-(0)14-571 863 • http://www.irmm.jrc.be

4. Date of receipt of sample : NA
Date of completion of measurement : 20 February 2006

5. Uncertainty:
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. 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 content and ratios; other values are derived from them. Reproducing the derived values may result in differences due to rounding errors.
The detailed uncertainty budget for the uranium amount content is enclosed (see Attachment).

6. Analytical measurement procedure

- Sample preparation has been accomplished by a chemical conditioning and subsequent separation on ion exchanger.
- Analytical method/technique used : Isotope Dilution by ThIMS
- Measurement of uranium Isotopic Ratios by the TRITON TIMS mass spectrometer.
- Reference number of the measurement data: S:\D04-IM\Secure Data\ARCHIVE IM Measurements data files\TRITON\TRITON DATA MP-2-01 T6216
- The atomic masses, used in the calculations, are[1]
  ^{238}Pu : 238.049 552 5(44) g·mol^{-1}
  ^{239}Pu : 239.052 155 6(44) g·mol^{-1}
  ^{240}Pu : 240.053 806 5(42) g·mol^{-1}
  ^{241}Pu : 241.056 844 4(42) g·mol^{-1}
  ^{242}Pu : 242.058 735 9(42) g·mol^{-1}
  ^{244}Pu : 244.064 197(10) g·mol^{-1}
- The half lives used in the calculations are
  ^{238}Pu : 8.77 (03) · 10^1 a[2]
  ^{239}Pu : 2.411 (03) · 10^4 a[2]
  ^{240}Pu : 6.563 (07) · 10^3 a[2]
  ^{241}Pu : 1.429 (06) · 10^1 a[3]
  ^{242}Pu : 3.735 (11) · 10^5 a[2]
  ^{244}Pu : 8.00 (09) · 10^7 a[2]

- Metrological weighings are performed by R Eykens. Mass spectrometric measurements were performed by S Richter using the TRITON TIMS mass spectrometer, using samples prepared by F. Kehoe and R. Eykens. A Verbruggen was responsible for the preparation and issuance of the certificate.

André Verbruggen
Task leader

Copies: P Taylor, IM Unit Head, R Wellum, S Richter, F Kehoe, R Eykens, Archive

[1] G. Audi and A.H. Wapstra, The 1993 atomic mass evaluation , Nucl Phys A565 (1993) 1-65.
[2] IAEA, Decay data of the Transactinium Nuclides, Technical Reports Series No. 261, 1986
[3] P. De Bièvre, A. Verbruggen, 'A new measurement of the ^{241}Pu half-life by isotope mass spectrometry', Int. Conf. on Nuclear Data for Science and Technology, May 19-24, 1997 Trieste, Italy

Uncertainty budget for isotope amount content

Quantity	Value	Standard uncertainty	%
mass of spike (g)	0.519 500	0.000 029	1.6
amount content spike (mol/g)	$4.299\,30 \cdot 10^{-6}$	$0.000\,34 \cdot 10^{-6}$	3.2
mass content MP2 solution (g/g)	$0.917\,679 \cdot 10^{-3}$	$0.000\,238 \cdot 10^{-3}$	34.2
mass MP2 solution (g)	150.322 90	0.000 87	0.0
$n(^{234}U)/n(^{233}U)$ in blend (mol/mol)	0.001 785 173	0.000 000 304	0.3
$n(^{235}U)/n(^{233}U)$ in blend (mol/mol)	0.158 356 4	0.000 053 0	54.0
$n(^{236}U)/n(^{233}U)$ in blend (mol/mol)	0.010 307 547	0.000 006 57	6.7

Annex 8 The certificate of IRMM-046c

EUROPEAN COMMISSION
JOINT RESEARCH CENTRE

Directorate G – Nuclear Safety and Security
G.2 – Standards for Nuclear Safety, Security and Safeguards Unit

CERTIFIED REFERENCE MATERIAL
IRMM – 046c

CERTIFICATE OF ANALYSIS

NITRIC ACID SOLUTION		
	Isotope amount content	
	Certified value [1] [µmol/g]	Uncertainty [2] [µmol/g]
^{242}Pu	0.35498	0.00014
^{233}U	4.4636	0.0010
	Isotope amount ratio	
	Certified value [1] [mol/mol]	Uncertainty [2] [mol/mol]
$n(^{234}U)/n(^{233}U)$	0.0001939	0.0000012
$n(^{235}U)/n(^{233}U)$	0.0000735	0.0000023
$n(^{236}U)/n(^{233}U)$	0.0000038	0.0000018
$n(^{238}U)/n(^{233}U)$	0.0021043	0.0000039
$n(^{238}Pu)/n(^{242}Pu)$	0.0053359	0.0000049
$n(^{239}Pu)/n(^{242}Pu)$	0.0022699	0.0000014
$n(^{240}Pu)/n(^{242}Pu)$	0.046084	0.000037
$n(^{241}Pu)/n(^{242}Pu)$	0.0029924	0.0000032
$n(^{244}Pu)/n(^{242}Pu)$	0.00025739	0.00000049

[1] The certified values are traceable to the International System of units (SI) via IRMM-1027m. The reference date for the certified values is July 1, 2010.
[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 material are carried out.

Geel, January 2014

Last revision January 2017

Signed: 10/02/2017

Dr. Willy Mondelaers
European Commission
Joint Research Centre
Directorate G – Nuclear Safety and Security
G.2 – Standard for Nuclear safety, Security and Safeguards
Retieseweg 111
B-2440 Geel, Belgium

Derived Values

	Isotopic mass fraction	
	Value [1] [%]	Uncertainty [2] [%]
$m(^{233}U)/m(U)\times100$	99.75836	0.00051
$m(^{234}U)/m(U)\times100$	0.01942	0.00012
$m(^{235}U)/m(U)\times100$	0.00740	0.00023
$m(^{236}U)/m(U)\times100$	0.00038	0.00019
$m(^{238}U)/m(U)\times100$	0.21443	0.00040
$m(^{238}Pu)/m(Pu)\times100$	0.49672	0.00044
$m(^{239}Pu)/m(Pu)\times100$	0.21220	0.00012
$m(^{240}Pu)/m(Pu)\times100$	4.3261	0.0033
$m(^{241}Pu)/m(Pu)\times100$	0.28208	0.00030
$m(^{242}Pu)/m(Pu)\times100$	94.6583	0.0038
$m(^{244}Pu)/m(Pu)\times100$	0.024364	0.000046
	Amount content	
	Value [1] [µmol/g]	Uncertainty [2] [µmol/g]
Pu	0.37519	0.00015
U	4.4742	0.0010
	Mass fraction	
	Value [1] [mg/g]	Uncertainty [2] [mg/g]
Pu	0.090775	0.000037
U	1.04271	0.00024

[1] The derived values are obtained from the certified values. The reference date for the derived values is July 1, 2010.
[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.

DESCRIPTION OF THE MATERIAL

The IRMM-046c is a mixed uranium-plutonium spike Isotopic Reference Material suplied with an isotope amount content of ^{233}U and ^{242}Pu and isotope amount ratios as certified above. A unit of IRMM-046c consists of a glass ampoule with a screw cap containing about 10 mg uranium and 1 mg plutonium in a 10 mL of nitric acid solution. The molarity is about 5 $mol \cdot L^{-1}$.

ANALYTICAL METHODS USED FOR CERTIFICATION

The certified values were established by isotope dilution mass spectrometry (IDMS) on a randomly selected units of IRMM-046c. The isotope ratio measurements were performed on a Triton TIMS (Thermo Fisher Scientific) using total evaporation method. Pu standard IRMM-290/A3 and U standard IRMM-074/10 were used to correct for the mass fractionation effects during isotopic measurement.

SAFETY INFORMATION

The IRMM-046c contains radioactive material. The ampoules 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 spike Isotopic Reference Material (IRM) is used as a calibrant to determine the plutonium and uranium amount content by isotope dilution mass spectrometry (IDMS).

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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(b) assume any liability with respect to, or for damages resulting from, the use of any information, material, apparatus, method or process disclosed in this document save for loss or damage arising solely and directly from the negligence of JRC or any of its subsidiaries.

LEGAL NOTICE

A technical report on the preparation of IRMM-046c can be obtained from JRC Directorate G – Nuclear Safety and Security, G.2 – Standards for Nuclear Safety, Security and Safeguards unit in Geel, Belgium on request.

European Commission – Joint Research Centre
Directorate G – Nuclear Safety and Security
G.2 – Standards for Nuclear safety, Security and Safeguards Unit
Retieseweg 111, B - 2440 Geel (Belgium)

Annex 9 Results of the process control measurements (4 blends, 3 replicates) for ^{235}U, ^{238}U and ^{239}Pu amount content in the mother solution of IRMM-1027u

Figure 11 The amount content of ^{235}U in the mother solution of IRMM-1027u measured by ID-TIMS using IRMM-046c (blue diamonds) spike CRM expressed as the relative difference from the gravimetric value (the average difference is 0.052 %). Error bars show the relative expanded uncertainties (coverage factor k = 2). Red dotted lines show the relative expanded uncertainty (k = 2) of the gravimetric value

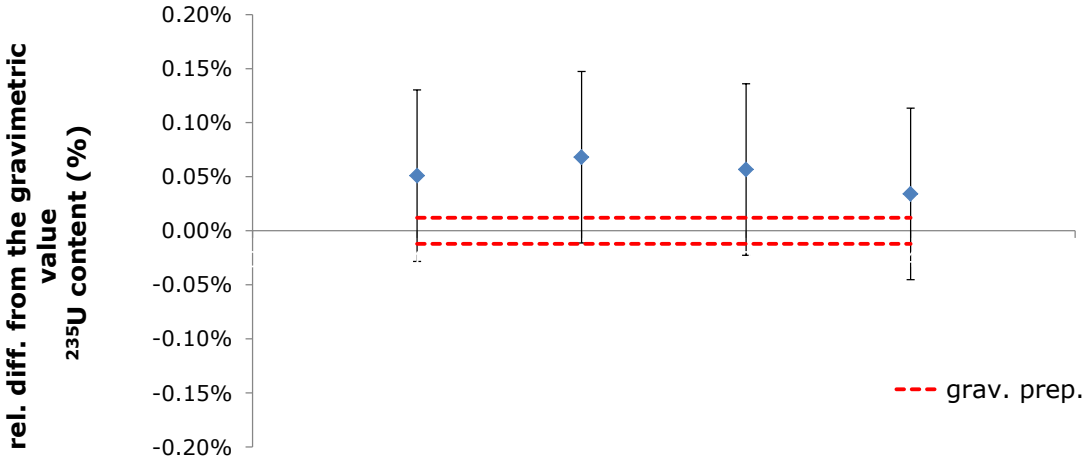


Figure 12 The amount content of ^{238}U in the mother solution of IRMM-1027u measured by ID-TIMS using IRMM-046c (blue diamonds) spike CRM expressed as the relative difference from the gravimetric value (the average difference is 0.020 %). Error bars show the relative expanded uncertainties (coverage factor k = 2). Red dotted lines show the relative expanded uncertainty (k = 2) of the gravimetric value

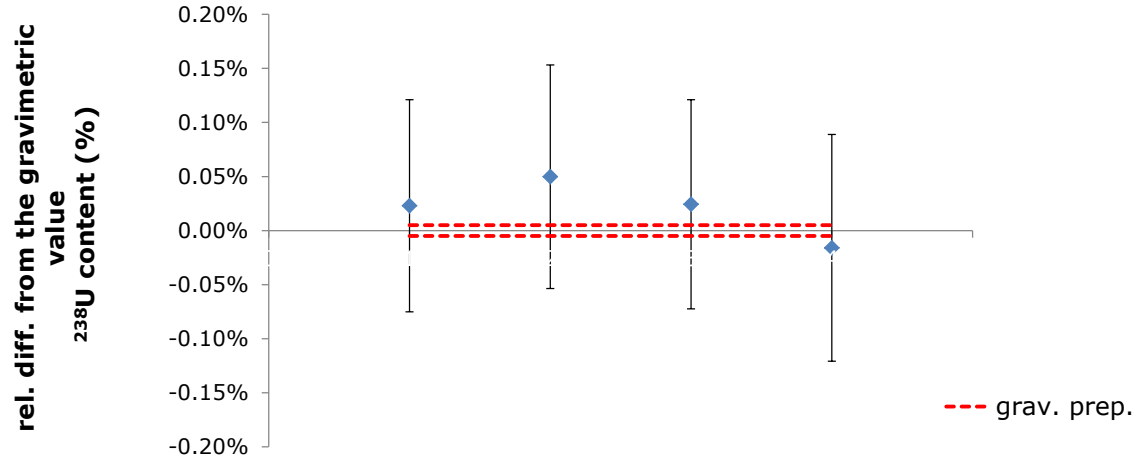
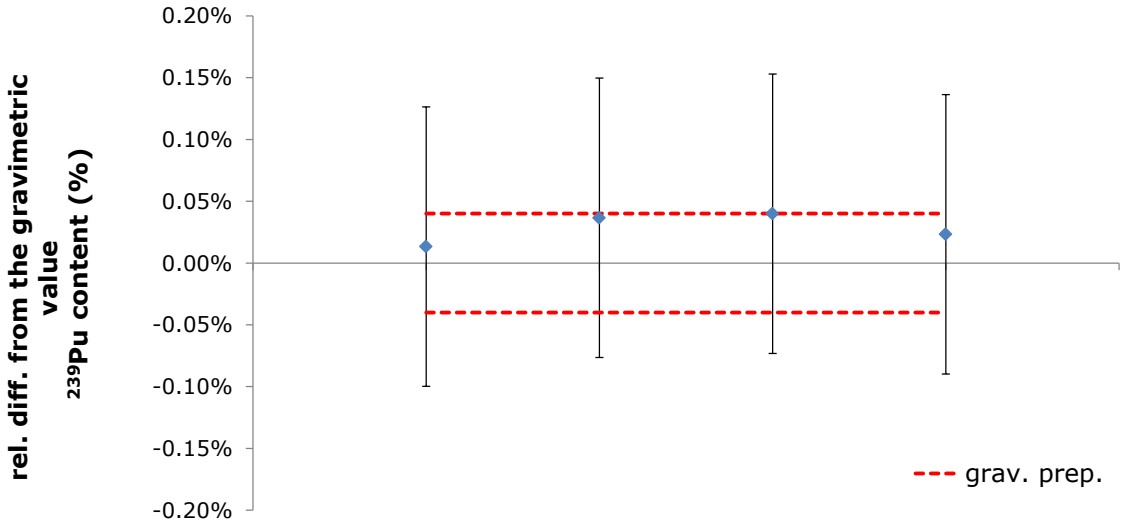


Figure 13 The amount content of ^{239}Pu in the mother solution of IRMM-1027u measured by ID-TIMS using IRMM-046c (blue diamonds) spike CRM expressed as the relative difference from the gravimetric value (the average difference is 0.028 %). Error bars show the relative expanded uncertainties (coverage factor k = 2). Red dotted lines show the relative expanded uncertainty (k = 2) of the gravimetric value



Annex 10 Results of the process control measurements (4 aliquots, 3 replicates) for the uranium and plutonium isotope amount ratios in the mother solution of IRMM-1027u

Figure 14 The $n(^{234}U)/n(^{238}U)$ amount ratio in the solution of IRMM-1027u prepared by gravimetric mixing compared with the measured values by TIMS (individual aliquots with blue diamonds and the average value with a green diamond). Error bars show the expanded uncertainties (coverage factor $k = 2$)

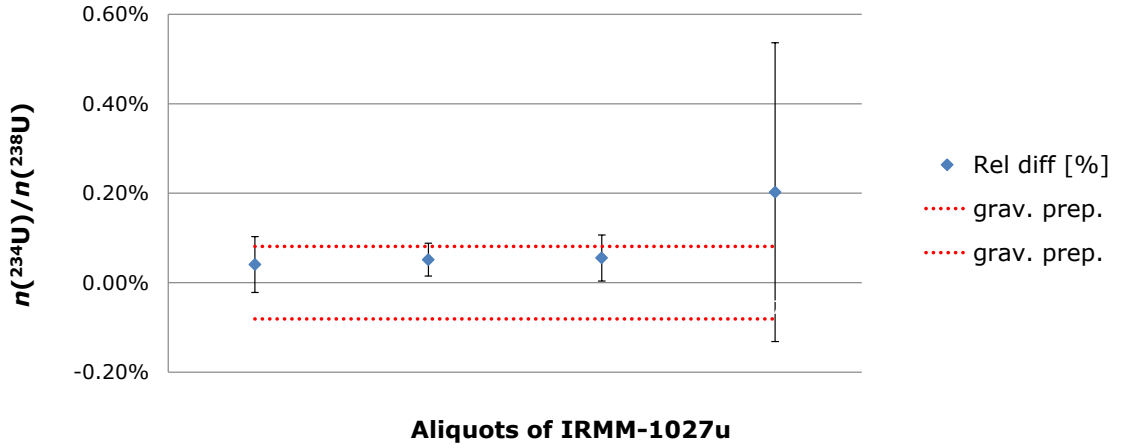


Figure 15 The $n(^{235}U)/n(^{238}U)$ amount ratio in the solution of IRMM-1027u prepared by gravimetric mixing compared with the measured values by TIMS (individual aliquots with blue diamonds and the average value with a green diamond). Error bars show the expanded uncertainties (coverage factor $k = 2$)

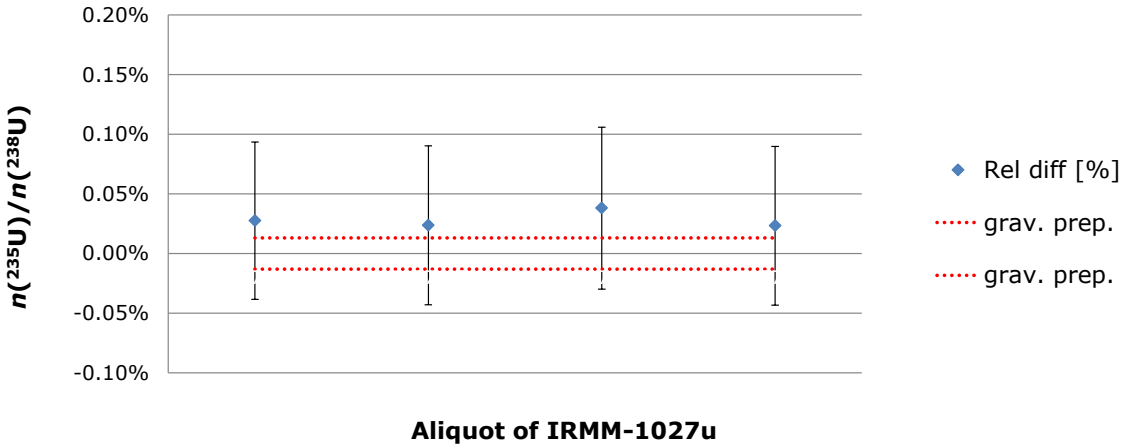


Figure 16 The $n(^{236}U)/n(^{238}U)$ amount ratio in the solution of IRMM-1027u prepared by gravimetric mixing compared with the measured values by TIMS (individual aliquots with blue diamonds and the average value with a green diamond). Error bars show the expanded uncertainties (coverage factor $k = 2$)

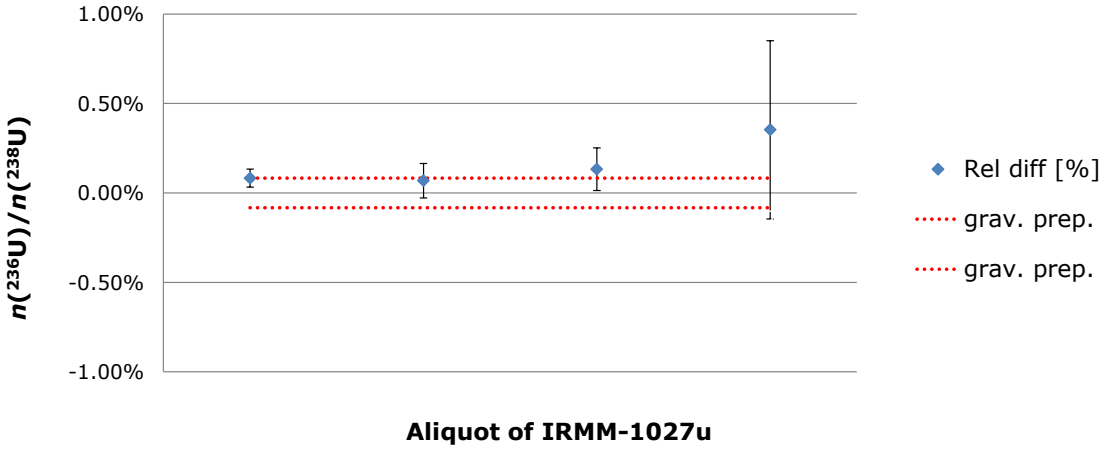


Figure 17 The $n(^{238}Pu)/n(^{239}Pu)$ amount ratio in the solution of IRMM-1027u prepared by gravimetric mixing compared with the measured values by TIMS (blue diamonds). Error bars show the expanded uncertainties (coverage factor $k = 2$)

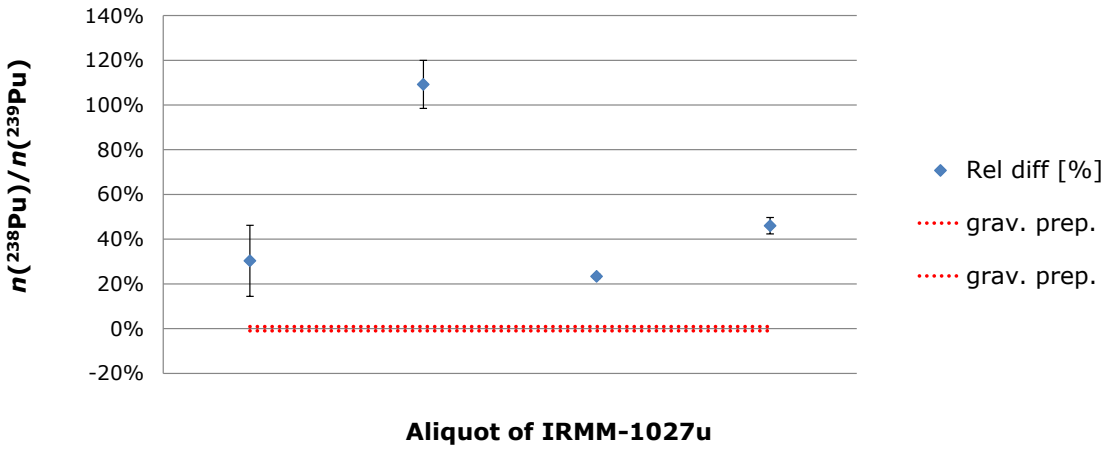


Figure 18 The $n(^{240}Pu)/n(^{239}Pu)$ amount ratio in the solution of IRMM-1027u prepared by gravimetric mixing compared with the measured values by TIMS (blue diamonds). Error bars show the expanded uncertainties (coverage factor k = 2)

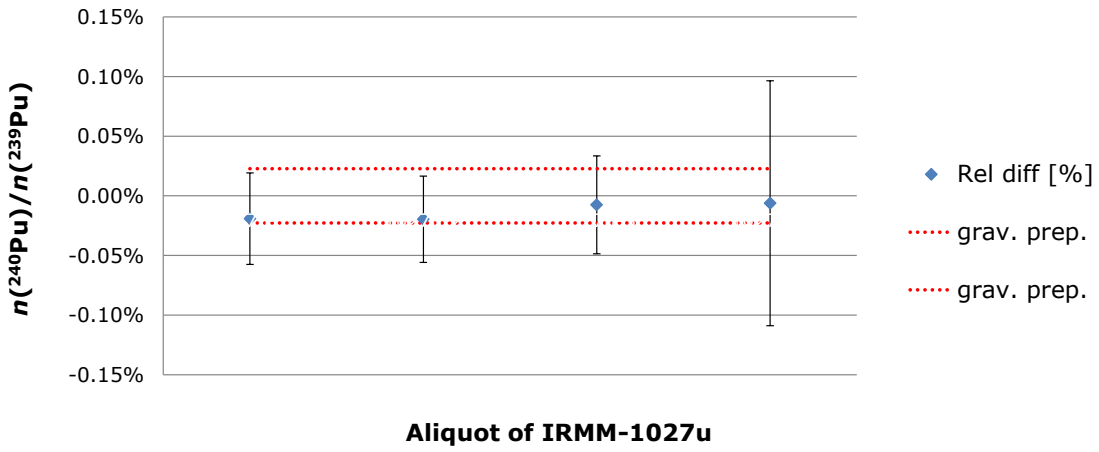


Figure 19 The $n(^{241}Pu)/n(^{239}Pu)$ amount ratio in the solution of IRMM-1027u prepared by gravimetric mixing compared with the measured values by TIMS (blue diamonds). Error bars show the expanded uncertainties (coverage factor k = 2)

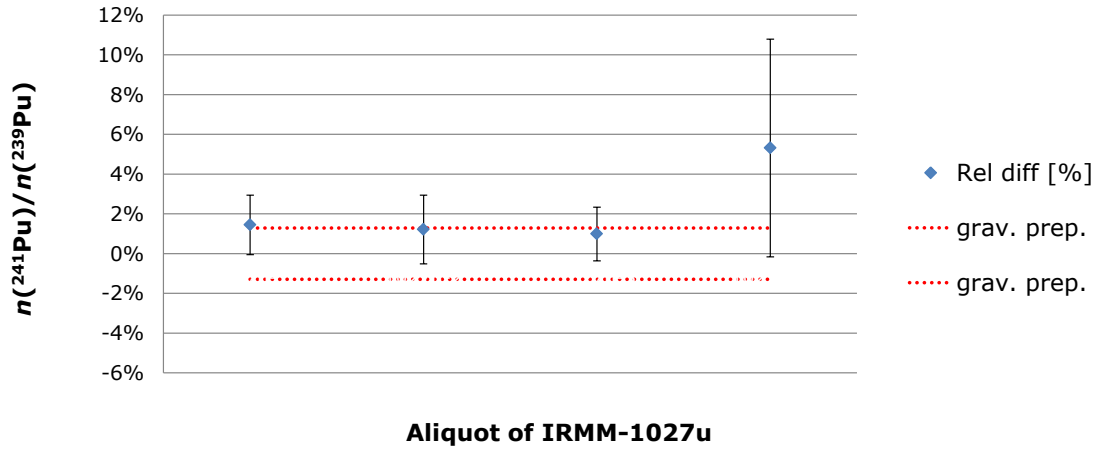
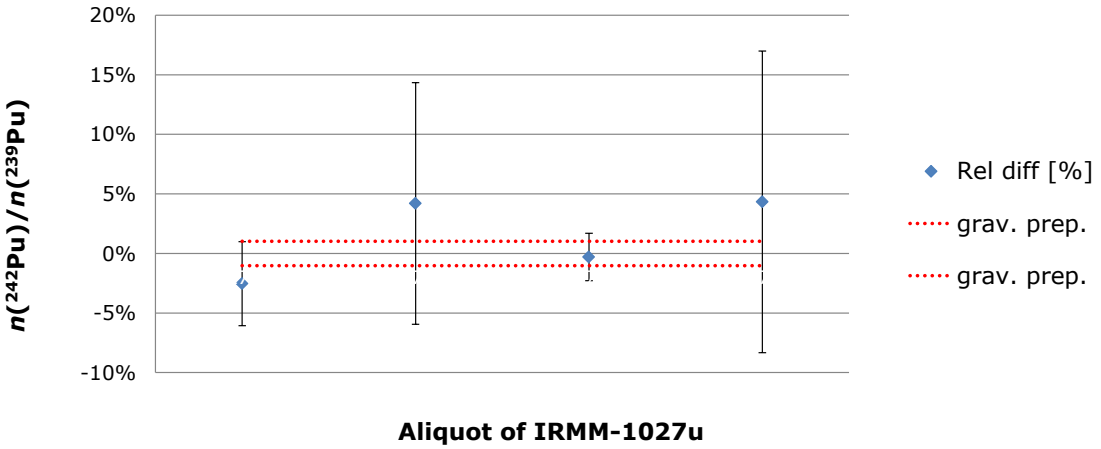


Figure 20 The $n(^{242}Pu)/n(^{239}Pu)$ amount ratio in the solution of IRMM-1027u prepared by gravimetric mixing compared with the measured values by TIMS (blue diamonds). Error bars show the expanded uncertainties (coverage factor k = 2)



Annex 11 Results of the homogeneity assessment for IRMM-1027u

Figure 21 The amount content (normalised) of ^{235}U from homogeneity study for the 35 replicate measurements (12 selected units, 3 replicates each. except 1 vial have 2 replicates) are shown as a function of the analytical sequence

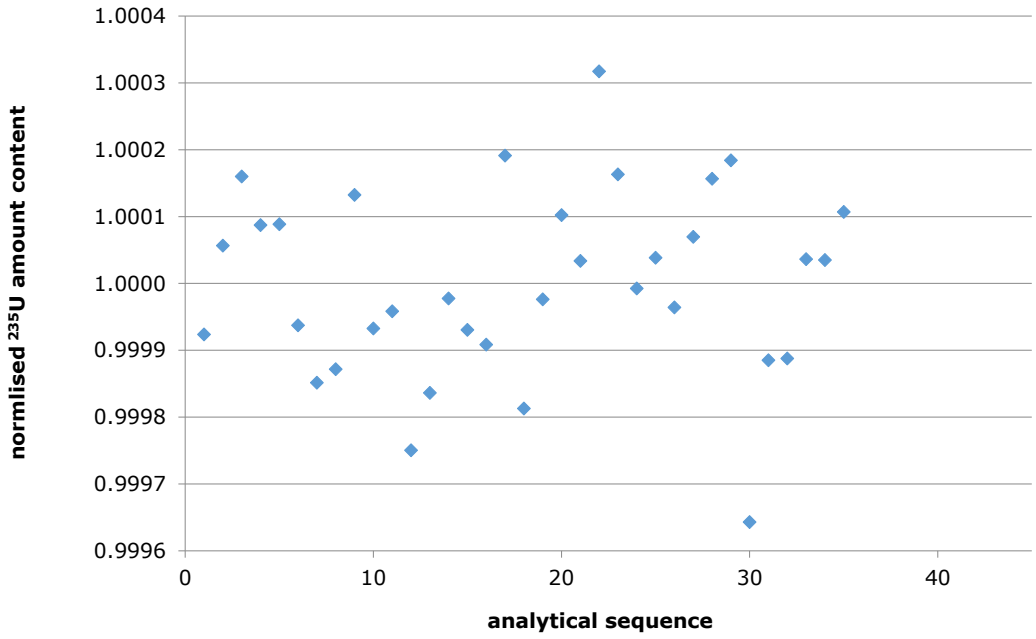


Figure 22 Mean amount contents (normalised) of ^{235}U from homogeneity study as a function of the units (filling sequence). The unit means are plotted with 95 % CI of the means

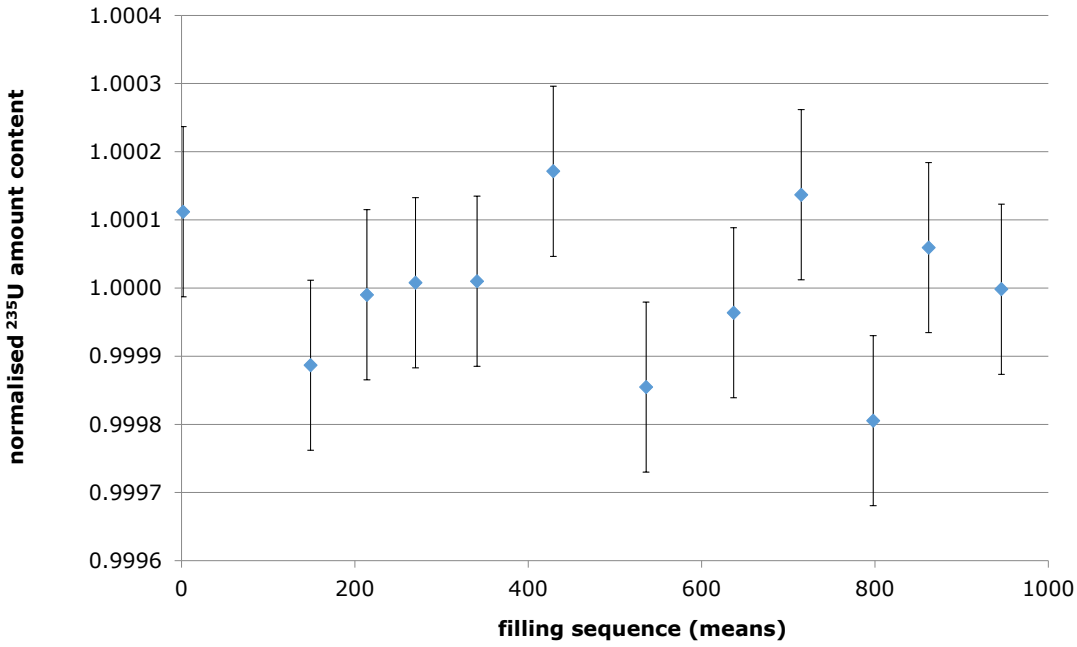


Figure 23 The amount content (normalised) of ^{238}U from homogeneity study for the 35 replicate measurements (12 selected units, 3 replicates each. except 1 vial have 2 replicates) are shown as a function of the analytical sequence

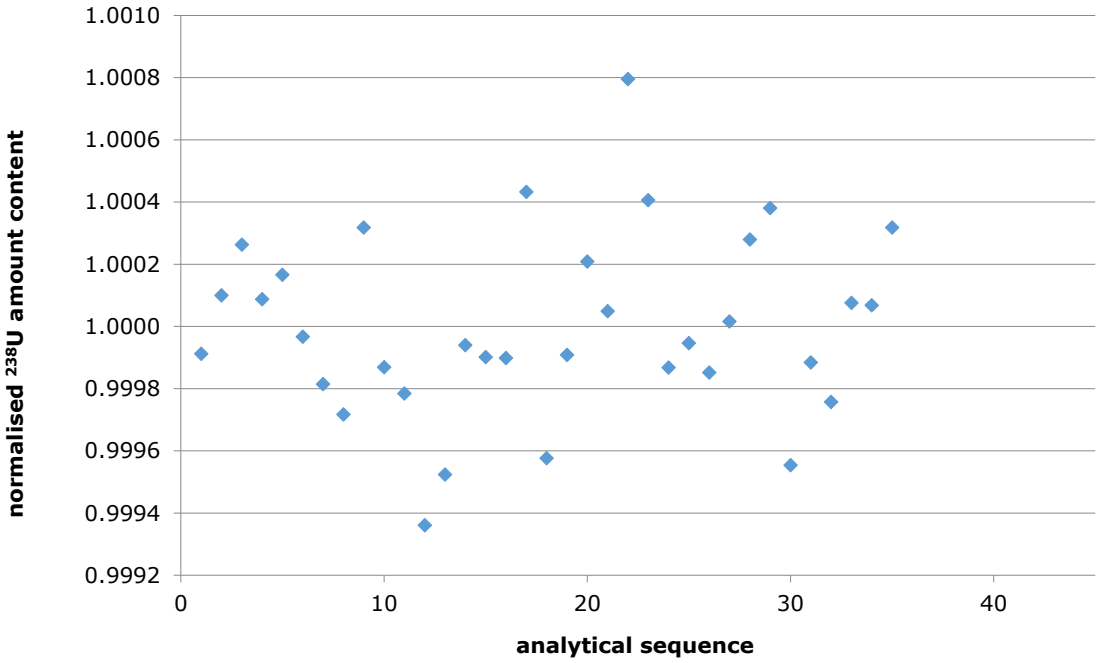


Figure 24 Mean amount contents (normalised) of ^{238}U from homogeneity study as a function of the units (filling sequence). The unit means are plotted with 95 % CI of the means.

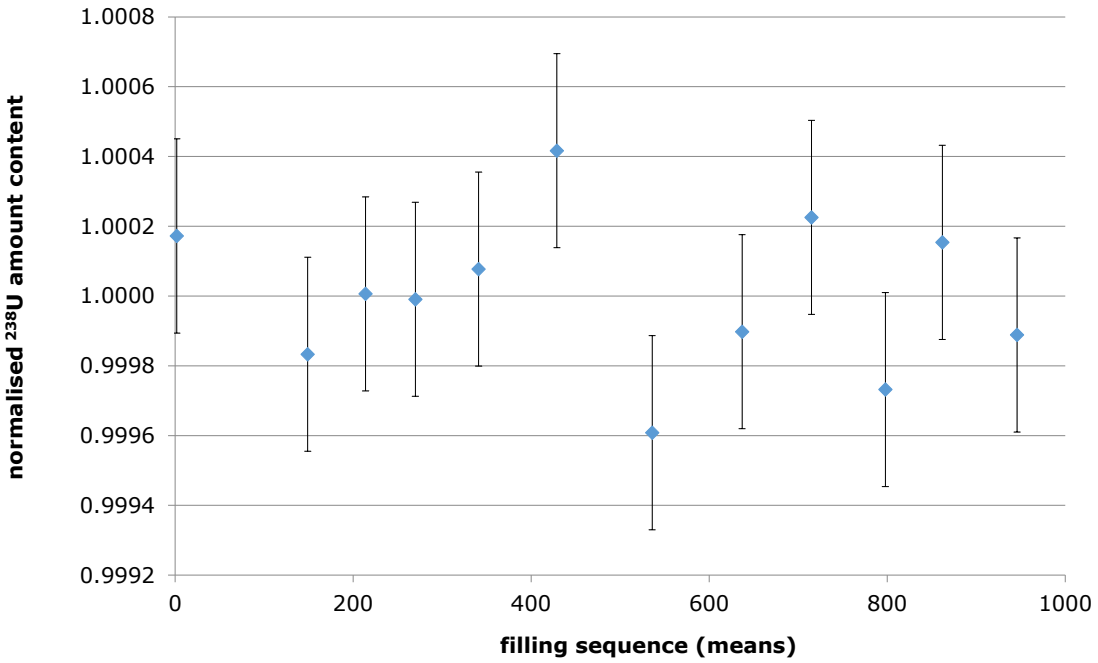


Figure 25 The amount content of ^{239}Pu from homogeneity study for the 36 replicate measurements (12 selected units, 3 replicates each) are shown as a function of the analytical sequence

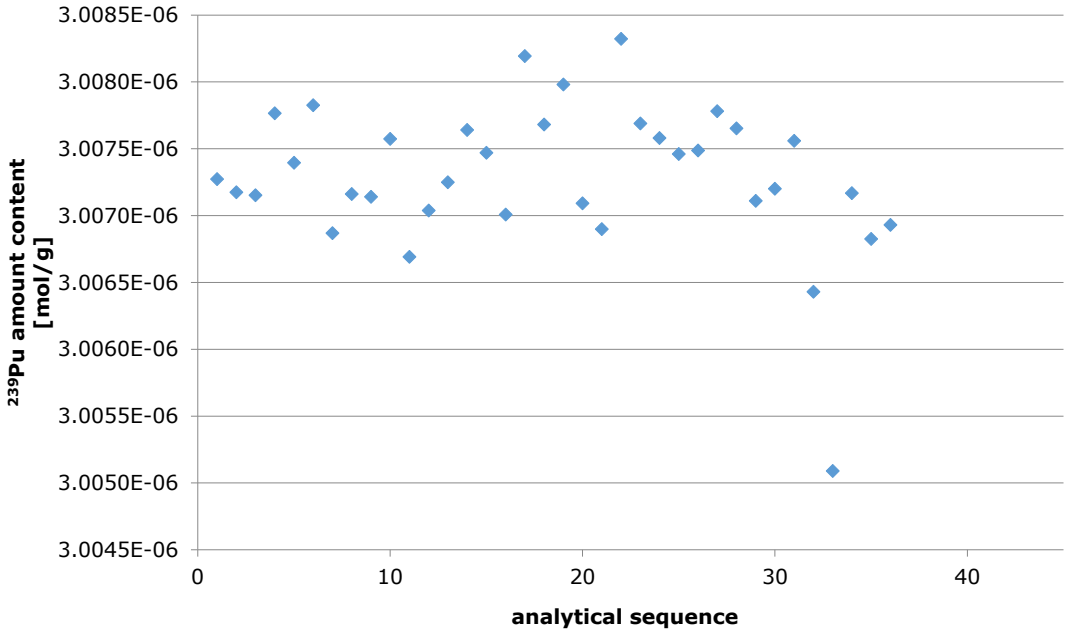
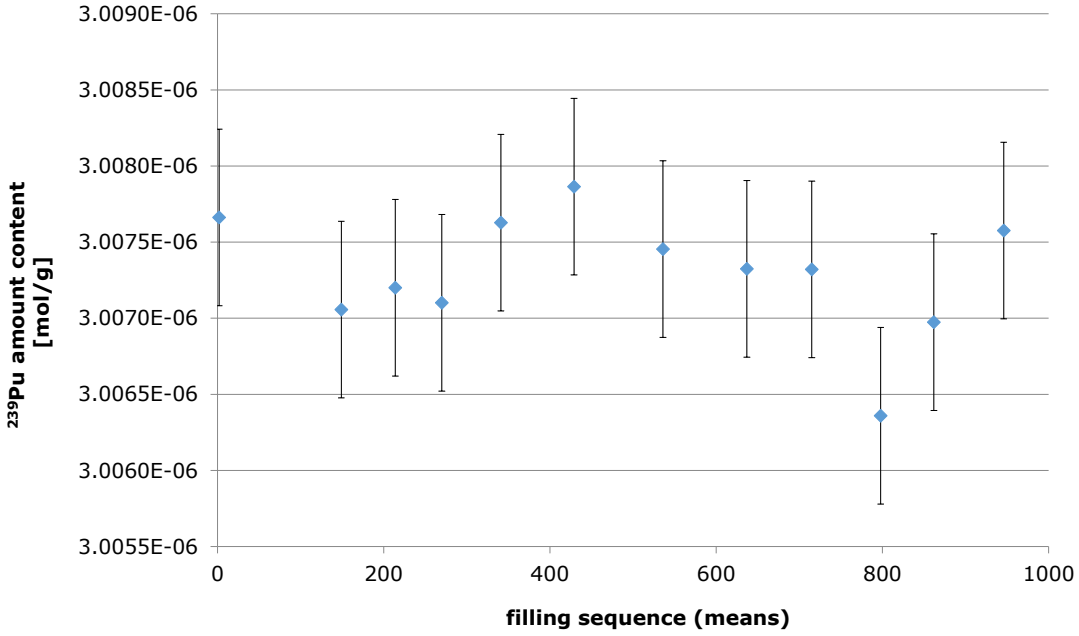


Figure 26 Mean amount contents of ^{239}Pu from homogeneity study as a function of the units (filling sequence). The unit means are plotted with 95 % CI of the means



Annex 12 The weighing certificate of the aliquots of dispensed solution of IRMM-1027u per unit before drying

Joint Research Centre	**Certificate of weighing**	Directorate G – Nuclear Safety and Security G.2 - Standards for Nuclear Safety, Security and Safeguards Unit

E. 3932 rev 1 **Issue date**: 16/09/2019, 29/01/2020 **Page** 1 **of** 7

Applicant: Renata Bujak **Project:** IRMM-1027u LSD spike CRM

Description: Dispensing the IRMM-1027u solution into vials

Request for analysis number: N.A **ID number:** N.A

Date of receipt of request: 29/01/2020 **Weighing dates**: 3-7 December 2018

Results:

The reported results apply only to the objects/samples described in this certificate and are shown in Annex.

Observations:

The dispensing and weighing were performed according to working instruction WI-D-00786/2 Preparation of Large-sized dried (LSD) spikes" on balance Sartorius TE124 with inventory No. 2006 00290 17 installed in the dispensing robot box.

During the calibration process the atmospheric parameters temperature, pressure and humidity were monitored, noted and used in the calculations.

Traceability:

The certified mass values are traceable to the International Kilogram Prototype via regular calibrations of the JRC G2's principal standards. The mass standard identified as H208 (cylinder + vial certificate 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 are expanded uncertainties $U = k \bullet u_c$ where u_c is the combined standard uncertainty calculated according to the ISO/BIPM Guide to the expression of Uncertainty in Measurement. The coverage factor $k = 2$ corresponds to a coverage probability of about 95%

Additional information:

The density of IRMM-1027u solution was determined to 1255 $kg \cdot m^{-3}$, with an estimated uncertainty (k=2) of 2 $kg \cdot m^{-3}$.
The vials #336, #338, #376, #378 and #585 are excluded from the certificate due to barcode failure or splashing during dispensing or drying.

~~Ulf Jacobsson~~
~~Technical responsible~~
Rožle Jakopič
Laboratory Responsible for Nuclear Chemistry

Jeroen Bauwens
Analyst

Annex: Mass of the nitrate solution in the vials of IRMM-1027u before drying.

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
001	2.5327	051	2.5284	101	2.5293	151	2.5284
002	2.5239	052	2.5267	102	2.5259	152	2.5228
003	2.5283	053	2.5249	103	2.5327	153	2.5284
004	2.5245	054	2.5315	104	2.5227	154	2.5328
005	2.5280	055	2.5228	105	2.5223	155	2.5198
006	2.5241	056	2.5296	106	2.5265	156	2.5277
007	2.5278	057	2.5259	107	2.5321	157	2.5250
008	2.5260	058	2.5232	108	2.5215	158	2.5264
009	2.5264	059	2.5316	109	2.5349	159	2.5245
010	2.5229	060	2.5235	110	2.5217	160	2.5274
011	2.5274	061	2.5292	111	2.5313	161	2.5289
012	2.5269	062	2.5336	112	2.5210	162	2.5286
013	2.5265	063	2.5250	113	2.5352	163	2.5228
014	2.5274	064	2.5207	114	2.5176	164	2.5259
015	2.5226	065	2.5277	115	2.5284	165	2.5307
016	2.5292	066	2.5282	116	2.5284	166	2.5224
017	2.5230	067	2.5270	117	2.5278	167	2.5244
018	2.5319	068	2.5284	118	2.5213	168	2.5247
019	2.5247	069	2.5262	119	2.5232	169	2.5296
020	2.5275	070	2.5264	120	2.5278	170	2.5284
021	2.5280	071	2.5268	121	2.5315	171	2.5223
022	2.5250	072	2.5301	122	2.5303	172	2.5278
023	2.5306	073	2.5211	123	2.5234	173	2.5260
024	2.5245	074	2.5254	124	2.5229	174	2.5272
025	2.5266	075	2.5299	125	2.5301	175	2.5239
026	2.5273	076	2.5310	126	2.5214	176	2.5273
027	2.5264	077	2.5274	127	2.5258	177	2.5239
028	2.5262	078	2.5233	128	2.5283	178	2.5301
029	2.5275	079	2.5309	129	2.5293	179	2.5213
030	2.5294	080	2.5192	130	2.5248	180	2.5280
031	2.5236	081	2.5297	131	2.5281	181	2.5243
032	2.5289	082	2.5327	132	2.5273	182	2.5212
033	2.5345	083	2.5245	133	2.5229	183	2.5224
034	2.5194	084	2.5200	134	2.5326	184	2.5323
035	2.5268	085	2.5264	135	2.5317	185	2.5224
036	2.5281	086	2.5291	136	2.5212	186	2.5233
037	2.5284	087	2.5348	137	2.5257	187	2.5287
038	2.5295	088	2.5171	138	2.5254	188	2.5224
039	2.5288	089	2.5358	139	2.5251	189	2.5268
040	2.5210	090	2.5246	140	2.5261	190	2.5268
041	2.5261	091	2.5218	141	2.5269	191	2.5264
042	2.5282	092	2.5304	142	2.5266	192	2.5261
043	2.5273	093	2.5223	143	2.5281	193	2.5300
044	2.5265	094	2.5330	144	2.5232	194	2.5230
045	2.5264	095	2.5260	145	2.5276	195	2.5236
046	2.5291	096	2.5233	146	2.5257	196	2.5356
047	2.5274	097	2.5300	147	2.5338	197	2.5189
048	2.5254	098	2.5282	148	2.5213	198	2.5255
049	2.5288	099	2.5229	149	2.5269	199	2.5269
050	2.5264	100	2.5268	150	2.5261	200	2.5276

Annex: Mass of the nitrate solution in the vials of IRMM-1027u before drying.

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
201	2.5222	251	2.5204	301	2.5252	351	2.5356
202	2.5265	252	2.5260	302	2.5257	352	2.5125
203	2.5277	253	2.5271	303	2.5267	353	2.5350
204	2.5281	254	2.5281	304	2.5247	354	2.5193
205	2.5241	255	2.5251	305	2.5196	355	2.5273
206	2.5250	256	2.5248	306	2.5316	356	2.5232
207	2.5284	257	2.5144	307	2.5235	357	2.5241
208	2.5201	258	2.5276	308	2.5253	358	2.5189
209	2.5276	259	2.5275	309	2.5176	359	2.5299
210	2.5230	260	2.5246	310	2.5284	360	2.5200
211	2.5280	261	2.5268	311	2.5273	361	2.5316
212	2.5230	262	2.5258	312	2.5170	362	2.5173
213	2.5264	263	2.5185	313	2.5212	363	2.5286
214	2.5254	264	2.5311	314	2.5270	364	2.5222
215	2.5251	265	2.5267	315	2.5249	365	2.5307
216	2.5237	266	2.5241	316	2.5248	366	2.5158
217	2.5285	267	2.5277	317	2.5219	367	2.5324
218	2.5233	268	2.5178	318	2.5243	368	2.5249
219	2.5251	269	2.5315	319	2.5204	369	2.5158
220	2.5256	270	2.5180	320	2.5333	370	2.5254
221	2.5255	271	2.5256	321	2.5191	371	2.5300
222	2.5290	272	2.5245	322	2.5260	372	2.5204
223	2.5257	273	2.5338	323	2.5315	373	2.5308
224	2.5227	274	2.5253	324	2.5180	374	2.5230
225	2.5347	275	2.5299	325	2.5303	375	2.5244
226	2.5230	276	2.5187	326	2.5225	376	N.A
227	2.5246	277	2.5281	327	2.5182	377	2.5265
228	2.5284	278	2.5308	328	2.5311	378	N.A
229	2.5235	279	2.5178	329	2.5244	379	2.5200
230	2.5298	280	2.5318	330	2.5234	380	2.5287
231	2.5254	281	2.5246	331	2.5202	381	2.5238
232	2.5223	282	2.5290	332	2.5197	382	2.5259
233	2.5287	283	2.5244	333	2.5362	383	2.5228
234	2.5233	284	2.5274	334	2.5152	384	2.5256
235	2.5295	285	2.5193	335	2.5298	385	2.5278
236	2.5238	286	2.5305	336	N.A	386	2.5248
237	2.5265	287	2.5197	337	2.5240	387	2.5218
238	2.5285	288	2.5289	338	N.A	388	2.5221
239	2.5230	289	2.5237	339	2.5243	389	2.5279
240	2.5253	290	2.5238	340	2.5183	390	2.5181
241	2.5350	291	2.5214	341	2.5308	391	2.5308
242	2.5202	292	2.5224	342	2.5225	392	2.5273
243	2.5209	293	2.5333	343	2.5187	393	2.5219
244	2.5283	294	2.5164	344	2.5314	394	2.5250
245	2.5273	295	2.5263	345	2.5245	395	2.5279
246	2.5202	296	2.5295	346	2.5227	396	2.5194
247	2.5270	297	2.5198	347	2.5314	397	2.5307
248	2.5250	298	2.5248	348	2.5188	398	2.5241
249	2.5281	299	2.5221	349	2.5284	399	2.5264
250	2.5254	300	2.5249	350	2.5158	400	2.5166

Annex: Mass of the nitrate solution in the vials of IRMM-1027u before drying.

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
401	2.5320	451	2.5209	501	2.5165	551	2.5220
402	2.5254	452	2.5248	502	2.5289	552	2.5197
403	2.5206	453	2.5236	503	2.5228	553	2.5302
404	2.5258	454	2.5290	504	2.5243	554	2.5195
405	2.5189	455	2.5149	505	2.5224	555	2.5195
406	2.5303	456	2.5277	506	2.5255	556	2.5260
407	2.5276	457	2.5247	507	2.5207	557	2.5144
408	2.5180	458	2.5211	508	2.5149	558	2.5314
409	2.5322	459	2.5209	509	2.5234	559	2.5218
410	2.5247	460	2.5301	510	2.5319	560	2.5152
411	2.5182	461	2.5251	511	2.5234	561	2.5227
412	2.5300	462	2.5211	512	2.5207	562	2.5251
413	2.5276	463	2.5232	513	2.5213	563	2.5208
414	2.5134	464	2.5253	514	2.5220	564	2.5258
415	2.5320	465	2.5192	515	2.5232	565	2.5169
416	2.5172	466	2.5209	516	2.5247	566	2.5293
417	2.5323	467	2.5210	517	2.5206	567	2.5209
418	2.5250	468	2.5238	518	2.5255	568	2.5207
419	2.5226	469	2.5189	519	2.5248	569	2.5185
420	2.5167	470	2.5243	520	2.5237	570	2.5193
421	2.5275	471	2.5282	521	2.5213	571	2.5257
422	2.5316	472	2.5225	522	2.5186	572	2.5226
423	2.5147	473	2.5202	523	2.5209	573	2.5197
424	2.5232	474	2.5242	524	2.5288	574	2.5223
425	2.5246	475	2.5260	525	2.5201	575	2.5216
426	2.5316	476	2.5226	526	2.5236	576	2.5220
427	2.5174	477	2.5219	527	2.5227	577	2.5282
428	2.5333	478	2.5179	528	2.5199	578	2.5132
429	2.5193	479	2.5215	529	2.5283	579	2.5285
430	2.5256	480	2.5337	530	2.5227	580	2.5221
431	2.5231	481	2.5217	531	2.5155	581	2.5199
432	2.5192	482	2.5195	532	2.5296	582	2.5248
433	2.5315	483	2.5289	533	2.5224	583	2.5171
434	2.5157	484	2.5212	534	2.5218	584	2.5278
435	2.5255	485	2.5316	535	2.5211	585	N.A
436	2.5208	486	2.5191	536	2.5153	586	2.5215
437	2.5205	487	2.5269	537	2.5327	587	2.5219
438	2.5251	488	2.5203	538	2.5128	588	2.5191
439	2.5203	489	2.5327	539	2.5254	589	2.5157
440	2.5274	490	2.5262	540	2.5290	590	2.5286
441	2.5240	491	2.5217	541	2.5198	591	2.5242
442	2.5230	492	2.5255	542	2.5202	592	2.5242
443	2.5244	493	2.5271	543	2.5221	593	2.5212
444	2.5266	494	2.5274	544	2.5253	594	2.5209
445	2.5232	495	2.5202	545	2.5212	595	2.5193
446	2.5164	496	2.5206	546	2.5229	596	2.5167
447	2.5231	497	2.5256	547	2.5170	597	2.5217
448	2.5236	498	2.5259	548	2.5248	598	2.5260
449	2.5262	499	2.5226	549	2.5254	599	2.5284
450	2.5205	500	2.5305	550	2.5221	600	2.5184

Annex: Mass of the nitrate solution in the vials of IRMM-1027u before drying.

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
601	2.5235	651	2.5194	701	2.5237	751	2.5202
602	2.5165	652	2.5178	702	2.5300	752	2.5151
603	2.5287	653	2.5295	703	2.5186	753	2.5219
604	2.5197	654	2.5212	704	2.5265	754	2.5327
605	2.5269	655	2.5194	705	2.5126	755	2.5179
606	2.5201	656	2.5251	706	2.5253	756	2.5247
607	2.5222	657	2.5190	707	2.5229	757	2.5213
608	2.5229	658	2.5247	708	2.5211	758	2.5188
609	2.5219	659	2.5233	709	2.5187	759	2.5223
610	2.5128	660	2.5161	710	2.5204	760	2.5222
611	2.5287	661	2.5169	711	2.5319	761	2.5139
612	2.5210	662	2.5268	712	2.5228	762	2.5286
613	2.5245	663	2.5237	713	2.5130	763	2.5244
614	2.5160	664	2.5200	714	2.5216	764	2.5195
615	2.5253	665	2.5242	715	2.5210	765	2.5231
616	2.5245	666	2.5195	716	2.5290	766	2.5162
617	2.5191	667	2.5275	717	2.5170	767	2.5226
618	2.5221	668	2.5119	718	2.5241	768	2.5194
619	2.5211	669	2.5316	719	2.5194	769	2.5286
620	2.5215	670	2.5227	720	2.5210	770	2.5210
621	2.5212	671	2.5227	721	2.5235	771	2.5266
622	2.5243	672	2.5163	722	2.5226	772	2.5207
623	2.5168	673	2.5249	723	2.5247	773	2.5315
624	2.5220	674	2.5210	724	2.5174	774	2.5141
625	2.5183	675	2.5149	725	2.5220	775	2.5270
626	2.5204	676	2.5233	726	2.5182	776	2.5222
627	2.5231	677	2.5191	727	2.5211	777	2.5291
628	2.5202	678	2.5304	728	2.5266	778	2.5178
629	2.5238	679	2.5138	729	2.5152	779	2.5297
630	2.5200	680	2.5308	730	2.5223	780	2.5209
631	2.5268	681	2.5178	731	2.5287	781	2.5193
632	2.5212	682	2.5209	732	2.5235	782	2.5253
633	2.5187	683	2.5195	733	2.5225	783	2.5338
634	2.5234	684	2.5281	734	2.5182	784	2.5207
635	2.5251	685	2.5203	735	2.5162	785	2.5257
636	2.5237	686	2.5220	736	2.5319	786	2.5181
637	2.5158	687	2.5214	737	2.5132	787	2.5229
638	2.5263	688	2.5207	738	2.5290	788	2.5242
639	2.5204	689	2.5267	739	2.5164	789	2.5187
640	2.5220	690	2.5151	740	2.5227	790	2.5324
641	2.5198	691	2.5206	741	2.5240	791	2.5191
642	2.5248	692	2.5238	742	2.5174	792	2.5219
643	2.5200	693	2.5194	743	2.5230	793	2.5187
644	2.5184	694	2.5246	744	2.5198	794	2.5273
645	2.5199	695	2.5199	745	2.5259	795	2.5229
646	2.5306	696	2.5290	746	2.5141	796	2.5193
647	2.5210	697	2.5194	747	2.5229	797	2.5259
648	2.5144	698	2.5183	748	2.5268	798	2.5241
649	2.5291	699	2.5201	749	2.5213	799	2.5160
650	2.5238	700	2.5198	750	2.5223	800	2.5282

Annex: Mass of the nitrate solution in the vials of IRMM-1027u before drying.

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
801	2.5207	851	2.5171	901	2.5222	951	2.5191
802	2.5226	852	2.5208	902	2.5209	952	2.5214
803	2.5230	853	2.5246	903	2.5229	953	2.5210
804	2.5214	854	2.5182	904	2.5173	954	2.5216
805	2.5226	855	2.5244	905	2.5224	955	2.5199
806	2.5205	856	2.5143	906	2.5209	956	2.5176
807	2.5236	857	2.5289	907	2.5238	957	2.5215
808	2.5243	858	2.5194	908	2.5217	958	2.5208
809	2.5190	859	2.5200	909	2.5153	959	2.5148
810	2.5256	860	2.5240	910	2.5305	960	2.5230
811	2.5248	861	2.5222	911	2.5196	961	2.5238
812	2.5171	862	2.5196	912	2.5188	962	2.5117
813	2.5234	863	2.5167	913	2.5204	963	2.5249
814	2.5219	864	2.5258	914	2.5154	964	2.5096
815	2.5230	865	2.5263	915	2.5219	965	2.5192
816	2.5230	866	2.5166	916	2.5260	966	2.5225
817	2.5169	867	2.5244	917	2.5149	967	2.5182
818	2.5291	868	2.5175	918	2.5203	968	2.5192
819	2.5144	869	2.5217	919	2.5206	969	2.5163
820	2.5234	870	2.5217	920	2.5262	970	2.5201
821	2.5177	871	2.5198	921	2.5167	971	2.5192
822	2.5272	872	2.5224	922	2.5206	972	2.5126
823	2.5181	873	2.5148	923	2.5190	973	2.5228
824	2.5164	874	2.5281	924	2.5288	974	2.5190
825	2.5333	875	2.5221	925	2.5118	975	2.5179
826	2.5230	876	2.5133	926	2.5273	976	2.5203
827	2.5181	877	2.5206	927	2.5239	977	2.5128
828	2.5183	878	2.5265	928	2.5170	978	2.5218
829	2.5219	879	2.5223	929	2.5230	979	2.5198
830	2.5223	880	2.5240	930	2.5189	980	2.5165
831	2.5202	881	2.5168	931	2.5236	981	2.5204
832	2.5151	882	2.5286	932	2.5129	982	2.5159
833	2.5255	883	2.5135	933	2.5259	983	2.5220
834	2.5190	884	2.5212	934	2.5197	984	2.5176
835	2.5242	885	2.5211	935	2.5236	985	2.5189
836	2.5238	886	2.5206	936	2.5253	986	2.5180
837	2.5154	887	2.5233	937	2.5163	987	2.5124
838	2.5297	888	2.5203	938	2.5209	988	2.5276
839	2.5240	889	2.5190	939	2.5185	989	2.5143
840	2.5198	890	2.5211	940	2.5223	990	2.5205
841	2.5180	891	2.5197	941	2.5178	991	2.5128
842	2.5233	892	2.5207	942	2.5193	992	2.5257
843	2.5230	893	2.5215	943	2.5233	993	2.5119
844	2.5164	894	2.5218	944	2.5199	994	2.5244
845	2.5199	895	2.5188	945	2.5223	995	2.5196
846	2.5261	896	2.5256	946	2.5254	996	2.5138
847	2.5215	897	2.5226	947	2.5121	997	2.5242
848	2.5188	898	2.5189	948	2.5211	998	2.5159
849	2.5227	899	2.5260	949	2.5214	999	2.5183
850	2.5244	900	2.5147	950	2.5229	1000	2.5219

Annex: Mass of the nitrate solution in the vials of IRMM-1027u before drying.

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
1001	2.5122						
1002	2.5224						
1003	2.5123						
1004	2.5238						
1005	2.5174						
1006	2.5176						
1007	2.5189						
1008	2.5076						

Annex 13 The weighing certificate for the preparation of the mother solution of IRMM-1027u

Joint Research Centre	**Certificate of weighing**	Directorate G – Nuclear Safety and Security G.2 - Standards for Nuclear Safety, Security and Safeguards Unit

E. 3917 **Issue date:** 05/03/2019 **Page 1 of 2**

Applicant: Renata Buják **Project:** IRMM-1027u certification

Description: Preparation of IRMM-1027u LSD mother solution

Request for analysis number: 4347 **ID number:** 30101

Date of receipt of request: 23/10/2018 **Weighing dates:** 6,7,28/11/2018

Results:

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

ID	Mass /g	Uncertainty /g
U metal (EC 101)	46.26719	0.00010
U metal (CRM 116-A)	11.32258	0.00011
Pu metal (MP2)	1.93127	0.00007
IRMM-1027u solution	2623.412	0.009

Observations:

The measurements were performed according to Procedure IMS-JRC.G-C1.1-PRO-0002 "Mass determination by substitution weighing".
Balances used were Mettler Toledo AT 261DR and with inventory No. 1999 0037 27, AT 201 with inventory no 1996 00547 73, and XPR 5003S with inventory No. 2018 00368 44 .

During the calibration process the atmospheric parameters temperature, pressure and humidity were monitored, noted and used in the calculations.

Traceability:

The certified mass values are traceable to the International Kilogram Prototype via regular calibrations of the JRC G2's principal standards. The sets of working mass standards M3 and M10 were used as reference in the mass determination.

Retieseweg, B-2440 Geel, Belgium; Tel.: +32-(0)14-571 211 • https://ec.europa.eu/jrc

Joint Research Centre	Certificate of weighing	Directorate G – Nuclear Safety and Security G.2 - Standards for Nuclear Safety, Security and Safeguards Unit

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Uncertainty:

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

Additional information

The density of IRMM-1027u solution was determined to 1255 $kg \cdot m^{-3}$, with an estimated uncertainty (k=2) of 2 $kg \cdot m^{-3}$.

Ulf Jacobsson
Technical responsible

Jeroen Bauwens
Analyst

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Annex 14 Uncertainty budget for the uranium gravimetric mixture of IRMM-1027u

Uranium gravimetric mixture of IRMM-1027u on the 1 November 2018 date of certificate

Author: Renata Bujak

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

Input parameters: 1) masses of the metals and the nitrate solution (E3917) 2) purity of the metals (metal certificates) 3) uranium isotope amount ratios of the metals (certificate) 4) the atomic masses according Wang et al. (The AME 2016 atomic mass evaluation (II). Tables, Graphs and References, Chinese Physics C, Vol. 41, No. 3, 2017).

U ingrowth from Pu MP2 metal is calculated from the measurement data (2006, IRMM) plus the ingrowth from 2006 to 1 November 2018 (certification date)

Model Equation:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$\gamma_{Umixture}=(m_{UCRM116A}*\eta_{purityCRM116A}+m_{UEC101}*\eta_{purityEC101}+m_{UMP2})/m_{solution1027u}$;

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

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

$m_{235Uvial1}=\gamma_{235Umixture}*m_{aliquot1}$;

$m_{238Uvial1}=\gamma_{238Umixture}*m_{aliquot1}$;

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

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

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

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

{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 CRM116-A}

$n_{233.b} = m_{UCRM116A}*\eta_{purityCRM116A} * f_{233Ub} / M_{Ub}$;

$n_{234.b} = m_{UCRM116A}*\eta_{purityCRM116A} * f_{234Ub} / M_{Ub}$;

$n_{235.b} = m_{UCRM116A}*\eta_{purityCRM116A} * f_{235Ub} / M_{Ub}$;

$n_{236.b} = m_{UCRM116A}*\eta_{purityCRM116A} * f_{236Ub} / M_{Ub}$;

$n_{238.b} = m_{UCRM116A}*\eta_{purityCRM116A} * f_{238Ub} / M_{Ub}$;

{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 in NBL CRM 116-A}

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

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

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

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

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

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

{Molar mass of uranium in NBL CRM 116-A}

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

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

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

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

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

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

List of Quantities:

Quantity	Unit	Definition
$\gamma_{Umixture}$	g/g	U mass fraction in IRMM-1027u
$\gamma_{235Umixture}$	g/g	^{235}U mass fraction in IRMM-1027u
$\gamma_{238Umixture}$	g/g	^{238}U mass fraction in IRMM-1027u
$c_{Umixture}$	mol/g	U amount content in IRMM-1027u
$c_{235Umixture}$	mol/g	^{235}U amount content in IRMM-1027u
$c_{238Umixture}$	mol/g	^{238}U amount content in IRMM-1027u
M_U	g/mol	Molar mass of U in IRMM-1027u
$R_{233U/238U}$	mol/mol	^{233}U/^{238}U amount ratio in IRMM-1027u
$R_{234U/238U}$	mol/mol	^{234}U/^{238}U amount ratio in IRMM-1027u
$R_{235U/238U}$	mol/mol	^{235}U/^{238}U amount ratio in IRMM-1027u
$R_{236U/238U}$	mol/mol	^{236}U/^{238}U amount ratio in IRMM-1027u
f_{233U}	mol/mol	^{233}U amount fraction in IRMM-1027u
f_{234U}	mol/mol	^{234}U amount fraction in IRMM-1027u
f_{235U}	mol/mol	^{235}U amount fraction in IRMM-1027u
f_{236U}	mol/mol	^{236}U amount fraction in IRMM-1027u
f_{238U}	mol/mol	^{238}U amount fraction in IRMM-1027u
w_{233U}	g/g	^{233}U mass fraction in IRMM-1027u
w_{234U}	g/g	^{234}U mass fraction in IRMM-1027u
w_{235U}	g/g	^{235}U mass fraction in IRMM-1027u
w_{236U}	g/g	^{236}U mass fraction in IRMM-1027u
w_{238U}	g/g	^{238}U mass fraction in IRMM-1027u
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

Quantity	Unit	Definition
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_{UEC101}	g	Mass of natural uranium metal, EC-NRM 101
$\eta_{purityEC101}$	g/g	Purity of natural uranium metal, EC NRM 101
$m_{UCRM116A}$	g	Mass of enriched uranium metal, NBL CRM 116-A
$\eta_{purityCRM116A}$	g/g	Purity of enriched uranium metal, NBL CRM 116-A
M_{Ua}	g/mol	Molar mass of U in EC NRM 101
f_{233Ua}	mol/mol	^{233}U amount fraction in EC NRM 101
f_{234Ua}	mol/mol	^{234}U amount fraction in EC NRM 101
f_{235Ua}	mol/mol	^{235}U amount fraction in EC NRM 101
f_{236Ua}	mol/mol	^{236}U amount fraction in EC NRM 101
f_{238Ua}	mol/mol	^{238}U amount fraction in EC NRM 101
M_{Ub}	g/mol	Molar mass of U in NBL CRM 116-A
f_{233Ub}	mol/mol	^{233}U amount fraction in NBL CRM 116-A
f_{234Ub}	mol/mol	^{234}U amount fraction in NBL CRM 116-A
f_{235Ub}	mol/mol	^{235}U amount fraction in NBL CRM 116-A
f_{236Ub}	mol/mol	^{236}U amount fraction in NBL CRM 116-A
f_{238Ub}	mol/mol	^{238}U amount fraction in NBL CRM 116-A
$n_{233.a}$	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-A
$n_{234.b}$	mol	^{234} U amount in NBL CRM 116-A
$n_{235.b}$	mol	^{235} U amount in NBL CRM 116-A
$n_{236.b}$	mol	^{236} U amount in NBL CRM 116-A
$n_{238.b}$	mol	^{238} U amount in NBL CRM 116-A
$R_{233U/238Ua}$	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-A

Quantity	Unit	Definition
$R_{234U/235Ub}$	mol/mol	$^{234}U/^{235}U$ amount ratio in NBL CRM 116-A
$R_{238U/235Ub}$	mol/mol	$^{238}U/^{235}U$ amount ratio in NBL CRM 116-A
$R_{236U/235Ub}$	mol/mol	$^{236}U/^{235}U$ amount ratio in NBL CRM 116-A
ΣR_U	mol/mol	Sum of amount ratios in gravimteric mixture, IRMM-1027u
ΣR_{Ua}	mol/mol	Sum of amount ratios in EC- NRM 101
ΣR_{Ub}	mol/mol	Sum of amount ratios in NBL CRM 116-A
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-A
w_{234Ub}	g/g	^{234}U mass fraction in CRM 116-A
w_{235Ub}	g/g	^{235}U mass fraction in CRM 116-A
w_{236Ub}	g/g	^{236}U mass fraction in CRM 116-A
w_{238Ub}	g/g	^{238}U mass fraction in CRM 116-A
$n_{234.c}$	mol	^{234} U amount ingrowth from Pu MP2
$n_{235.c}$	mol	^{235} U amount ingrowth from Pu MP2
$n_{236.c}$	mol	^{236} U amount ingrowth from Pu MP2
$n_{233.c}$	mol	^{233} U amount ingrowth from Pu MP2
$n_{238.c}$	mol	^{238} U amount ingrowth from Pu MP2
m_{UMP2}	g	mass of total ingrown U from Pu MP2
$m_{solution1027u}$	g	mass of the mother solution of IRMM-1027u
$m_{235Uvial1}$	g	Mass of ^{235}U in vial 1
$m_{aliquot1}$	g	Mass of dispensed mother solution of IRMM-1027u in vial 1
$m_{238Uvial1}$	g	Mass of ^{238}U in vial 1

M_{233U}: Type B normal distribution
Value: 233.0396344 g/mol
Expanded Uncertainty: 0.0000024 g/mol
Coverage Factor: 1

the atomic masses according Wang et al. (The AME 2017 atomic mass evaluation (II). Tables, Graphs and References, Chinese Physics C, Vol. 41, No. 3, 2017)

M_{234U}: Type B normal distribution
Value: 234.0409504 g/mol
Expanded Uncertainty: 0.0000012 g/mol
Coverage Factor: 1

the atomic masses according Wang et al. (The AME 2017 atomic mass evaluation (II). Tables, Graphs and References, Chinese Physics C, Vol. 41, No. 3, 2017)

M_{235U}: Type B normal distribution
Value: 235.0439282 g/mol
Expanded Uncertainty: 0.0000012 g/mol
Coverage Factor: 1

the atomic masses according Wang et al. (The AME 2017 atomic mass evaluation (II). Tables, Graphs and References, Chinese Physics C, Vol. 41, No. 3, 2017)

M_{236U}: Type B normal distribution
Value: 236.0455662 g/mol
Expanded Uncertainty: 0.0000012 g/mol
Coverage Factor: 1

the atomic masses according Wang et al. (The AME 2017 atomic mass evaluation (II). Tables, Graphs and References, Chinese Physics C, Vol. 41, No. 3, 2017)

M_{238U}: Type B normal distribution
Value: 238.0507870 g/mol
Expanded Uncertainty: 0.0000016 g/mol
Coverage Factor: 1

the atomic masses according Wang et al. (The AME 2017 atomic mass evaluation (II). Tables, Graphs and References, Chinese Physics C, Vol. 41, No. 3, 2017)

m_{UEC101}: Type B normal distribution
Value: 46.26719 g
Expanded Uncertainty: 0.00010 g
Coverage Factor: 2

E3917

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

EC NRM 101 certificate

$m_{UCRM116A}$: Type B normal distribution
Value: 11.32258 g
Expanded Uncertainty: 0.00011 g
Coverage Factor: 2

$\eta_{purityCRM116A}$: Type B normal distribution
Value: 0.99945 g/g
Expanded Uncertainty: 0.00014 g/g
Coverage Factor: 2.4

NBL CRM 116-A certificate (coverage factor 2.4)

$R_{233U/238Ua}$: Type B normal distribution
Value: 0 mol/mol
Expanded Uncertainty: 0 mol/mol
Coverage Factor: 2

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

$R_{234U/238Ua}$: Type B normal distribution
Value: 0.00005548 mol/mol
Expanded Uncertainty: 0.00000022 mol/mol
Coverage Factor: 2

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

$R_{235U/238Ua}$: Type B normal distribution
Value: 0.0072593 mol/mol
Expanded Uncertainty: 0.0000036 mol/mol
Coverage Factor: 2

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

$R_{236U/238Ua}$: Type B normal distribution
Value: 0.000000151 mol/mol
Expanded Uncertainty: 0.000000040 mol/mol
Coverage Factor: 2

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

$R_{233U/235Ub}$: Type B normal distribution
Value: 0.0000003863 mol/mol
Expanded Uncertainty: 0.0000000086 mol/mol
Coverage Factor: 3.3

CRM 116-A certificate (coverage factor k= 3.3)

$R_{234U/235Ub}$: Type B normal distribution
Value: 0.0115836 mol/mol
Expanded Uncertainty: 0.0000097 mol/mol
Coverage Factor: 2

CRM 116-A certificate

$R_{238U/235Ub}$: Type B normal distribution
Value: 0.051277 mol/mol
Expanded Uncertainty: 0.000041 mol/mol
Coverage Factor: 2

CRM 116-A certificate

$R_{236U/235Ub}$: Type B normal distribution
Value: 0.0094713 mol/mol
Expanded Uncertainty: 0.0000077 mol/mol
Coverage Factor: 2

CRM 116-A certificate

$n_{234.c}$: Import
Filename: U ingrowth in MP2 on 1 November 2018.smu
Symbol: n_{234U}Total

$n_{235.c}$: Import
Filename: U ingrowth in MP2 on 1 November 2018.smu
Symbol: n_{235U}Total

$n_{236.c}$: Import
Filename: U ingrowth in MP2 on 1 November 2018.smu
Symbol: n_{236U}Total

$n_{233.c}$:
Type B normal distribution
Value: 0 mol
Expanded Uncertainty: 0 mol
Coverage Factor: 2

$n_{238.c}$:
Import
Filename: U ingrowth in MP2 on 1 November 2018.smu
Symbol: n_{238U}Total

m_{UMP2}:
Import
Filename: U ingrowth in MP2 on 1 November 2018.smu
Symbol: m_UTotal

$m_{solution1027u}$:
Type B normal distribution
Value: 2623.412 g
Expanded Uncertainty: 0.009 g
Coverage Factor: 2

E3917

$m_{aliquot1}$:
Type B normal distribution
Value: 2.5327 g
Expanded Uncertainty: 0.0006 g
Coverage Factor: 2

E

Input Correlation:

	$n_{234.c}$	$n_{235.c}$	$n_{236.c}$	$n_{238.c}$	m_{UMP2}
$n_{234.c}$	1	0.2004	0.1362	0.0025	0.2364
$n_{235.c}$	0.2004	1	0.6200	0.0117	0.9954
$n_{236.c}$	0.1362	0.6200	1	0.0079	0.6866
$n_{238.c}$	0.0025	0.0117	0.0079	1	0.0117
m_{UMP2}	0.2364	0.9954	0.6866	0.0117	1

Interim Results:

Quantity	Value	Standard Uncertainty
f_{233U}	$71.487 \cdot 10^{-9}$ mol/mol	$482 \cdot 10^{-12}$ mol/mol
w_{233U}	$70.155 \cdot 10^{-9}$ g/g	$473 \cdot 10^{-12}$ g/g
n_{233U}	$17.334 \cdot 10^{-9}$ mol	$117 \cdot 10^{-12}$ mol
n_{234U}	0.000530540 mol	$219 \cdot 10^{-9}$ mol
n_{236U}	0.000425662 mol	$173 \cdot 10^{-9}$ mol
n_{238U}	0.19523674 mol	0.00000492 mol
M_{Ua}	238.02889667 g/mol	0.00000558 g/mol
f_{234Ua}	0.000055077 mol/mol	$109 \cdot 10^{-9}$ mol/mol
f_{235Ua}	0.00720658 mol/mol	0.00000177 mol/mol
f_{236Ua}	$149.9 \cdot 10^{-9}$ mol/mol	$19.9 \cdot 10^{-9}$ mol/mol
f_{238Ua}	0.99273819 mol/mol	0.00000178 mol/mol
M_{Ub}	235.1857225 g/mol	0.0000551 g/mol
f_{233Ub}	$360.24 \cdot 10^{-9}$ mol/mol	$2.43 \cdot 10^{-9}$ mol/mol
f_{234Ub}	0.01080225 mol/mol	0.00000448 mol/mol
f_{235Ub}	0.9325468 mol/mol	0.0000186 mol/mol
f_{236Ub}	0.00883243 mol/mol	0.00000356 mol/mol
f_{238Ub}	0.0478182 mol/mol	0.0000182 mol/mol
$n_{234.a}$	0.0000107041 mol	$21.2 \cdot 10^{-9}$ mol
$n_{235.a}$	0.001400579 mol	$347 \cdot 10^{-9}$ mol
$n_{236.a}$	$29.13 \cdot 10^{-9}$ mol	$3.86 \cdot 10^{-9}$ mol
$n_{238.a}$	0.19293589 mol	0.00000484 mol
$n_{233.b}$	$17.334 \cdot 10^{-9}$ mol	$117 \cdot 10^{-12}$ mol
$n_{234.b}$	0.000519768 mol	$218 \cdot 10^{-9}$ mol
$n_{235.b}$	0.04487104 mol	0.00000278 mol
$n_{236.b}$	0.000424987 mol	$173 \cdot 10^{-9}$ mol
$n_{238.b}$	0.002300852 mol	$886 \cdot 10^{-9}$ mol
ΣR_U	1.2419404 mol/mol	0.0000160 mol/mol
ΣR_{Ua}	1.00731493 mol/mol	0.00000180 mol/mol
ΣR_{Ub}	1.0723323 mol/mol	0.0000214 mol/mol
w_{234Ua}	0.000054154 g/g	$107 \cdot 10^{-9}$ g/g
w_{235Ua}	0.00711621 g/g	0.00000175 g/g
w_{236Ua}	$148.7 \cdot 10^{-9}$ g/g	$19.7 \cdot 10^{-9}$ g/g
w_{238Ua}	0.99282949 g/g	0.00000176 g/g
w_{233Ub}	$356.96 \cdot 10^{-9}$ g/g	$2.41 \cdot 10^{-9}$ g/g
w_{234Ub}	0.01074967 g/g	0.00000446 g/g
w_{235Ub}	0.9319845 g/g	0.0000188 g/g

Quantity	Value	Standard Uncertainty
w_{236Ub}	0.00886472 g/g	0.00000358 g/g
w_{238Ub}	0.0484007 g/g	0.0000184 g/g

Uncertainty Budgets:

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

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
M_{233U}	233.03963440 g/mol	0.00000240 g/mol	normal	$-6.2\cdot10^{-12}$	$-15\cdot10^{-18}$ g/g	0.0 %
M_{234U}	234.04095040 g/mol	0.00000120 g/mol	normal	$-180\cdot10^{-9}$	$-220\cdot10^{-15}$ g/g	0.0 %
M_{235U}	235.04392820 g/mol	0.00000120 g/mol	normal	0.0000017	$2.0\cdot10^{-12}$ g/g	0.0 %
M_{236U}	236.04556620 g/mol	0.00000120 g/mol	normal	$-150\cdot10^{-9}$	$-180\cdot10^{-15}$ g/g	0.0 %
M_{238U}	238.05078700 g/mol	0.00000160 g/mol	normal	-0.0000013	$-2.1\cdot10^{-12}$ g/g	0.0 %
m_{UEC101}	46.2671900 g	0.0000500 g	normal	0.0000027	$140\cdot10^{-12}$ g/g	0.0 %
$\eta_{purityEC101}$	0.9998500 g/g	0.0000250 g/g	normal	0.00013	$3.1\cdot10^{-9}$ g/g	0.0 %
$m_{UCRM116A}$	11.3225800 g	0.0000550 g	normal	0.00036	$20\cdot10^{-9}$ g/g	0.6 %
$\eta_{purityCRM116A}$	0.9994500 g/g	0.0000583 g/g	normal	0.0040	$230\cdot10^{-9}$ g/g	87.3 %
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	normal	0.0	0.0 g/g	0.0 %
$R_{234U/238Ua}$	0.000055480 mol/mol	$110\cdot10^{-9}$ mol/mol	normal	-0.00012	$-13\cdot10^{-12}$ g/g	0.0 %
$R_{235U/238Ua}$	0.00725930 mol/mol	0.00000180 mol/mol	normal	0.017	$31\cdot10^{-9}$ g/g	1.5 %
$R_{236U/238Ua}$	$151.0\cdot10^{-9}$ mol/mol	$20.0\cdot10^{-9}$ mol/mol	normal	-0.00012	$-2.5\cdot10^{-12}$ g/g	0.0 %
$R_{233U/235Ub}$	$386.30\cdot10^{-9}$ mol/mol	$2.61\cdot10^{-9}$ mol/mol	normal	-0.0037	$-9.7\cdot10^{-12}$ g/g	0.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	0.00000485 mol/mol	normal	-0.0037	$-18\cdot10^{-9}$ g/g	0.5 %
$R_{238U/235Ub}$	0.0512770 mol/mol	0.0000205 mol/mol	normal	-0.0038	$-78\cdot10^{-9}$ g/g	9.6 %
$R_{236U/235Ub}$	0.00947130 mol/mol	0.00000385 mol/mol	normal	-0.0038	$-14\cdot10^{-9}$ g/g	0.3 %
$n_{234.c}$	$67.745\cdot10^{-9}$ mol	$115\cdot10^{-12}$ mol		-0.017	$-1.9\cdot10^{-12}$ g/g	0.0 %
$n_{235.c}$	0.00000782530 mol	$2.84\cdot10^{-9}$ mol		0.073	$210\cdot10^{-12}$ g/g	0.0 %
$n_{236.c}$	$645.532\cdot10^{-9}$ mol	$345\cdot10^{-12}$ mol		-0.017	$-5.9\cdot10^{-12}$ g/g	0.0 %
$n_{233.c}$	0.0 mol	0.0 mol	normal	0.0	0.0 g/g	0.0 %
$n_{238.c}$	$14.089\cdot10^{-12}$ mol	$134\cdot10^{-15}$ mol		-0.017	$-2.3\cdot10^{-15}$ g/g	0.0 %
m_{UMP2}	0.002007523 g	$726\cdot10^{-9}$ g		0.000072	$52\cdot10^{-12}$ g/g	0.0 %
$m_{solution1027u}$	2623.41200 g	0.00450 g	normal	-0.0000016	$-7.1\cdot10^{-9}$ g/g	0.0 %
$\gamma_{235Umixture}$	0.004146395 g/g	$251\cdot10^{-9}$ g/g				

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

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
M_{233U}	233.03963440 g/mol	0.00000240 g/mol	normal	$-320\cdot10^{-15}$	$-770\cdot10^{-21}$ g/g	0.0 %
M_{234U}	234.04095040 g/mol	0.00000120 g/mol	normal	$-14\cdot10^{-9}$	$-16\cdot10^{-15}$ g/g	0.0 %
M_{235U}	235.04392820 g/mol	0.00000120 g/mol	normal	-0.0000014	$-1.6\cdot10^{-12}$ g/g	0.0 %
M_{236U}	236.04556620 g/mol	0.00000120 g/mol	normal	$-8.1\cdot10^{-9}$	$-9.7\cdot10^{-15}$ g/g	0.0 %
M_{238U}	238.05078700 g/mol	0.00000160 g/mol	normal	0.0000014	$2.2\cdot10^{-12}$ g/g	0.0 %
m_{UEC101}	46.2671900 g	0.0000500 g	normal	0.00038	$19\cdot10^{-9}$ g/g	0.2 %
$\eta_{purityEC101}$	0.9998500 g/g	0.0000250 g/g	normal	0.018	$440\cdot10^{-9}$ g/g	95.7 %
$m_{UCRM116A}$	11.3225800 g	0.0000550 g	normal	0.000018	$1.0\cdot10^{-9}$ g/g	0.0 %
$\eta_{purityCRM116A}$	0.9994500 g/g	0.0000583 g/g	normal	0.00021	$12\cdot10^{-9}$ g/g	0.0 %
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	normal	0.0	0.0 g/g	0.0 %
$R_{234U/238Ua}$	0.000055480 mol/mol	$110\cdot10^{-9}$ mol/mol	normal	-0.017	$-1.9\cdot10^{-9}$ g/g	0.0 %
$R_{235U/238Ua}$	0.00725930 mol/mol	0.00000180 mol/mol	normal	-0.017	$-31\cdot10^{-9}$ g/g	0.5 %
$R_{236U/238Ua}$	$151.0\cdot10^{-9}$ mol/mol	$20.0\cdot10^{-9}$ mol/mol	normal	-0.017	$-340\cdot10^{-12}$ g/g	0.0 %
$R_{233U/235Ub}$	$386.30\cdot10^{-9}$ mol/mol	$2.61\cdot10^{-9}$ mol/mol	normal	-0.00019	$-500\cdot10^{-15}$ g/g	0.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	0.00000485 mol/mol	normal	-0.00019	$-940\cdot10^{-12}$ g/g	0.0 %
$R_{238U/235Ub}$	0.0512770 mol/mol	0.0000205 mol/mol	normal	0.0039	$79\cdot10^{-9}$ g/g	3.1 %
$R_{236U/235Ub}$	0.00947130 mol/mol	0.00000385 mol/mol	normal	-0.00020	$-750\cdot10^{-12}$ g/g	0.0 %
$n_{234.c}$	$67.745\cdot10^{-9}$ mol	$115\cdot10^{-12}$ mol		-0.072	$-8.3\cdot10^{-12}$ g/g	0.0 %
$n_{235.c}$	0.00000782530 mol	$2.84\cdot10^{-9}$ mol		-0.072	$-210\cdot10^{-12}$ g/g	0.0 %
$n_{236.c}$	$645.532\cdot10^{-9}$ mol	$345\cdot10^{-12}$ mol		-0.073	$-25\cdot10^{-12}$ g/g	0.0 %
$n_{233.c}$	0.0 mol	0.0 mol	normal	0.0	0.0 g/g	0.0 %
$n_{238.c}$	$14.089\cdot10^{-12}$ mol	$134\cdot10^{-15}$ mol		0.017	$2.4\cdot10^{-15}$ g/g	0.0 %
m_{UMP2}	0.002007523 g	$726\cdot10^{-9}$ g		0.00031	$220\cdot10^{-12}$ g/g	0.0 %
$m_{solution1027u}$	2623.41200 g	0.00450 g	normal	-0.0000068	$-30\cdot10^{-9}$ g/g	0.5 %
$\gamma_{238Umixture}$	0.017715959 g/g	$448\cdot10^{-9}$ g/g				

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

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
M_{233U}	233.03963440 g/mol	0.00000240 g/mol	normal	$-4.0\cdot10^{-12}$	$-9.7\cdot10^{-18}$ mol/mol	0.0 %
M_{234U}	234.04095040 g/mol	0.00000120 g/mol	normal	$-120\cdot10^{-9}$	$-140\cdot10^{-15}$ mol/mol	0.0 %
M_{235U}	235.04392820 g/mol	0.00000120 g/mol	normal	-0.000010	$-12\cdot10^{-12}$ mol/mol	0.0 %
M_{236U}	236.04556620 g/mol	0.00000120 g/mol	normal	$-99\cdot10^{-9}$	$-120\cdot10^{-15}$ mol/mol	0.0 %
M_{238U}	238.05078700 g/mol	0.00000160 g/mol	normal	0.000010	$17\cdot10^{-12}$ mol/mol	0.0 %
m_{UEC101}	46.2671900 g	0.0000500 g	normal	-0.000057	$-2.8\cdot10^{-9}$ mol/mol	0.0 %
$\eta_{purityEC101}$	0.9998500 g/g	0.0000250 g/g	normal	-0.0026	$-66\cdot10^{-9}$ mol/mol	0.3 %
$m_{UCRM116A}$	11.3225800 g	0.0000550 g	normal	0.00023	$13\cdot10^{-9}$ mol/mol	0.0 %
$\eta_{purityCRM116A}$	0.9994500 g/g	0.0000583 g/g	normal	0.0026	$150\cdot10^{-9}$ mol/mol	1.9 %
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	normal	0.0	0.0 mol/mol	0.0 %
$R_{234U/238Ua}$	0.000055480 mol/mol	$110\cdot10^{-9}$ mol/mol	normal	0.99	$110\cdot10^{-9}$ mol/mol	0.9 %
$R_{235U/238Ua}$	0.00725930 mol/mol	0.00000180 mol/mol	normal	0.0026	$4.6\cdot10^{-9}$ mol/mol	0.0 %
$R_{236U/238Ua}$	$151.0\cdot10^{-9}$ mol/mol	$20.0\cdot10^{-9}$ mol/mol	normal	0.0026	$52\cdot10^{-12}$ mol/mol	0.0 %
$R_{233U/235Ub}$	$386.30\cdot10^{-9}$ mol/mol	$2.61\cdot10^{-9}$ mol/mol	normal	-0.0024	$-6.3\cdot10^{-12}$ mol/mol	0.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	0.00000485 mol/mol	normal	0.23	0.0000011 mol/mol	96.5 %
$R_{238U/235Ub}$	0.0512770 mol/mol	0.0000205 mol/mol	normal	-0.0031	$-64\cdot10^{-9}$ mol/mol	0.3 %
$R_{236U/235Ub}$	0.00947130 mol/mol	0.00000385 mol/mol	normal	-0.0025	$-9.5\cdot10^{-9}$ mol/mol	0.0 %
$n_{234.c}$	$67.745\cdot10^{-9}$ mol	$115\cdot10^{-12}$ mol		5.1	$590\cdot10^{-12}$ mol/mol	0.0 %
$n_{238.c}$	$14.089\cdot10^{-12}$ mol	$134\cdot10^{-15}$ mol		-0.014	$-1.9\cdot10^{-15}$ mol/mol	0.0 %
$R_{234U/238U}$	0.00271742 mol/mol	0.00000112 mol/mol				

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

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
M_{233U}	233.03963440 g/mol	0.00000240 g/mol	normal	$-350\cdot10^{-12}$	$-830\cdot10^{-18}$ mol/mol	0.0 %
M_{234U}	234.04095040 g/mol	0.00000120 g/mol	normal	-0.000010	$-12\cdot10^{-12}$ mol/mol	0.0 %
M_{235U}	235.04392820 g/mol	0.00000120 g/mol	normal	-0.00089	$-1.1\cdot10^{-9}$ mol/mol	0.0 %
M_{236U}	236.04556620 g/mol	0.00000120 g/mol	normal	-0.0000085	$-10\cdot10^{-12}$ mol/mol	0.0 %
M_{238U}	238.05078700 g/mol	0.00000160 g/mol	normal	0.00090	$1.4\cdot10^{-9}$ mol/mol	0.0 %
m_{UEC101}	46.2671900 g	0.0000500 g	normal	-0.0049	$-250\cdot10^{-9}$ mol/mol	0.0 %
$\eta_{purityEC101}$	0.9998500 g/g	0.0000250 g/g	normal	-0.23	-0.0000057 mol/mol	13.1 %
$m_{UCRM116A}$	11.3225800 g	0.0000550 g	normal	0.020	0.0000011 mol/mol	0.5 %
$\eta_{purityCRM116A}$	0.9994500 g/g	0.0000583 g/g	normal	0.23	0.000013 mol/mol	71.4 %
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	normal	0.0	0.0 mol/mol	0.0 %
$R_{234U/238Ua}$	0.000055480 mol/mol	$110\cdot10^{-9}$ mol/mol	normal	0.22	$24\cdot10^{-9}$ mol/mol	0.0 %
$R_{235U/238Ua}$	0.00725930 mol/mol	0.00000180 mol/mol	normal	1.2	0.0000022 mol/mol	1.9 %
$R_{236U/238Ua}$	$151.0\cdot10^{-9}$ mol/mol	$20.0\cdot10^{-9}$ mol/mol	normal	0.22	$4.5\cdot10^{-9}$ mol/mol	0.0 %
$R_{233U/235Ub}$	$386.30\cdot10^{-9}$ mol/mol	$2.61\cdot10^{-9}$ mol/mol	normal	-0.21	$-550\cdot10^{-12}$ mol/mol	0.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	0.00000485 mol/mol	normal	-0.21	-0.0000010 mol/mol	0.4 %
$R_{238U/235Ub}$	0.0512770 mol/mol	0.0000205 mol/mol	normal	-0.27	-0.0000055 mol/mol	12.3 %
$R_{236U/235Ub}$	0.00947130 mol/mol	0.00000385 mol/mol	normal	-0.21	$-820\cdot10^{-9}$ mol/mol	0.3 %
$n_{235.c}$	0.00000782530 mol	$2.84\cdot10^{-9}$ mol		5.1	$15\cdot10^{-9}$ mol/mol	0.0 %
$n_{238.c}$	$14.089\cdot10^{-12}$ mol	$134\cdot10^{-15}$ mol		-1.2	$-160\cdot10^{-15}$ mol/mol	0.0 %
$R_{235U/238U}$	0.2370427 mol/mol	0.0000157 mol/mol				

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

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
M_{233U}	233.03963440 g/mol	0.00000240 g/mol	normal	$-3.3\cdot10^{-12}$	$-7.9\cdot10^{-18}$ mol/mol	0.0 %
M_{234U}	234.04095040 g/mol	0.00000120 g/mol	normal	$-98\cdot10^{-9}$	$-120\cdot10^{-15}$ mol/mol	0.0 %
M_{235U}	235.04392820 g/mol	0.00000120 g/mol	normal	-0.0000085	$-10\cdot10^{-12}$ mol/mol	0.0 %
M_{236U}	236.04556620 g/mol	0.00000120 g/mol	normal	$-81\cdot10^{-9}$	$-97\cdot10^{-15}$ mol/mol	0.0 %
M_{238U}	238.05078700 g/mol	0.00000160 g/mol	normal	0.0000085	$14\cdot10^{-12}$ mol/mol	0.0 %
m_{UEC101}	46.2671900 g	0.0000500 g	normal	-0.000047	$-2.3\cdot10^{-9}$ mol/mol	0.0 %
$\eta_{purityEC101}$	0.9998500 g/g	0.0000250 g/g	normal	-0.0022	$-54\cdot10^{-9}$ mol/mol	0.4 %
$m_{UCRM116A}$	11.3225800 g	0.0000550 g	normal	0.00019	$10\cdot10^{-9}$ mol/mol	0.0 %
$\eta_{purityCRM116A}$	0.9994500 g/g	0.0000583 g/g	normal	0.0022	$130\cdot10^{-9}$ mol/mol	2.0 %
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	normal	0.0	0.0 mol/mol	0.0 %
$R_{234U/238Ua}$	0.000055480 mol/mol	$110\cdot10^{-9}$ mol/mol	normal	0.0021	$230\cdot10^{-12}$ mol/mol	0.0 %
$R_{235U/238Ua}$	0.00725930 mol/mol	0.00000180 mol/mol	normal	0.0021	$3.8\cdot10^{-9}$ mol/mol	0.0 %
$R_{236U/238Ua}$	$151.0\cdot10^{-9}$ mol/mol	$20.0\cdot10^{-9}$ mol/mol	normal	0.99	$20\cdot10^{-9}$ mol/mol	0.0 %
$R_{233U/235Ub}$	$386.30\cdot10^{-9}$ mol/mol	$2.61\cdot10^{-9}$ mol/mol	normal	-0.0020	$-5.2\cdot10^{-12}$ mol/mol	0.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	0.00000485 mol/mol	normal	-0.0020	$-9.7\cdot10^{-9}$ mol/mol	0.0 %
$R_{238U/235Ub}$	0.0512770 mol/mol	0.0000205 mol/mol	normal	-0.0025	$-52\cdot10^{-9}$ mol/mol	0.3 %
$R_{236U/235Ub}$	0.00947130 mol/mol	0.00000385 mol/mol	normal	0.23	$880\cdot10^{-9}$ mol/mol	97.2 %
$n_{236.c}$	$645.532\cdot10^{-9}$ mol	$345\cdot10^{-12}$ mol		5.1	$1.8\cdot10^{-9}$ mol/mol	0.0 %
$n_{238.c}$	$14.089\cdot10^{-12}$ mol	$134\cdot10^{-15}$ mol		-0.011	$-1.5\cdot10^{-15}$ mol/mol	0.0 %
$R_{236U/238U}$	0.002180234 mol/mol	$890\cdot10^{-9}$ mol/mol				

$m_{235Uvial1}$: **Mass of ^{235}U in vial 1**

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
M_{233U}	233.03963440 g/mol	0.00000240 g/mol	normal	$-16\cdot10^{-12}$	$-37\cdot10^{-18}$ g	0.0 %
M_{234U}	234.04095040 g/mol	0.00000120 g/mol	normal	$-470\cdot10^{-9}$	$-560\cdot10^{-15}$ g	0.0 %
M_{235U}	235.04392820 g/mol	0.00000120 g/mol	normal	0.0000043	$5.2\cdot10^{-12}$ g	0.0 %
M_{236U}	236.04556620 g/mol	0.00000120 g/mol	normal	$-380\cdot10^{-9}$	$-460\cdot10^{-15}$ g	0.0 %
M_{238U}	238.05078700 g/mol	0.00000160 g/mol	normal	-0.0000034	$-5.4\cdot10^{-12}$ g	0.0 %
m_{UEC101}	46.2671900 g	0.0000500 g	normal	0.0000069	$340\cdot10^{-12}$ g	0.0 %
$\eta_{purityEC101}$	0.9998500 g/g	0.0000250 g/g	normal	0.00032	$7.9\cdot10^{-9}$ g	0.0 %
$m_{UCRM116A}$	11.3225800 g	0.0000550 g	normal	0.00090	$49\cdot10^{-9}$ g	0.1 %
$\eta_{purityCRM116A}$	0.9994500 g/g	0.0000583 g/g	normal	0.010	$590\cdot10^{-9}$ g	18.1 %
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	normal	0.0	0.0 g	0.0 %
$R_{234U/238Ua}$	0.000055480 mol/mol	$110\cdot10^{-9}$ mol/mol	normal	-0.00031	$-34\cdot10^{-12}$ g	0.0 %
$R_{235U/238Ua}$	0.00725930 mol/mol	0.00000180 mol/mol	normal	0.043	$78\cdot10^{-9}$ g	0.3 %
$R_{236U/238Ua}$	$151.0\cdot10^{-9}$ mol/mol	$20.0\cdot10^{-9}$ mol/mol	normal	-0.00031	$-6.3\cdot10^{-12}$ g	0.0 %
$R_{233U/235Ub}$	$386.30\cdot10^{-9}$ mol/mol	$2.61\cdot10^{-9}$ mol/mol	normal	-0.0094	$-25\cdot10^{-12}$ g	0.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	0.00000485 mol/mol	normal	-0.0094	$-46\cdot10^{-9}$ g	0.1 %
$R_{238U/235Ub}$	0.0512770 mol/mol	0.0000205 mol/mol	normal	-0.0096	$-200\cdot10^{-9}$ g	2.0 %
$R_{236U/235Ub}$	0.00947130 mol/mol	0.00000385 mol/mol	normal	-0.0095	$-37\cdot10^{-9}$ g	0.0 %
$n_{234.c}$	$67.745\cdot10^{-9}$ mol	$115\cdot10^{-12}$ mol		-0.043	$-4.9\cdot10^{-12}$ g	0.0 %
$n_{235.c}$	0.00000782530 mol	$2.84\cdot10^{-9}$ mol		0.18	$520\cdot10^{-12}$ g	0.0 %
$n_{236.c}$	$645.532\cdot10^{-9}$ mol	$345\cdot10^{-12}$ mol		-0.043	$-15\cdot10^{-12}$ g	0.0 %
$n_{233.c}$	0.0 mol	0.0 mol	normal	0.0	0.0 g	0.0 %
$n_{238.c}$	$14.089\cdot10^{-12}$ mol	$134\cdot10^{-15}$ mol		-0.043	$-5.8\cdot10^{-15}$ g	0.0 %
m_{UMP2}	0.002007523 g	$726\cdot10^{-9}$ g		0.00018	$130\cdot10^{-12}$ g	0.0 %
$m_{solution1027u}$	2623.41200 g	0.00450 g	normal	-0.0000040	$-18\cdot10^{-9}$ g	0.0 %
$m_{aliquot1}$	2.532700 g	0.000300 g	normal	0.0041	0.0000012 g	79.3 %
$m_{235Uvial1}$	0.01050157 g	0.00000140 g				

$m_{238Uvial1}$: **Mass of ^{238}U in vial 1**

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
M_{233U}	233.03963440 g/mol	0.00000240 g/mol	normal	$-810 \cdot 10^{-15}$	$-1.9 \cdot 10^{-18}$ g	0.0 %
M_{234U}	234.04095040 g/mol	0.00000120 g/mol	normal	$-35 \cdot 10^{-9}$	$-42 \cdot 10^{-15}$ g	0.0 %
M_{235U}	235.04392820 g/mol	0.00000120 g/mol	normal	-0.0000034	$-4.1 \cdot 10^{-12}$ g	0.0 %
M_{236U}	236.04556620 g/mol	0.00000120 g/mol	normal	$-20 \cdot 10^{-9}$	$-24 \cdot 10^{-15}$ g	0.0 %
M_{238U}	238.05078700 g/mol	0.00000160 g/mol	normal	0.0000034	$5.5 \cdot 10^{-12}$ g	0.0 %
m_{UEC101}	46.2671900 g	0.0000500 g	normal	0.00096	$48 \cdot 10^{-9}$ g	0.0 %
$\eta_{purityEC101}$	0.9998500 g/g	0.0000250 g/g	normal	0.044	0.0000011 g	4.2 %
$m_{UCRM116A}$	11.3225800 g	0.0000550 g	normal	0.000047	$2.6 \cdot 10^{-9}$ g	0.0 %
$\eta_{purityCRM116A}$	0.9994500 g/g	0.0000583 g/g	normal	0.00053	$31 \cdot 10^{-9}$ g	0.0 %
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	normal	0.0	0.0 g	0.0 %
$R_{234U/238Ua}$	0.000055480 mol/mol	$110 \cdot 10^{-9}$ mol/mol	normal	-0.043	$-4.8 \cdot 10^{-9}$ g	0.0 %
$R_{235U/238Ua}$	0.00725930 mol/mol	0.00000180 mol/mol	normal	-0.043	$-78 \cdot 10^{-9}$ g	0.0 %
$R_{236U/238Ua}$	$151.0 \cdot 10^{-9}$ mol/mol	$20.0 \cdot 10^{-9}$ mol/mol	normal	-0.044	$-870 \cdot 10^{-12}$ g	0.0 %
$R_{233U/235Ub}$	$386.30 \cdot 10^{-9}$ mol/mol	$2.61 \cdot 10^{-9}$ mol/mol	normal	-0.00049	$-1.3 \cdot 10^{-12}$ g	0.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	0.00000485 mol/mol	normal	-0.00049	$-2.4 \cdot 10^{-9}$ g	0.0 %
$R_{238U/235Ub}$	0.0512770 mol/mol	0.0000205 mol/mol	normal	0.0098	$200 \cdot 10^{-9}$ g	0.1 %
$R_{236U/235Ub}$	0.00947130 mol/mol	0.00000385 mol/mol	normal	-0.00049	$-1.9 \cdot 10^{-9}$ g	0.0 %
$n_{234.c}$	$67.745 \cdot 10^{-9}$ mol	$115 \cdot 10^{-12}$ mol		-0.18	$-21 \cdot 10^{-12}$ g	0.0 %
$n_{235.c}$	0.00000782530 mol	$2.84 \cdot 10^{-9}$ mol		-0.18	$-520 \cdot 10^{-12}$ g	0.0 %
$n_{236.c}$	$645.532 \cdot 10^{-9}$ mol	$345 \cdot 10^{-12}$ mol		-0.18	$-63 \cdot 10^{-12}$ g	0.0 %
$n_{233.c}$	0.0 mol	0.0 mol	normal	0.0	0.0 g	0.0 %
$n_{238.c}$	$14.089 \cdot 10^{-12}$ mol	$134 \cdot 10^{-15}$ mol		0.044	$6.0 \cdot 10^{-15}$ g	0.0 %
m_{UMP2}	0.002007523 g	$726 \cdot 10^{-9}$ g		0.00078	$570 \cdot 10^{-12}$ g	0.0 %
$m_{solution1027u}$	2623.41200 g	0.00450 g	normal	-0.000017	$-77 \cdot 10^{-9}$ g	0.0 %
$m_{aliquot1}$	2.532700 g	0.000300 g	normal	0.018	0.0000053 g	95.6 %
$m_{238Uvial1}$	0.04486921 g	0.00000543 g				

Results:

Quantity	Value	Expanded Uncertainty	Coverage factor	Coverage
$\gamma_{Umixture}$	0.0219480 g/g	0.0000010 g/g	2.00	manual
$\gamma_{235Umixture}$	0.00414640 g/g	$500 \cdot 10^{-9}$ g/g	2.00	95% (normal)
$\gamma_{238Umixture}$	0.01771596 g/g	$900 \cdot 10^{-9}$ g/g	2.00	95% (normal)
$c_{Umixture}$	0.0000924264 mol/g	$4.3 \cdot 10^{-9}$ mol/g	2.00	manual
$c_{235Umixture}$	0.0000176409 mol/g	$2.1 \cdot 10^{-9}$ mol/g	2.00	manual
$c_{238Umixture}$	0.0000744209 mol/g	$3.8 \cdot 10^{-9}$ mol/g	2.00	manual
M_U	237.464589 g/mol	0.000062 g/mol	2.00	manual
$R_{233U/238U}$	$88.8 \cdot 10^{-9}$ mol/mol	$1.2 \cdot 10^{-9}$ mol/mol	2.00	manual
$R_{234U/238U}$	0.0027174 mol/mol	0.0000022 mol/mol	2.00	manual
$R_{235U/238U}$	0.237043 mol/mol	0.000031 mol/mol	2.00	manual
$R_{236U/238U}$	0.0021802 mol/mol	0.0000018 mol/mol	2.00	manual
f_{234U}	0.0021880 mol/mol	0.0000018 mol/mol	2.00	manual
f_{235U}	0.190865 mol/mol	0.000020 mol/mol	2.00	manual
f_{236U}	0.0017555 mol/mol	0.0000014 mol/mol	2.00	manual
f_{238U}	0.805192 mol/mol	0.000021 mol/mol	2.00	manual
w_{234U}	0.0021565 g/g	0.0000018 g/g	2.00	manual
w_{235U}	0.188919 g/g	0.000020 g/g	2.00	manual
w_{236U}	0.0017450 g/g	0.0000014 g/g	2.00	manual
w_{238U}	0.807179 g/g	0.000021 g/g	2.00	manual
n_{235U}	0.0462794 mol	0.0000056 mol	2.00	manual
$m_{235Uvial1}$	0.0105016 g	0.0000028 g	2.00	95% (normal)
$m_{238Uvial1}$	0.044869 g	0.000011 g	2.00	95% (normal)

Annex 15 Uncertainty budget for the plutonium gravimetric mixture of IRMM-1027u

Plutonium gravimetric mixture of IRMM-1027u normalised to 1 November 2018

Author: Renata Bujak

The plutonium gravimetric mixture was prepared by dissolving plutonium MP2 metal (CEA/CETAMA) in 20 mL 6 M hydrochloric acid and in 6+8 M nitric acid. Before the dissolution the MP2 metals were electropolished. The dissolution of the metals were done directly in the big flask of the mother soltution.

Input parameters:

1) Mass of plutonium metal and the nitrate solution (E3917 certificate and E3917 Bujak IRMM-1027u metals and stock solution.xlsx excel file) 2) Purity of plutonium metal (MP2 metal certificate) 3) Plutonium isotope amount ratios (IRMM certificate, issued 11 April 2007, date of measurment completed: 7 November 2006) 4) The atomic masses according Wang et al. (The AME 2016 atomic mass evaluation (II). Tables, Graphs and References, Chinese Physics C, Vol. 41, No. 3, 2017). 5) Purity of MP2 metal on 30 May 2018 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).

The values are normalised to 1 November 2018 (date of certificate)

The weighing date of the mother solution is 28/11/2018 and the dispensing started on the 3/12/2018. No weighing was done before the dispensing thus no evaporation correction was taking into account on the stock solution.

Date of MP2 dissolution: 06 November 2018

MP2 unit numbers: E495, D599, D288

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-1027u, 1 November 2018}

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

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

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

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

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

{Decayed and normalised isotope amount fractions in gravimetric mixture, IRMM-1027u, 1 November 2018}

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

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

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

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

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

{Decayed molar mass of plutonium in gravimetric mixtures, IRMM-1027u, 1 November 2018}

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

{Decayed and normalised isotope mass fractios in gravimetric mixture, IRMM-1027u, 1 November 2018}

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

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

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

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

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

{Decayed amount ratios for purity calculation, 1 November 2018}

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

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

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

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

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

{Decayed isotope masses for purity calculation, 1 November 2018}

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

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

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

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

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

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

$\eta_{PuMP2Nov2018}=\eta_{PuMP2Jan2007}*\Sigma md_{Pu}/m_{Pu}$;

{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-1027u, 1 November 2018}

$\gamma_{Pumixture}=(m_{PuMP2}*\eta_{PuMP2Nov2018})/m_{solution1027u}$;

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

$m_{239Puvial1}=\gamma_{Pumixture239}*m_{aliquot1}$;

{Plutonium amount content in gravimetric mixture, IRMM-1027u, 1 November 2018}

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

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

List of Quantities:

Quantity	Unit	Definition
$\gamma_{Pumixture}$	g/g	Pu mass fraction in IRMM-1027u
$\gamma_{Pumixture239}$	g/g	^{239}Pu mass fraction in IRMM-1027u
$c_{Pumixture239}$	mol/g	^{239}Pu amount content in IRMM-1027u
$c_{Pumixture}$	mol/g	Pu amount content in IRMM-1027u
$Rd_{238Pu/239Pu}$	mol/mol	decayed ^{238}Pu/^{239}Pu amount ratio in IRMM-1027u, 1 November 2018
$Rd_{240Pu/239Pu}$	mol/mol	decayed ^{240}Pu/^{239}Pu amount ratio in IRMM-1027u, 1 November 2018
$Rd_{241Pu/239Pu}$	mol/mol	decayed ^{241}Pu/^{239}Pu amount ratio in IRMM-1027u, 1 November 2018
$Rd_{242Pu/239Pu}$	mol/mol	decayed ^{242}Pu/^{239}Pu amount ratio in IRMM-1027u, 1 November 2018
$R_{238Pu/239Pu}$	mol/mol	^{238}Pu/^{239}Pu amount ratio in MP2, 1 Jan 2007
Δt	a	time difference between certification date MP2 (1 Jan 2007) and the date of certification of IRMM-1027u (1 Nov 2018)
$R_{240Pu/239Pu}$	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		
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

Quantity	Unit	Definition
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-1027u, 1 November 2018
$fdnorm_{238Pu}$	mol/mol	Decayed and normalised ^{238}Pu amount fraction in gravimetric mixture, IRMM-1027u, 1 November 2018
$fdnorm_{239Pu}$	mol/mol	Decayed and normalised ^{239}Pu amount fraction in gravimetric mixture, IRMM-1027u, 1 November 2018
$fdnorm_{240Pu}$	mol/mol	Decayed and normalised ^{240}Pu amount fraction in gravimetric mixture, IRMM-1027u, 1 November 2018
$fdnorm_{241Pu}$	mol/mol	Decayed and normalised ^{241}Pu amount fraction in gravimetric mixture, IRMM-1027u, 1 November 2018
$fdnorm_{242Pu}$	mol/mol	Decayed and normalised ^{242}Pu amount fraction in gravimetric mixture, IRMM-1027u, 1 November 2018
Md_{Pu}	g/mol	Decayed molar mass of Pu in gravimetric mixture, IRMM-1027u, 1 November 2018
$wdnorm_{238Pu}$	g/g	Decayed and normalised ^{238}Pu mass fraction in gravimetric mixture, IRMM-1027u, 1 November 2018
$wdnorm_{239Pu}$	g/g	Decayed and normalised ^{239}Pu mass fraction in gravimetric mixture, IRMM-1027u, 1 November 2018
$wdnorm_{240Pu}$	g/g	Decayed and normalised ^{240}Pu mass fraction in gravimetric mixture, IRMM-1027u, 1 November 2018
$wdnorm_{241Pu}$	g/g	Decayed and normalised ^{241}Pu mass fraction in gravimetric mixture, IRMM-1027u, 1 November 2018
$wdnorm_{242Pu}$	g/g	Decayed and normalised ^{242}Pu mass fraction in gravimetric mixture, IRMM-1027u, 1 November 2018
ln_2		
τ_{238}	a	Half-life ^{238}Pu
τ_{239}	a	Half-life ^{239}Pu
τ_{240}	a	Half-life ^{240}Pu
τ_{241}	a	Half-life ^{241}Pu
τ_{242}	a	Half-life ^{242}Pu
m_{PuMP2}	g	Mass of plutonium MP2 metal
m_{Pu}	g	
md_{238Pu}	g	Decayed mass of ^{238}Pu, from 1 Jan 2007 to 1 November 2018
md_{239Pu}	g	Decayed mass of ^{239}Pu, from 1 Jan 2007 to 1 November 2018
md_{240Pu}	g	Decayed mass of ^{240}Pu, from 1 Jan 2007 to 1 November 2018
md_{241Pu}	g	Decayed mass of ^{241}Pu, from 1 Jan 2007 to 1 November 2018
md_{242Pu}	g	Decayed mass of ^{242}Pu, from 1 Jan 2007 to 1 November 2018
Σmd_{Pu}	g	Sum of decayed Pu masses

Quantity	Unit	Definition
$\eta_{PuMP2Jan2007}$	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 2018
fd_{239Pu}	mol/mol	Decayed ^{239}Pu amount fraction in MP2, from 1 Jan 2007 to 1 November 2018
fd_{240Pu}	mol/mol	Decayed ^{240}Pu amount fraction in MP2, from 1 Jan 2007 to 1 November 2018
fd_{241Pu}	mol/mol	Decayed ^{241}Pu amount fraction in MP2, from 1 Jan 2007 to 1 November 2018
fd_{242Pu}	mol/mol	Decayed ^{242}Pu amount fraction in MP2, from 1 Jan 2007 to 1 November 2018
$\eta_{PuMP2Nov2018}$	g/g	purity of MP2 metal, 1 November 2018
$m_{solution1027u}$	g	Mass of gravimetric mixture
$m_{239Puvial1}$	g	Mass of ^{238}Pu in vial 1
$m_{aliquot1}$	g	Mass of dispensed mother solution of IRMM-1027u in vial 1

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

IRMM MP2 certificate 2007

Δt: Constant
Value: 11.83299 a

01/01/2007, 01/11/2018, delta t= 4322 days / 365.25 = 11.83299 a

$R_{240Pu/239Pu}$: 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: 238.0495583 g/mol
Expanded Uncertainty: 0.0000012 g/mol
Coverage Factor: 1

The AME 2016 atomic mass evaluation (II). Tables, Graphs and References, Chinese Physics C, Vol. 41, No. 3, 2017

M_{239Pu}: Type B normal distribution
Value: 239.0521617 g/mol
Expanded Uncertainty: 0.0000012 g/mol
Coverage Factor: 1

The AME 2016 atomic mass evaluation (II). Tables, Graphs and References, Chinese Physics C, Vol. 41, No. 3, 2017

M_{240Pu}: Type B normal distribution
Value: 240.0538118 g/mol
Expanded Uncertainty: 0.0000012 g/mol
Coverage Factor: 1

The AME 2016 atomic mass evaluation (II). Tables, Graphs and References, Chinese Physics C, Vol. 41, No. 3, 2017

M_{241Pu}: Type B normal distribution
Value: 241.0568497 g/mol
Expanded Uncertainty: 0.0000012 g/mol
Coverage Factor: 1

The AME 2016 atomic mass evaluation (II). Tables, Graphs and References, Chinese Physics C, Vol. 41, No. 3, 2017

M_{242Pu}: Type B normal distribution
Value: 242.0587410 g/mol
Expanded Uncertainty: 0.0000013 g/mol
Coverage Factor: 1

The AME 2016 atomic mass evaluation (II). Tables, Graphs and References, Chinese Physics C, Vol. 41, No. 3, 2017

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: 1.93127 g
Expanded Uncertainty: 0.00007 g
Coverage Factor: 2

E3917

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

$\eta_{PuMP2Jan2007}$: Import
Filename: ..\..\..\..\..\Secure Data\Project Data\LSD spikes\IRMM-1027s ISO 17034\Processing\GUM calculations\Decay MP2 from 12-03-2001 to 01-01-2007.smu
Symbol: $\eta_{PuMP2Jan2007}$

$m_{solution1027u}$: Type B normal distribution
Value: 2623.412 g
Expanded Uncertainty: 0.009 g
Coverage Factor: 2

E3917

$m_{aliquot1}$: Type B normal distribution
Value: 2.5327 g
Expanded Uncertainty: 0.0006 g
Coverage Factor: 2

E

Input Correlation:

The abundance set for Pu is assumed as uncorrelated.

Interim Results:

Quantity	Value	Standard Uncertainty
M_{Pu}	239.07478914 g/mol	$4.20 \cdot 10^{-6}$ 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}	1.02265000 mol/mol	$2.73 \cdot 10^{-6}$ mol/mol
md_{238Pu}	$27.336 \cdot 10^{-6}$ g	$129 \cdot 10^{-9}$ g
md_{239Pu}	0.97730529 g	$2.90 \cdot 10^{-6}$ g
md_{240Pu}	0.02199514 g	$2.45 \cdot 10^{-6}$ g
md_{241Pu}	$132.237 \cdot 10^{-6}$ g	$864 \cdot 10^{-9}$ g
md_{242Pu}	$74.936 \cdot 10^{-6}$ g	$386 \cdot 10^{-9}$ g
Σmd_{Pu}	0.999534947 g	$686 \cdot 10^{-9}$ 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}	$27.453 \cdot 10^{-6}$ mol/mol	$129 \cdot 10^{-9}$ mol/mol
fd_{239Pu}	0.97739780 mol/mol	$2.88 \cdot 10^{-6}$ mol/mol
fd_{240Pu}	0.02190544 mol/mol	$2.44 \cdot 10^{-6}$ mol/mol
fd_{241Pu}	$131.150 \cdot 10^{-6}$ mol/mol	$857 \cdot 10^{-9}$ mol/mol
fd_{242Pu}	$74.013 \cdot 10^{-6}$ mol/mol	$381 \cdot 10^{-9}$ mol/mol

Uncertainty Budgets:

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

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$R_{238Pu/239Pu}$	$30.830 \cdot 10^{-6}$ mol/mol	$145 \cdot 10^{-9}$ mol/mol	normal	$-700 \cdot 10^{-6}$	$-100 \cdot 10^{-12}$ g/g	0.0 %
Δt	11.83299 a					
$R_{240Pu/239Pu}$	0.02243240 mol/mol	$2.55 \cdot 10^{-6}$ mol/mol	normal	$-710 \cdot 10^{-6}$	$-1.8 \cdot 10^{-9}$ g/g	0.0 %
$R_{241Pu/239Pu}$	$237.80 \cdot 10^{-6}$ mol/mol	$1.55 \cdot 10^{-6}$ mol/mol	normal	$-710 \cdot 10^{-6}$	$-1.1 \cdot 10^{-9}$ g/g	0.0 %
$R_{242Pu/239Pu}$	$75.700 \cdot 10^{-6}$ mol/mol	$390 \cdot 10^{-9}$ mol/mol	normal	$-710 \cdot 10^{-6}$	$-280 \cdot 10^{-12}$ g/g	0.0 %
e	2.718281828459					
M_{238Pu}	238.04955830 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$-91 \cdot 10^{-12}$	$-110 \cdot 10^{-18}$ g/g	0.0 %
M_{239Pu}	239.05216170 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$67 \cdot 10^{-9}$	$81 \cdot 10^{-15}$ g/g	0.0 %
M_{240Pu}	240.05381180 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$-66 \cdot 10^{-9}$	$-79 \cdot 10^{-15}$ g/g	0.0 %
M_{241Pu}	241.05684970 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$-700 \cdot 10^{-12}$	$-840 \cdot 10^{-18}$ g/g	0.0 %
M_{242Pu}	242.05874100 g/mol	$1.30 \cdot 10^{-6}$ g/mol	normal	$-220 \cdot 10^{-12}$	$-290 \cdot 10^{-18}$ g/g	0.0 %
τ_{238}	87.7400 a	0.0300 a	normal	0.0	0.0 g/g	0.0 %
τ_{239}	$24.1000 \cdot 10^{3}$ a	11.0 a	normal	$10 \cdot 10^{-12}$	$110 \cdot 10^{-12}$ g/g	0.0 %
τ_{240}	$6.56100 \cdot 10^{3}$ a	7.00 a	normal	0.0	0.0 g/g	0.0 %
τ_{241}	14.3250 a	0.0120 a	normal	not valid!	$13 \cdot 10^{-24}$ g/g	0.0 %
τ_{242}	$373.00 \cdot 10^{3}$ a	$3.00 \cdot 10^{3}$ a	normal	0.0	0.0 g/g	0.0 %
m_{PuMP2}	1.9312700 g	$35.0 \cdot 10^{-6}$ g	normal	$370 \cdot 10^{-6}$	$13 \cdot 10^{-9}$ g/g	0.8 %
m_{Pu}	1.0 g	0.0 g	normal	0.0	0.0 g/g	0.0 %
$\eta_{PuMP2Jan2007}$	0.998746 g/g	$200 \cdot 10^{-6}$ g/g		$720 \cdot 10^{-6}$	$140 \cdot 10^{-9}$ g/g	99.2 %
$m_{solution1027u}$	$2.62341200 \cdot 10^{3}$ g	$4.50 \cdot 10^{-3}$ g	normal	$-270 \cdot 10^{-9}$	$-1.2 \cdot 10^{-9}$ g/g	0.0 %
$\gamma_{Pumixture239}$	$718.558 \cdot 10^{-6}$ g/g	$144 \cdot 10^{-9}$ g/g				

$Rd_{240Pu/239Pu}$: decayed $^{240}Pu/^{239}Pu$ amount ratio in IRMM-1027u, 1 November 2018

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
Δt	11.83299 a					
$R_{240Pu/239Pu}$	0.02243240 mol/mol	$2.55 \cdot 10^{-6}$ mol/mol	normal	1.0	$2.5 \cdot 10^{-6}$ mol/mol	100.0 %
e	2.718281828459					
τ_{239}	$24.1000 \cdot 10^{3}$ a	11.0 a	normal	$-320 \cdot 10^{-12}$	$-3.5 \cdot 10^{-9}$ mol/mol	0.0 %
τ_{240}	$6.56100 \cdot 10^{3}$ a	7.00 a	normal	$4.3 \cdot 10^{-9}$	$30 \cdot 10^{-9}$ mol/mol	0.0 %
$Rd_{240Pu/239Pu}$	0.02241200 mol/mol	$2.55 \cdot 10^{-6}$ mol/mol				

$Rd_{241Pu/239Pu}$: decayed $^{241}Pu/^{239}Pu$ amount ratio in IRMM-1027u, 1 November 2018

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
Δt	11.83299 a					
$R_{241Pu/239Pu}$	$237.80 \cdot 10^{-6}$ mol/mol	$1.55 \cdot 10^{-6}$ mol/mol	normal	0.56	$870 \cdot 10^{-9}$ mol/mol	99.5 %
e	2.718281828459					
τ_{239}	$24.1000 \cdot 10^{3}$ a	11.0 a	normal	$-1.9 \cdot 10^{-12}$	$-21 \cdot 10^{-12}$ mol/mol	0.0 %
τ_{241}	14.3250 a	0.0120 a	normal	$5.4 \cdot 10^{-6}$	$64 \cdot 10^{-9}$ mol/mol	0.5 %
$Rd_{241Pu/239Pu}$	$134.183 \cdot 10^{-6}$ mol/mol	$877 \cdot 10^{-9}$ mol/mol				

$Rd_{242Pu/239Pu}$: decayed $^{242}Pu/^{239}Pu$ amount ratio in IRMM-1027u, 1 November 2018

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
Δt	11.83299 a					
$R_{242Pu/239Pu}$	$75.700 \cdot 10^{-6}$ mol/mol	$390 \cdot 10^{-9}$ mol/mol	normal	1.0	$390 \cdot 10^{-9}$ mol/mol	100.0 %
e	2.718281828459					
τ_{239}	$24.1000 \cdot 10^{3}$ a	11.0 a	normal	$-1.1 \cdot 10^{-12}$	$-12 \cdot 10^{-12}$ mol/mol	0.0 %
τ_{242}	$373.00 \cdot 10^{3}$ a	$3.00 \cdot 10^{3}$ a	normal	$4.5 \cdot 10^{-15}$	$13 \cdot 10^{-12}$ mol/mol	0.0 %
$Rd_{242Pu/239Pu}$	$75.724 \cdot 10^{-6}$ mol/mol	$390 \cdot 10^{-9}$ mol/mol				

$m_{239Puvial1}$: **Mass of ^{238}Pu in vial 1**

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$R_{238Pu/239Pu}$	$30.830 \cdot 10^{-6}$ mol/mol	$145 \cdot 10^{-9}$ mol/mol	normal	$-1.8 \cdot 10^{-3}$	$-260 \cdot 10^{-12}$ g	0.0 %
Δt	11.83299 a					
$R_{240Pu/239Pu}$	0.02243240 mol/mol	$2.55 \cdot 10^{-6}$ mol/mol	normal	$-1.8 \cdot 10^{-3}$	$-4.6 \cdot 10^{-9}$ g	0.0 %
$R_{241Pu/239Pu}$	$237.80 \cdot 10^{-6}$ mol/mol	$1.55 \cdot 10^{-6}$ mol/mol	normal	$-1.8 \cdot 10^{-3}$	$-2.8 \cdot 10^{-9}$ g	0.0 %
$R_{242Pu/239Pu}$	$75.700 \cdot 10^{-6}$ mol/mol	$390 \cdot 10^{-9}$ mol/mol	normal	$-1.8 \cdot 10^{-3}$	$-700 \cdot 10^{-12}$ g	0.0 %
e	2.718281828459					
M_{238Pu}	238.04955830 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$-230 \cdot 10^{-12}$	$-280 \cdot 10^{-18}$ g	0.0 %
M_{239Pu}	239.05216170 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$170 \cdot 10^{-9}$	$200 \cdot 10^{-15}$ g	0.0 %
M_{240Pu}	240.05381180 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$-170 \cdot 10^{-9}$	$-200 \cdot 10^{-15}$ g	0.0 %
M_{241Pu}	241.05684970 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$-1.8 \cdot 10^{-9}$	$-2.1 \cdot 10^{-15}$ g	0.0 %
M_{242Pu}	242.05874100 g/mol	$1.30 \cdot 10^{-6}$ g/mol	normal	$-560 \cdot 10^{-12}$	$-730 \cdot 10^{-18}$ g	0.0 %
τ_{238}	87.7400 a	0.0300 a	normal	0.0	0.0 g	0.0 %
τ_{239}	$24.1000 \cdot 10^{3}$ a	11.0 a	normal	$26 \cdot 10^{-12}$	$280 \cdot 10^{-12}$ g	0.0 %
τ_{240}	$6.56100 \cdot 10^{3}$ a	7.00 a	normal	0.0	0.0 g	0.0 %
τ_{241}	14.3250 a	0.0120 a	normal	not valid!	$26 \cdot 10^{-24}$ g	0.0 %
τ_{242}	$373.00 \cdot 10^{3}$ a	$3.00 \cdot 10^{3}$ a	normal	0.0	0.0 g	0.0 %
m_{PuMP2}	1.9312700 g	$35.0 \cdot 10^{-6}$ g	normal	$940 \cdot 10^{-6}$	$33 \cdot 10^{-9}$ g	0.6 %
m_{Pu}	1.0 g	0.0 g	normal	0.0	0.0 g	0.0 %
$\eta_{PuMP2Jan2007}$	0.998746 g/g	$200 \cdot 10^{-6}$ g/g		$1.8 \cdot 10^{-3}$	$360 \cdot 10^{-9}$ g	73.6 %
$m_{solution1027u}$	$2.62341200 \cdot 10^{3}$ g	$4.50 \cdot 10^{-3}$ g	normal	$-690 \cdot 10^{-9}$	$-3.1 \cdot 10^{-9}$ g	0.0 %
$m_{aliquot1}$	2.532700 g	$300 \cdot 10^{-6}$ g	normal	$720 \cdot 10^{-6}$	$220 \cdot 10^{-9}$ g	25.8 %
$m_{239Puvial1}$	$1.819892 \cdot 10^{-3}$ g	$425 \cdot 10^{-9}$ g				

Results:

Quantity	Value	Expanded Uncertainty	Coverage factor	Coverage
$\gamma_{Pumixture}$	$734.90 \cdot 10^{-6}$ g/g	$300 \cdot 10^{-9}$ g/g	2.00	manual
$\gamma_{Pumixture239}$	$718.56 \cdot 10^{-6}$ g/g	$290 \cdot 10^{-9}$ g/g	2.00	manual
$c_{Pumixture239}$	$3.0059 \cdot 10^{-6}$ mol/g	$1.2 \cdot 10^{-9}$ mol/g	2.00	manual
$c_{Pumixture}$	$3.0739 \cdot 10^{-6}$ mol/g	$1.2 \cdot 10^{-9}$ mol/g	2.00	manual
$Rd_{238Pu/239Pu}$	$28.09 \cdot 10^{-6}$ mol/mol	$260 \cdot 10^{-9}$ mol/mol	2.00	manual
$Rd_{240Pu/239Pu}$	0.0224120 mol/mol	$5.1 \cdot 10^{-6}$ mol/mol	2.00	manual
$Rd_{241Pu/239Pu}$	$134.2 \cdot 10^{-6}$ mol/mol	$1.8 \cdot 10^{-6}$ mol/mol	2.00	manual
$Rd_{242Pu/239Pu}$	$75.72 \cdot 10^{-6}$ mol/mol	$780 \cdot 10^{-9}$ mol/mol	2.00	manual
$fdnorm_{238Pu}$	$27.47 \cdot 10^{-6}$ mol/mol	$260 \cdot 10^{-9}$ mol/mol	2.00	manual
$fdnorm_{239Pu}$	0.9778517 mol/mol	$5.2 \cdot 10^{-6}$ mol/mol	2.00	manual
$fdnorm_{240Pu}$	0.0219156 mol/mol	$4.9 \cdot 10^{-6}$ mol/mol	2.00	manual
$fdnorm_{241Pu}$	$131.2 \cdot 10^{-6}$ mol/mol	$1.7 \cdot 10^{-6}$ mol/mol	2.00	manual
$fdnorm_{242Pu}$	$74.05 \cdot 10^{-6}$ mol/mol	$760 \cdot 10^{-9}$ mol/mol	2.00	manual
Md_{Pu}	239.0745716 g/mol	$6.8 \cdot 10^{-6}$ g/mol	2.00	manual
$wdnorm_{238Pu}$	$27.35 \cdot 10^{-6}$ g/g	$260 \cdot 10^{-9}$ g/g	2.00	manual
$wdnorm_{239Pu}$	0.9777600 g/g	$5.2 \cdot 10^{-6}$ g/g	2.00	manual
$wdnorm_{240Pu}$	0.0220054 g/g	$4.9 \cdot 10^{-6}$ g/g	2.00	manual
$wdnorm_{241Pu}$	$132.3 \cdot 10^{-6}$ g/g	$1.7 \cdot 10^{-6}$ g/g	2.00	manual
$wdnorm_{242Pu}$	$74.97 \cdot 10^{-6}$ g/g	$770 \cdot 10^{-9}$ g/g	2.00	manual
$\eta_{PuMP2Nov2018}$	0.99828 g/g	$400 \cdot 10^{-6}$ g/g	2.00	manual
$m_{239Puvial1}$	$1.81989 \cdot 10^{-3}$ g	$850 \cdot 10^{-9}$ g	2.00	manual

Annex 16 The weighing certificate of the blend mixtures for the confirmation measurements of ^{235}U, ^{238}U and ^{239}Pu amount content by ID-TIMS using IRMM-046c

Joint Research Centre	**Certificate of weighing**	Directorate G – Nuclear Safety and Security G.2 - Standards for Nuclear Safety, Security and Safeguards Unit

E. 3924 rev 1 **Issue date**: 29/04/2019, 29/01/2020 **Page** 1 of 2

Applicant: Renata Bujak **Project:** IRMM-1027u

Description: Homogeneity of IRMM-1027u vials with ~~IRMM-016c~~ IRMM-046c ; NBL-126/CRM-116A QC

Request for analysis number: 4373 **ID number:** 30436

Date of receipt of request: 12/02/2019 **Weighing dates**: 6/3, 7/3, 8/3, 17/4/2019

Results:

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

ID	IRMM-046c mass /g	IRMM-046c uncertainty /g
1027u-2/046c-40-1	2.01942	0.00008
1027u-149/046c-40-2	2.03630	0.00009
1027u-214/046c-40-3	2.01598	0.00009
1027u-270/046c-40-4	1.98977	0.00011
QC7/046c-40-5	2.02122	0.00012
1027u-341/046c-36-1	1.99723	0.00011
1027u-429/046c-36-2	1.99641	0.00013
1027u-536/046c-36-3	1.99793	0.00011
1027u-637/046c-36-4	2.25842	0.00010
QC8/046c-36-5	2.17352	0.00012
1027u-715/046c-47-1	2.00745	0.00008
1027u-798/046c-47-2	2.01305	0.00008
1027u-862/046c-47-3	1.99646	0.00008
1027u-946/046c-47-4	1.94364	0.00008
QC9/046c-47-5	2.01888	0.00008

ID	NBL-126 mass /g	NBL-126 uncertainty /g
QC7/046c-40-5	0.50335	0.00010
QC8/046c-36-5	0.63316	0.00010
QC9/046c-47-5	0.50126	0.00009

ID	CRM-116A mass /g	CRM-116A uncertainty /g
QC7/046c-40-5	1.05904	0.00013
QC8/046c-36-5	1.16568	0.00007
QC9/046c-47-5	1.02392	0.00007

Observations:

The measurements were performed according to Procedure IMS-JRC.G-C1.1-PRO-0002 "Mass determination by substitution weighing".
The balance used was Mettler Toledo AT 261DR with inventory No. 1999 0037 27.

During the calibration process the atmospheric parameters temperature, pressure and humidity were monitored, noted and used in the calculations.

Traceability:

The certified mass values are traceable to the International Kilogram Prototype via regular calibrations of the JRC G2's principal standards. The set of working mass standards M3 was used as reference in the mass determination.

Uncertainty:

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

Additional information:

~~Ulf Jacobsson~~
~~Technical responsible~~
Rozle Jakopic
Laboratory Responsible for Nuclear Chemistry

Carmel Hennessy
Analyst

Annex 17 The internal test report (#4373) for the selected units of IRMM-1027u

EUROPEAN COMMISSION
DIRECTORATE-GENERAL
JOINT RESEARCH CENTRE

Directorate G - Nuclear Safety and Security
Unit G.2 - Standards for Nuclear Safety, Security and Safeguards (SN3S)

INTERNAL TEST REPORT # 4373

Requested by: Renata Bujak

Samples

Sample ID	Applicant sample identification
30436	IDMS for U and Pu for the IRMM-1027u vials, for homogeneity verification

Date of receipt of samples: April 2019

Condition of the samples: Plutonium and uranium nitrate solutions. Radioactive material. Pu/U separation followed by Pu and U chemical purifications prior to mass spectrometry measurements by ID-TIMS (following WI-D-00352, 353 and 354), using the TE method (WI-D-00348 for U, WI-D-00360 for Pu).

Sample ID	Analyte	Result[3] (expanded uncertainty[1])	Unit	Method[2]
Pu-IDMS, P190402				
Date:	02/04/2019			
1027u-214	$n(^{242}Pu)/n(^{239}Pu)$	0.094288 (98)	mol / mol	TIMS/TE
1027u-2	$n(^{242}Pu)/n(^{239}Pu)$	0.094490 (98)	mol / mol	TIMS/TE
1027u-149	$n(^{242}Pu)/n(^{239}Pu)$	0.095186 (99)	mol / mol	TIMS/TE
1027u-270	$n(^{242}Pu)/n(^{239}Pu)$	0.093340 (98)	mol / mol	TIMS/TE

Sample ID	Analyte	Result[3] (expanded uncertainty[1])	Unit	Method[2]
Pu-IDMS, P190430				
Date:	30/04/2019			
1027u-536	$n(^{242}Pu)/n(^{239}Pu)$	0.093812 (96)	mol / mol	TIMS/TE
1027u-341	$n(^{242}Pu)/n(^{239}Pu)$	0.093200 (98)	mol / mol	TIMS/TE
1027u-637	$n(^{242}Pu)/n(^{239}Pu)$	0.10601 (11)	mol / mol	TIMS/TE
1027u-429	$n(^{242}Pu)/n(^{239}Pu)$	0.093580 (97)	mol / mol	TIMS/TE

Sample ID	Analyte	Result[3] (expanded uncertainty[1])	Unit	Method[2]
Pu-IDMS, P190606				
Date:	11/06/2019			
1027u-946	$n(^{242}Pu)/n(^{239}Pu)$	0.090897 (93)	mol / mol	TIMS/TE
1027u-715	$n(^{242}Pu)/n(^{239}Pu)$	0.094050 (97)	mol / mol	TIMS/TE
1027u-798	$n(^{242}Pu)/n(^{239}Pu)$	0.09423 (11)	mol / mol	TIMS/TE
1027u-862	$n(^{242}Pu)/n(^{239}Pu)$	0.093598 (96)	mol / mol	TIMS/TE

Sample ID	Analyte	Result[3] (expanded uncertainty[1])	Unit	Method[2]
U-IDMS, P190409				
Date:	09/04/2019			
1027u-214	$n(^{235}U)/n(^{238}U)$	0.237119 (68)	mol / mol	TIMS/TE
1027u-214	$n(^{233}U)/n(^{238}U)$	0.047875 (24)	mol / mol	TIMS/TE
1027u-2	$n(^{235}U)/n(^{238}U)$	0.237108 (68)	mol / mol	TIMS/TE
1027u-2	$n(^{233}U)/n(^{238}U)$	0.047977 (23)	mol / mol	TIMS/TE
1027u-149	$n(^{235}U)/n(^{238}U)$	0.237135 (71)	mol / mol	TIMS/TE
1027u-149	$n(^{233}U)/n(^{238}U)$	0.048337 (24)	mol / mol	TIMS/TE
1027u-270	$n(^{235}U)/n(^{238}U)$	0.237127 (83)	mol / mol	TIMS/TE
1027u-270	$n(^{233}U)/n(^{238}U)$	0.047392 (27)	mol / mol	TIMS/TE

Sample ID	Analyte	Result[3] (expanded uncertainty[1])	Unit	Method[2]
U-IDMS, P190415				
Date:	15/04/2019			
1027u-536	$n(^{235}U)/n(^{238}U)$	0.23720 (10)	mol / mol	TIMS/TE
1027u-536	$n(^{233}U)/n(^{238}U)$	0.047668 (35)	mol / mol	TIMS/TE
1027u-341	$n(^{235}U)/n(^{238}U)$	0.23713 (10)	mol / mol	TIMS/TE
1027u-341	$n(^{233}U)/n(^{238}U)$	0.047337 (35)	mol / mol	TIMS/TE
1027u-637	$n(^{235}U)/n(^{238}U)$	0.23715 (10)	mol / mol	TIMS/TE
1027u-637	$n(^{233}U)/n(^{238}U)$	0.053856 (40)	mol / mol	TIMS/TE
1027u-429	$n(^{235}U)/n(^{238}U)$	0.23708 (11)	mol / mol	TIMS/TE
1027u-429	$n(^{233}U)/n(^{238}U)$	0.047517 (37)	mol / mol	TIMS/TE

Sample ID	Analyte	Result[3] (expanded uncertainty[1])	Unit	Method[2]
U-IDMS, P190603				
Date:	06/06/2019			
1027u-946	$n(^{235}U)/n(^{238}U)$	0.237118 (70)	mol / mol	TIMS/TE
1027u-946	$n(^{233}U)/n(^{238}U)$	0.046151 (23)	mol / mol	TIMS/TE
1027u-715	$n(^{235}U)/n(^{238}U)$	0.237070 (78)	mol / mol	TIMS/TE
1027u-715	$n(^{233}U)/n(^{238}U)$	0.047733 (26)	mol / mol	TIMS/TE
1027u-798	$n(^{235}U)/n(^{238}U)$	0.237109 (72)	mol / mol	TIMS/TE
1027u-798	$n(^{233}U)/n(^{238}U)$	0.047831 (25)	mol / mol	TIMS/TE
1027u-862	$n(^{235}U)/n(^{238}U)$	0.237069 (75)	mol / mol	TIMS/TE
1027u-862	$n(^{233}U)/n(^{238}U)$	0.047501 (25)	mol / mol	TIMS/TE

Notes:

Notes		
	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)*
	2	Method used for the measurements (TE: Total Evaporation)
	3	For the full dataset including raw data, k-factor and QC samples, the reader is advised to consult the files referred to below.

Files name(s) of raw data

For Pu and U measurements:
G:\JRC.G.2\Nuclear Safeguards\Nuclear\PUTON DATA - SHARED\IRMM LSD 1027u
Data Files:
P190402 Pu IDMS of IRMM1027u vials with 046c set A.xlsm
P190430 Pu IDMS of IRMM1027u vials with 046c set B.xlsm
P190606 Pu IDMS of IRMM1027u vials with 046c set C.xlsm

P190409 U IDMS of IRMM1027u vials with 046c set A.xlsm
P190415 U IDMS of IRMM1027u vials with 046c set B.xlsm
P190603 U IDMS of IRMM1027u vials with 046c set C.xlsm

14/06/2019 ..... Stephan Richter .....

Date — Signature Analyst — Name + Signature Laboratory Responsible

Laboratory Name: IRMM

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