European Commission

JRC REFERENCE MATERIALS REPORT

CERTIFICATION REPORT

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

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

Jakopič, R., Bauwens, J., Buják, R., Hennessy, C., Kehoe, F., Jacobsson, U., Toth, K., Richter, S., Aregbe, Y.

2019

EUR 29742 EN

Joint Research Centre

This publication is a Reference Materials report by the Joint Research Centre (JRC), the European Commission's science and knowledge service. It aims to provide evidence-based scientific support to the European policymaking process. The scientific output expressed does not imply a policy position of the European Commission. Neither the European Commission nor any person acting on behalf of the Commission is responsible for the use that might be made of this publication.

Contact information
Name: Rožle Jakopič
Address: Joint Research Centre, Retieseweg 111, 2440 Geel, Belgium
Email: rozle.jakopic@ec.europa.eu
Tel.: + 32 (0) 14 571 617

JRC Science Hub
https://ec.europa.eu/jrc

JRC113681

EUR 29742 EN

PDF ISBN 978-92-76-03326-4 ISSN 1831-9424 doi:10.2760/639219

Luxembourg: Publications Office of the European Union, 2019

How to cite this report: Jakopic, R. et all, *Certified reference material for the masses of 239Pu, 235U, 238U and Pu and U isotope amount ratios*, EUR 29742 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-03326-4, doi:10.2760/639219, JRC113681

Table of contents

Acknowledgement

The authors would like to thank Jan Truyens from the JRC-Geel and the experts of the Certification Advisory Panel, S. D. Balsley and S. Boulyga from the International Atomic Energy Agency (IAEA), Vienna, Austria and Danièle Roudil from the Commissariat à l'Energie Atomique et aux Energies Alternatives, Direction de l'Energie Nucléaire (CEA/DEN), Marcoule, France for reviewing the certification report.

Authors

R. Jakopič, J. Bauwens, R. Buják, C. Hennessy, F. Kehoe, U. Jacobsson, K. Toth, S. Richter and Y. Aregbe

European Commission, Joint Research Centre, Directorate G - Nuclear Safety and Security, G.2 – Standards for Nuclear Safety, Security and Safeguards, Geel, Belgium

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-1027t 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 35:2006 [2].

The certified reference materials uranium metal EC NRM 101, enriched uranium metal NBL CRM 116-A and plutonium metal CETAMA MP2 were used as starting materials to prepare the mother solution. This solution was dispensed into individual units by means of an automated robot system and dried down. A solution of an organic substance, cellulose acetate butyrate with dioctyl phtalate (CAB/DOP) or carboxymethyl cellulose (CMC) was dried on the spike material as a stabiliser to retain the dried material at the bottom of the vial. In total 1074 units were produced.

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

The certified values were obtained from the gravimetric preparation of the mother solution, taking into account the mass, purity and isotopic 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-1027t.

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 50 mg of uranium with a relative mass fraction $m(^{235}U)/m(U)$ of 19.4 % and 1.9 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]
$n(^{234}U)/n(^{238}U)$	0.0028041	0.0000023
$n(^{235}U)/n(^{238}U)$	0.244526	0.000032
$n(^{235}U)/n(^{238}U)$	0.0022515	0.0000018
$n(^{240}Pu)/n(^{239}Pu)$	0.0224137	0.0000051
$n(^{241}Pu)/n(^{239}Pu)$	0.0001408	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.

[1] The certified values are traceable to the values on the respective metal certificates (Annexes 2 - 6). The reference date for the certified values is November 1, 2017.

[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 (50 mg U and 1.9 mg Pu), isotopically different to the uranium and plutonium in the test sample and are in dried nitrate form. Up to 1200 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-1027t batch of LSD spikes was prepared from natural uranium (EC NRM 101), enriched uranium (NBL CRM 116-A) and plutonium (CETAMA MP2) certified reference metals. Each unit of IRMM-1027t contains about 50 mg of uranium with a relative mass fraction $m(^{235}U)/m(U)$ of 19.4 % and 1.9 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.

Until now, the cellulose acetate butyrate (CAB) has been used as a stabilising material for the IRMM-1027 LSD spikes. The CAB produces a stable layer at the bottom of the vial and guarantees the integrity of the LSD spikes for about 3 years. Customers, however, require a longer shelf-life of IRMM-1027 LSD spikes.

For this reason, the JRC-Geel and JRC-Karlsruhe have engaged in an exploratory research project on the optimisation of the preparation of the organic layer with embedded uranyl and plutonium nitrates as well as investigations of new types of materials and spikes with different U/Pu ratios. The main objectives were to find a material that would prolong the shelf-life of LSD spikes from 3 to 5 years, dissolves readily in nitric acid and does not interfere with a chemical separation or mass spectrometry. Among the tested materials, the carboxymethyl cellulose (CMC) has shown very promising results [10, 11].

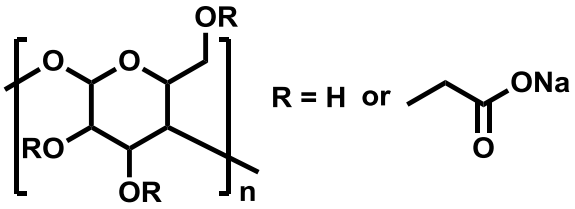
CMC is, similar to CAB, also built up from a repeating anhydroglucose unit but this cellulose derivative is functionalised with carboxymethyl groups (Figure 1), which are converted into a sodium salt. This difference makes the CMC insoluble in most organic

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 dioctyl phthalate (DOP), which acts as a plasticizer.

As a result of the successful outcome of the exploratory research project, the LSD spikes of the IRMM-1027t series were prepared both with the CMC and with the CAB/DOP material.

Figure 1 Structure of CMC material



1.3 Design of the project

The individual units of IRMM-1027t 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 nitric and hydrofluoric 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 given by 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

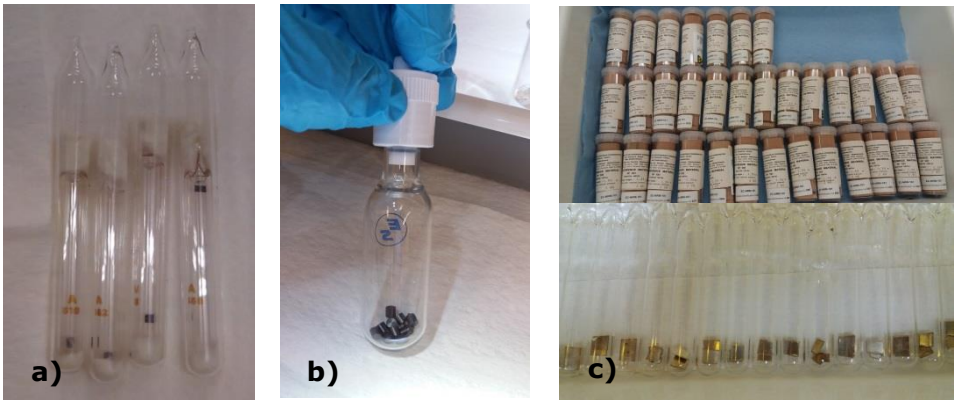
Project management and evaluation, processing, homogeneity study, stability study and characterisation have been performed at the European Commission, Joint Research Centre, Directorate G – Nuclear Safety and Security, G.2 - Standards for Nuclear Safety, Security and Safeguards in Geel, Belgium.

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 CRM 116-A, Argonne, USA) and plutonium (CETAMA MP2, CEA Marcoule, France) metals were used as starting materials (Figure 2) for the preparation of the IRMM-1027t LSD spikes. The isotopic composition and the purity of the metals are given in Annexes 2 - 6.

Figure 2 Starting materials for the preparation of IRMM-1027t LSD spikes: a) Pu MP2 metal b) U NBL CRM 116-A metal and c) U EC NRM 101 metal



3.2 Processing

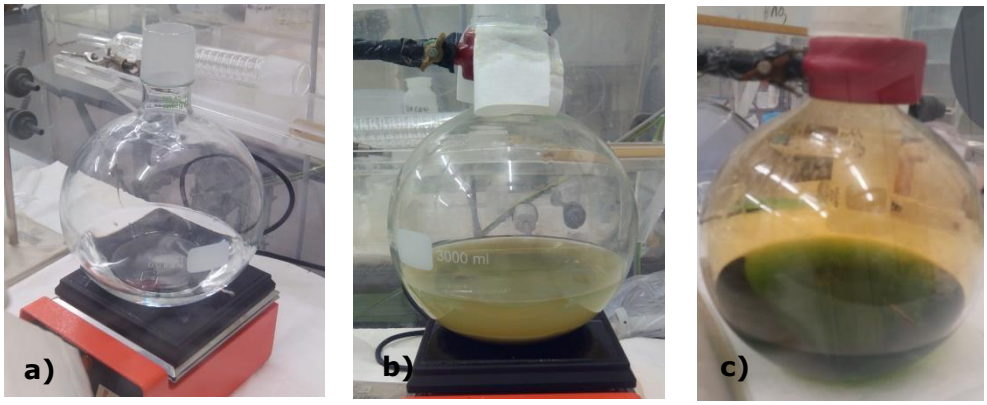
Dissolution of the Pu metal

An optimised protocol for the dissolution of Pu MP2 metal was used in 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 [12]. It has to be mentioned, that this protocol does not comply with MP2 certificate and associated recommendation for use (see Annex 4). As a result, the mass of the sample and Pu content uncertainty values can be altered.

However, for the preparation of the current batch (IRMM-1027t), an existing Pu solution, prepared in 2014 was used. Thus, this solution was prepared by the old procedure dissolving 4 units of plutonium MP2 metal in about 200 mL nitric acid solution (c = 8 mol L^{-1}, *p.a.*, Merck, Darmstadt, Germany) and heating on a hot plate at 90 °C for several days. Finally, 4 mL of hydrofluoric acid (c = 1 mol L^{-1}, *p.a.*, Merck, Darmstadt, Germany) were added into the Pu solution to dissolve any remaining pieces of the Pu metal.

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: a and b) dissolution of Pu MP2 metal in nitric acid c) Pu nitrate solution after addition of HF

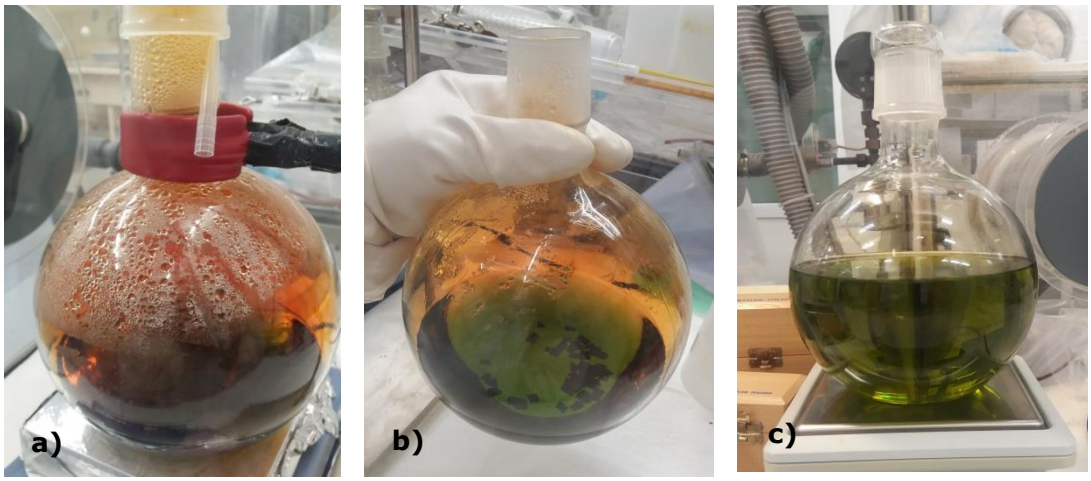


Dissolution of the U metals

The respective units of enriched uranium metal (NBL 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 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 down. 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 several aliquots were analysed by isotope dilution thermal ionisation mass spectrometry (ID-TIMS) to verify the gravimetrically determined amount contents of plutonium and uranium and by thermal ionisation mass spectrometry (TIMS) to verify the uranium and plutonium isotope amount ratios (see Process Control, Section 3.3).

Figure 4 Dissolution of U metals: a) addition of the NBL 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-1027t



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) [13]. 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 3 kg) was dispensed into 1074 units over five consecutive working days.

The drying of the dispensed solution contained in the units was carried out on a hot plate. This temperature was increased to a maximum of 60 °C and the units were kept at this temperature for several days (typically 4-5 days continuous heating) to evaporate the solution completely.

For the IRMM-1027t LSD spikes two organic materials were used: a) 719 units were prepared by using CAB with a plasticizer dioctyl phthalate (DOP) and b) 355 units prepared by using CMC.

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 1.6 g DOP (Sigma-Aldrich, Merck, Darmstad, Germany) in 100 g acetone. The CAB/DOP solution in the vials was evaporated at room temperature and then heated to about 45 °C to dry completely. Two dedicated glove boxes were used for drying and CAB/DOP application, allowing the preparation of up to 48 units per day. The vials were closed with a stopper and an aluminium cap, sealed in PVC package and labelled.

b) CMC protocol

10 g 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 until the complete dissolution of CMC (usually 2-3 hours) and then allowed to cool down 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 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 down and closed with a silicon cap. This protocol allows for the preparation of up to 24 units per day.

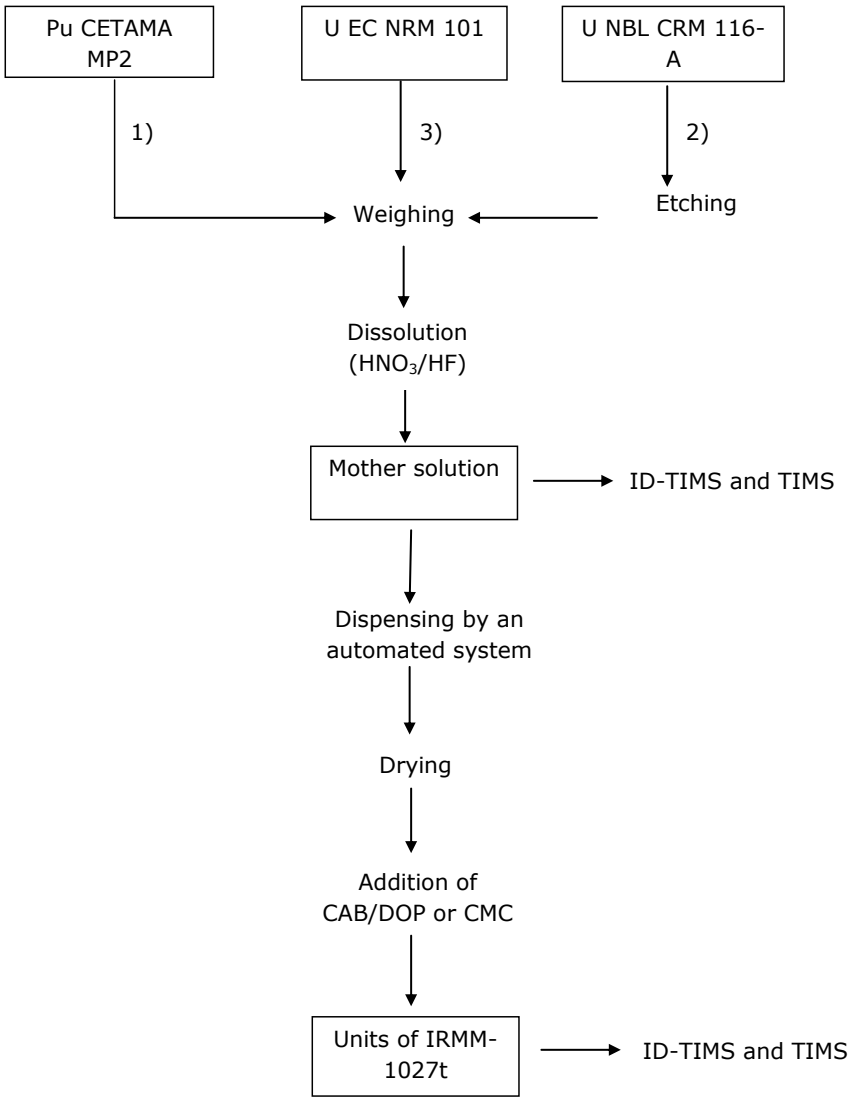
CAB/DOP and CMC were added to retain the dried material at the bottom of the penicillin vial so that it can resist physical shocks that might be encountered during transport and to avoid flaking of the material during long-term storage. Both cellulose matrixes dissolve readily in warm nitric acid solution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

The units of IRMM-1027t LSD prepared with CAB/DOP and CMC spikes can be seen in Figure 5.

Figure 5 Units of IRMM-1027t LSD spike: a) treated with CAB/DOP and b) treated with CMC

The processing steps are shown in Figure 6.

Figure 6 Preparation of IRMM-1027t LSD spikes



3.3 Process control

This section describes the measurements performed on the mother solution of IRMM-1027t 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-1027t are shown in Annex 13 and Annex 14.

Six aliquots of the mother solution (about 2.5 g each) were individually spiked with a mixed $^{233}U/^{242}Pu$ spike CRM (*ca*. 1.5 g IRMM-046c) for ID-TIMS analysis. The certificate of IRMM-046c can be found in Annex 7. Four un-spiked aliquots (about 1 g each) of the IRMM-1027t mother solution were analysed to verify the 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 [14].

The results of the process control measurements for ^{238}U, ^{235}U and ^{239}Pu amount contents as well as the uranium and plutonium isotope amount ratios in the mother solution of IRMM-1027t agreed within the uncertainties with the values from the gravimetric preparation, except for the $n(^{238}Pu)/n(^{239}Pu)$ amount ratio. A higher 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. The results of the confirmation measurements for the mother solution of IRMM-1027t are shown in Annex 8 and Annex 9.

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.

4.1 Between-unit homogeneity

The between-unit homogeneity was evaluated to ensure that the certified values of the CRM are valid for all 1074 units of the material, within the stated uncertainty.

Fifteen units were selected (CAB unit No.: 21, 92, 247, 306, 455, 589, 660, 786, 876 and 965; CMC unit No.: 145, 365, 541, 839 and 1025) 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 batch was divided into fifteen 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 (1074). However, for the IRMM-1027t batch, slightly higher number of the selected units was taken. This was done because the LSD spikes were prepared with two coating materials (CAB/DOP and CMC).

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

The whole amount of sample per unit (equals minimum sample intake) was taken for analysis. Selected units of IRMM-1027t were spiked with a mixed $^{233}U/^{242}Pu$ spike CRM (IRMM-046c) and 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) [14].

Each sample was measured in two-three replicates together with isotopic standards (IRMM-074/10 for U and IRMM-290/A3 for Pu) to correct for instrumental mass fractionation. This enabled five independent samples to be measured on the same TIMS turret on the same day. Therefore, the measurements for all fifteen units of IRMM-1027t 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 10.

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 Grubbs outlier test at a confidence level of 99 % on the individual results and on the unit means.

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-1027t

	Trends [1)]		Outliers [2)]		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	none	none	unimodal	unimodal

[1)] at 95 % confidence level

[2)] at 99 % 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 therefore subject to random fluctuations. Therefore, the mean square between groups ($MS_{between}$) can be smaller than the mean squares within groups (MS_{within}), resulting in negative arguments under the square root used for the estimation of the between-unit variation, whereas the true variation cannot be lower than zero. In this case, u^*_{bb}, the maximum inhomogeneity that could be hidden by method repeatability, was calculated as described by Linsinger et al. [15]. 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 of method intermediate precision ($s_{wb,rel}$), relative between–unit standard deviation ($s_{bb,rel}$) and relative maximum inhomogeneity ($u^*_{bb,rel}$) were calculated as:

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

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

$$u^*_{bb,rel} = \frac{\sqrt{\frac{MS_{within}}{N}}\sqrt[4]{\frac{2}{v_{MSwithin}}}}{\bar{y}}$$ 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 ^{239}Pu. For that reason, the data for the amount content of ^{239}Pu 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-1027t

	$s_{wb,rel}$ [%]	$s_{bb,rel}$ [%]	$u^*_{bb,rel}$ [%]
^{235}U amount content	0.016	0.016	0.0051
^{238}U amount content	0.040	n.c.	0.012
^{239}Pu amount content	0.032	0.020	0.010

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

The homogeneity study showed no outlying unit means at a 99 % confidence level 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.

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-1027t 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-1027t.

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-1027t 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-1027t 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. It is self-evident that the radionuclides are 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 IRMM-1027q, a thorough short-term stability study of the CAB was carried out [16]. As the IRMM-1027t batch was prepared with a slightly adopted CAB protocol by adding a plasticizer dioctyl phthalate (DOP) to the CAB solution (see 3.2) and with CMC, the short-term stability study had to be re-assessed.

The test samples contained CAB/DOP and CMC material without any plutonium and uranyl nitrates similar to the study of the IRMM-1027q. 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, see in Annex 17. 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 evolved 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 [17].

IRMM-1027t LSD spikes are packed and shipped to customers following the legal requirements related to radioprotection measures for transport of radioactive materials [18]. IRMM-1027t 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.

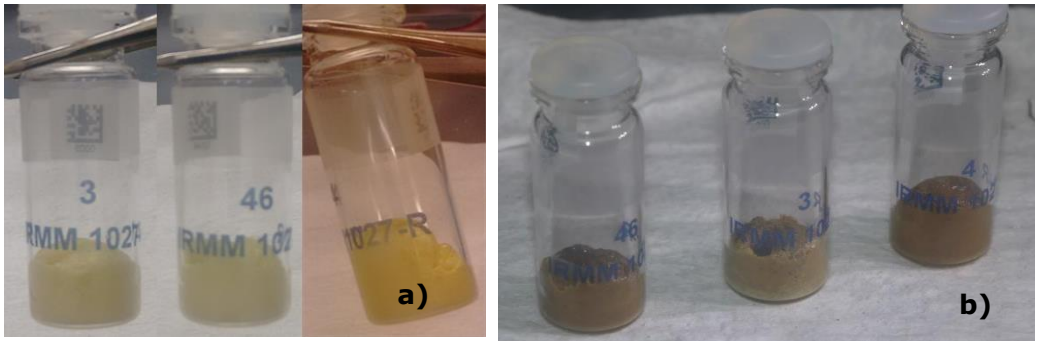
5.2 Long-term stability

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 [19] 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 [20, 21, 22]. Furthermore, the JRC-Geel (Belgium), the JRC-Karlsruhe (Germany) and the IAEA are engaged in mutual verification measurements of mixed uranium/plutonium spike reference materials via EC support task to the IAEA [23]. 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.

The long-term stability of the LSD spikes prepared with CMC can be demonstrated via the results of the INS-CRM exploratory research project [11, 17]. 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. The stability of the CMC foam is shown in Figure 7.

Figure 7 Stability of the LSD spikes prepared with CMC foam: a) freshly prepared CMC foam, b) CMC foam after about 2 years



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

After the certification campaign, IRMM-1027t material will be subjected to the post-certification monitoring programme to control its stability. Two units of IRMM-1027t (one CAB/DOP, one CMC) will be analysed every year to verify the certified values. The validity of the material certificate is 3 years and may be extended after further stability test are carried out.

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-1027t 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 11. The mother solution was prepared by gravimetric mixing of uranium and plutonium metals (see Section 3.2).

Each unit of IRMM-1027t LSD spike is certified for the mass of ^{239}Pu, ^{235}U and ^{238}U and the $n(^{234}\text{U})/n(^{238}\text{U})$, $n(^{235}\text{U})/n(^{238}\text{U})$, $n(^{236}\text{U})/n(^{238}\text{U})$, $n(^{240}\text{Pu})/n(^{239}\text{Pu})$, $n(^{241}\text{Pu})/n(^{239}\text{Pu})$, and $n(^{242}\text{Pu})/n(^{239}\text{Pu})$ 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, 2017 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-1027t are calculated from the gravimetric preparation of the mother solution, taking into account the mass of the metals, their purity and isotopic composition (e.g. isotope amount ratios), 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-1027t are summarised.

Table 3 Gravimetric mixing to prepare the mother solution of IRMM-1027t

	MP2	EC NRM 101	NBL CRM116-A	Mother solution
Mass [1] [g]	2.13568	44.18372	11.16901	2969.547
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	

[1] The masses of the metals are obtained from the weighing certificate, see Annex 12.

[2] The purity of the metals is obtained from the metal certificates; see Annexes 2 – 4, 13.

[3] The isotope amount ratios are obtained from the metal certificates; see Annexes 3, 5 – 6.

The uncertainties on the certified mass (u_{char}) of ^{235}U, ^{238}U and ^{239}Pu in the vial are composed of several contributions (Table 4), i.e. the uncertainty on the mass determination ($u_{char,1}$, $u_{char,2}$ and $u_{char,3}$), the uncertainty on the purity of the metals ($u_{char,4}$), and the uncertainties on the amount ratios ($u_{char,5}$). The complete and detailed calculations of the mass fractions, amount ratios and their uncertainty budgets are given in Annex 13 and Annex 14.

Table 4 Uncertainty budgets for the masses of ^{235}U, ^{238}U and ^{239}Pu in the vials of IRMM-1027t

	Standard uncertainty contribution					Combined relative uncertainty $u_{char,\,rel}$ [6] [%]
	$u_{char,1}$ [1] [g]	$u_{char,2}$ [2] [g]	$u_{char,3}$ [3] [g]	$u_{char,4}$ [4] [g/g]	$u_{char,5}$ [5] [mol/mol]	
^{235}U	0.000065	0.0125	0.00030	0.000070	0.0000205	0.0133
^{238}U	0.000070	0.0125	0.00030	0.000025	0.0000018	0.0120
^{239}Pu	0.000035	0.0125	0.00030	0.00020	0.00000255	0.0233

1) Standard uncertainty of the mass determination of the metals, see Annex 12.

2) Standard uncertainty of the mass determination of the mother solution, see Annex 12.

3) Standard uncertainty of the mass determination of an aliquot, see Annex 11.

4) Standard uncertainty of the purity of the metals, see Annexes 2 - 3.

5) Standard uncertainty of the largest amount ratio, for other ratios, see Annexes 3, 5 - 6.

6) This final combined relative uncertainty is calculated using $\sqrt{\sum_{i=1}^{5}(u_{char,rel,i}^2)}$. Note that rounding rules are not applicable to the intermediate results.

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 13 and Annex 14. The uranium and plutonium isotope amount ratios from the characterisation assessment (gravimetric preparation) of IRMM-1027t are summarised in Table 5.

Table 5 The U and Pu isotope amount ratios and their standard uncertainties from the characterisation assessment of IRMM-1027t

	Value [1] [mol/mol]	u_{char} [mol/mol]	$u_{char,\,rel}$ [%]
$n(^{234}U)/n(^{238}U)$	0.0028041	$1.16\cdot10^{-6}$	0.041
$n(^{235}U)/n(^{238}U)$	0.244526	$16.2\cdot10^{-6}$	0.0066
$n(^{236}U)/n(^{238}U)$	0.0022515	$9.19\cdot10^{-7}$	0.041
$n(^{240}Pu)/n(^{239}Pu)$	0.0224137	$2.55\cdot10^{-6}$	0.011
$n(^{241}Pu)/n(^{239}Pu)$	0.0001408	$9.20\cdot10^{-7}$	0.65
$n(^{242}Pu)/n(^{239}Pu)$	0.00007572	$3.90\cdot10^{-7}$	0.52

1) The reference date for the isotope amount ratios is November 1, 2017.

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 11. 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 variability of the balance [13].

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 variability 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).

Fifteen units of IRMM-1027t (10 units with CAB/DOP and 5 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 vials, 2.5 - 3 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 [14] (see Annex 15 and Annex 16). 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-1027t measured by ID-TIMS (CAB/DOP: blue diamonds, CMC: black circles) 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

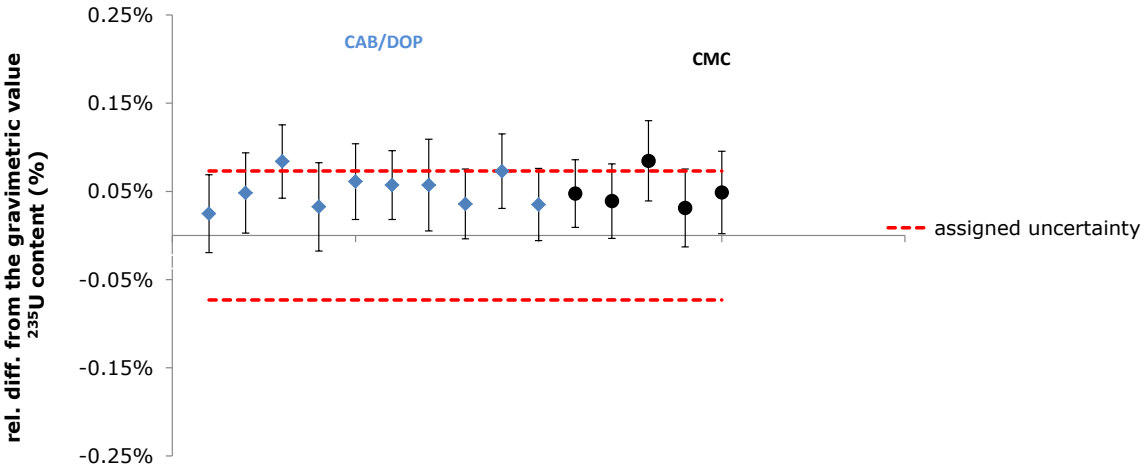


Figure 9 The amount content of ^{238}U in the selected vials of IRMM-1027t measured by ID-TIMS (CAB/DOP: blue diamonds, CMC: black circles) expressed as the relative difference from the gravimetric value. Error bars show the relative expanded uncertainty (coverage factor k = 2). Red dotted lines show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

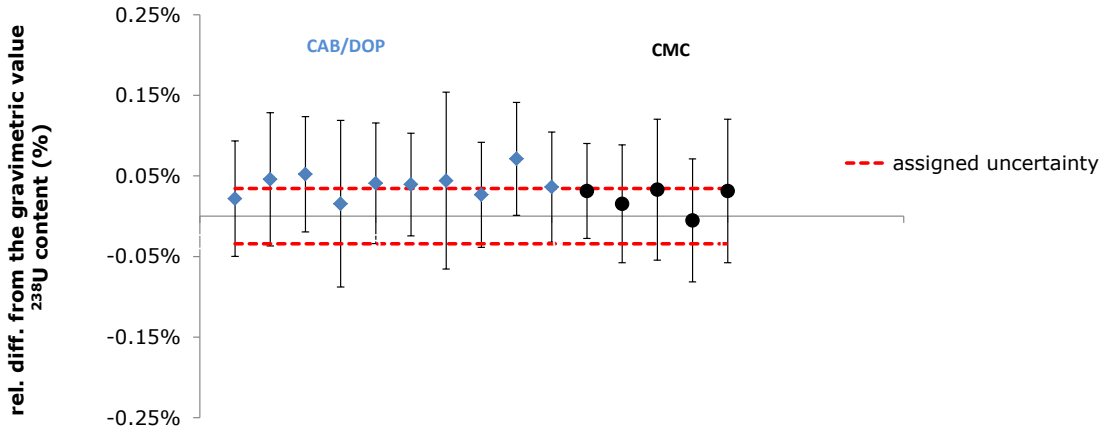
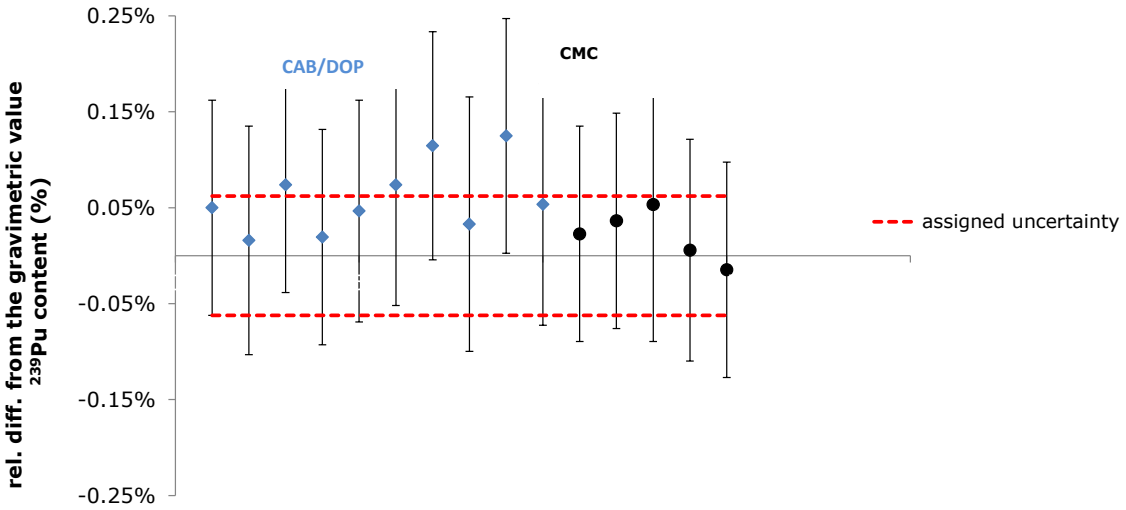


Figure 10 The amount content of ^{239}Pu in the selected vials of IRMM-1027t measured by ID-TIMS (CAB/DOP: blue diamonds, CMC: black circles) expressed as the relative difference from the gravimetric value. Error bars show the relative expanded uncertainty (coverage factor k = 2). Red dotted lines show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



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-1027t.

Furthermore, the compatibility check was performed for the results of the confirmation measurements (IDMS) using the compatibility equation [24] below:

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

X_{IDMS} individual result obtained by IDMS

X_{grav} 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

Vial No.	^{235}U amount content	^{238}U amount content	^{239}Pu amount content
589	0.58	0.55	0.78
786	1.12	1.02	0.24
965	1.99	1.31	1.15
660	0.73	0.28	0.30
876	1.44	0.99	0.71
21	1.38	1.09	1.05
247	1.28	0.77	1.71
455	0.86	0.72	0.45
92	1.73	1.82	1.82
306	0.84	0.94	0.76
145	1.15	0.92	0.35
541	0.92	0.38	0.57
1025	1.96	0.70	0.69
365	0.73	0.13	0.09
839	1.12	0.66	0.23

From Table 6 it can be seen that the compatibility is found to be ≤ 2 at a 95 % CI for 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 observed that all the IDMS results of the ^{235}U amount content are higher than the gravimetric value (Figure 8). On average this relative deviation is about 0.05%. This deviation is slightly higher than it was observed in the mother solution for the same measurand (See Annex 8, Figure 11). The reason for this deviation was not found

despite thorough investigation. To account for this, a conservative approach was applied and the uncertainty of the ^{235}U amount content was increased by 0.03%.

The confirmation measurement for the U and Pu isotope amount ratios in the selected vials of IRMM-1027t were deemed unnecessary. The results of the process control measurements (Annex 9) 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-1027t 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 [16, 25].

7. Value Assignment

Certified values are values that fulfil the highest standards of accuracy. Certified values for IRMM-1027t 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} 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 1074 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 vial No.1 of IRMM-1027t (as an example)

Mass	Certified value [mg]	$u_{char, rel}$ [%]	$s_{bb, rel}$ or $u^*_{bb,rel}$ [%]	$U_{CRM, rel}$ [1)] [%]	U_{CRM} [1)] [mg]
^{235}U mass [2)]	9.2018	0.013	0.016	0.073	0.0067
^{238}U mass	38.113	0.012	0.012	0.034	0.013
^{239}Pu mass	1.7894	0.023	0.020	0.062	0.0011

[1)] Expanded (k = 2) uncertainty

[2)] The uncertainty was increased by 0.03% using conservative approach

Table 8 Certified isotope amount ratios in IRMM-1027t and their uncertainties

Isotope amount ratios	Certified value [1] [mol/mol]	$u_{char, rel}$ [%]	$U_{CRM, rel}$ [2] [%]	U_{CRM} [2] [mol/mol]
$n(^{234}U)/n(^{238}U)$	0.0028041	0.041	0.082	0.0000023
$n(^{235}U)/n(^{238}U)$	0.244526	0.0066	0.013	0.000032
$n(^{236}U)/n(^{238}U)$	0.0022515	0.041	0.082	0.0000018
$n(^{240}Pu)/n(^{239}Pu)$	0.0224137	0.011	0.022	0.0000051
$n(^{241}Pu)/n(^{239}Pu)$	0.0001408	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, 2017.

[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 13 and 14) 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-1027t

	Isotope mass fraction (·100)	
	Value [1] [g/g]	Uncertainty [2] [g/g]
$m(^{234}U)/m(U)$ [3]	0.22118	0.00018
$m(^{235}U)/m(U)$ [3]	19.3704	0.0021
$m(^{236}U)/m(U)$ [3]	0.17912	0.00015
$m(^{238}U)/m(U)$ [3]	80.2293	0.0021
$m(^{238}Pu)/m(Pu)$ [3]	0.002756	0.000026
$m(^{239}Pu)/m(Pu)$ [3]	97.77517	0.00053
$m(^{240}Pu)/m(Pu)$ [3]	2.20069	0.00049
$m(^{241}Pu)/m(Pu)$ [3]	0.01388	0.00018
$m(^{242}Pu)/m(Pu)$ [3]	0.007497	0.000077
	Amount content	
	Value [1] [µmol/g solution]	Uncertainty [2] [4] [µmol/g solution]
^{235}U	15.3587	0.0019
^{238}U	62.8100	0.0032
U	78.4863	0.0037
^{239}Pu	2.9366	0.0012
Pu	3.0032	0.0012

	Mass fraction	
	Value [1] [mg/g solution]	Uncertainty [2] [4] [mg/g solution]
^{235}U	3.60997	0.00044
^{238}U	14.95198	0.00077
U	18.63655	0.00088
^{239}Pu	0.70201	0.00028
Pu	0.71798	0.00029
	Isotope amount ratios	
	Value [1] [mol/mol]	Uncertainty [2] [mol/mol]
$n(^{238}Pu)/n(^{239}Pu)$	0.00002831	0.00000027

[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-1027t is November 1, 2017.

[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 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 [26] 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-1027t 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-1027t 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-1027t 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-1027t contains about 50 mg of uranium with a relative mass fraction $m(^{235}U)/m(U)$ of 19.4 % and 1.9 mg of plutonium with a relative mass fraction $m(^{239}Pu)/m(Pu)$ of 97.8 % as dried nitrates in CAB/DOP or CMC.

References

1 ISO 17034, General requirements for the competence of reference materials producers, International Organization for Standardization, Geneva, Switzerland, 2016

2 ISO Guide 35, Reference materials – General and statistical principles for certification, International Organization for Standardization, Geneva, Switzerland, 2006

3 ISO/IEC Guide 98-3, Guide to the Expression of Uncertainty in Measurement (GUM, 1995), International Organization for Standardization, Geneva, Switzerland, 2008

4 M. Wang et al., The AME 2016 atomic mass evaluation (II). Tables, Graphs and References, Chinese Physics C, Vol. 41, No. 3, 1603-2014, 2017

5 http://www.nucleide.org/DDEP_WG/DDEPdata.htm "last checked on May 4, 2018"

6 R. Wellum, A. Verbruggen, R. Kessel, A new evaluation of the half-life of ^{241}Pu, J. Anal. At. Spectrom., 24, 801-807, 2009

7 International Target Values 2010 for Measurement Uncertainties in Safeguarding Nuclear Materials, IAEA-STR-368, Vienna, November 2010

8 L. Duinslaeger, K. Casteleyn, C.-I. Andor, R. Buda, R. C. Marquez, L. Commin, F. D. Amati, L. Embico, T. Enright, M. Hild, J. H. Domenech, A. Le Terrier, K. Luetzenkirchen, S. Mialle, S. Morel, A. Muehleisen, A. Nicholl, C. Nourry, D. Poublan, M. Ramos Pascual, G. Rasmussen, A. M. Sanchez-Hernandez, F. Sarli, S. Street, G. Suurkuusk, G. Toma, O. S. Valu, P. van Belle, D. Wojnowski, E. Zuleger, F. Lipcsei, P. Schwalbach, S. Synetos, Euratom On-Site Laboratories Refurbishments and developments, ESARDA Bulletin, No. 56, June 2018

9 K. Casteleyn, L. Duinslaeger, M. Boella, P. Chare, F. Lipcsei, P. Schwalbach, S. Synetos, T. Enright, A. Le Terrier, K. Luetzenkirchen, P. Van Belle, E. Zuleger, Y. Aregbe, On-site Laboratories of Euratom: Ten Years of Excellent Results and Time to Renew, 52nd Annual Meeting of the Institute of Nuclear Materials Management (INMM), Palm Springs, USA, 2011

10 A. M. Sanchez, K. Toth, Y. Aregbe, N. L. Banik, J. Bauwens, R. Buda, R. Bujak, R. Carlos Marquez, K. Casteleyn, L. Duislaeger, C. Hennessy, R. Jakopic, F. Kehoe, P. van Belle, E. Zuleger, Alternative nuclear certified reference materials for safeguards ad industry, 39th ESARDA Annual Meeting: Symposium, proceeding paper, Dusseldorf, Germany, 2017

11 K. Toth, R. Buják, A. M. Sánchez Hernández, J. Bauwens, R. Carlos Marquez, R. Buda, N. L. Banik, R. Jakopič, E. Zuleger, Y. Aregbe, Research on long-term stability of mixed U and Pu large-sized dried (LSD) spikes for fissile material control, Progress in Nuclear Science and Technology, 5, 48-51, 2018

12 R. Jakopič, J. Bauwens, R. Bujak, C. Hennessy, F. Kehoe, U. Jacobsson, S. Richter, Y. Aregbe, Preparation and certification of Large-Sized Dried (LSD) spike IRMM-1027s, EUR 29274 EN, 2018

13 A. Verbruggen, J. Bauwens, N. van De Steene, U. Jacobsson, R. Eykens, R. Wellum, Y. Aregbe, An automated system for the preparation of Large Size Dried (LSD) spikes, ATALANTE, Montpellier, France 2008

14 R. Jakopič, J. Bauwens, R. Buják, R. Eykens, C, Hennessy, F. Kehoe, H. Kühn, S. Richter, Y. Aregbe, Preparation and certification of Large-Sized Dried (LSD) spike IRMM-1027o, EUR 25857 EN, 2013

15 T.P.J. Linsinger, J. Pauwels, A.M.H. van der Veen, H. Schimmel, A. Lamberty, Homogeneity and stability of reference materials, Accred. Qual. Assur., 6, 20-25, 2001

16 R. Jakopič, J. Bauwens, C, Hennessy, F. Kehoe, U. Jacobsson, S. Richter, Y. Aregbe, Preparation and certification of Large-Sized Dried (LSD) spike IRMM-1027q, EUR 27211 EN, 2015

17 Y. Aregbe, N. L. Banik, J. Bauwens, R. Buda, R. Buják, R. Carlos Marquez, K. Casteleyn, L. Duinslaeger, F. Kehoe, C. Hennessy, R. Jakopič, A. M. Sánchez Hernández, K. Tóth, E. Zuleger, INS-CRM: Innovative nuclear certified reference materials (CRM) for EURATOM safeguards and industry – Scientific Report, in progress

18 IAEA Regulations for the Safe Transport of Radioactive Material, 1996 Edition, "Requirements", IAEA Safety Standards Series No. TS-R-1 (ST-1, Revised), IAEA, Vienna, 2000

19 R. Jakopič, J. Bauwens, R. Bujak, C. Hennessy, F. Kehoe, U. Jacobsson, S. Richter, Y. Aregbe, Preparation and certification of Large-Sized Dried (LSD) spike IRMM-1027r, EUR 28081 EN, 2016

20 A. Verbruggen, J. Bauwens, R. Eykens, U. Jacobsson, R. Jakopič, F. Kehoe, H. Kühn, Y. Kushigeta, S. Richter, Y. Aregbe, Preparation and certification of IRMM-1027m, Large-sized Dried (LSD) spike, EUR 24119 EN, 2009

21 R. Jakopič, J. Bauwens, S. Richter, M. Sturm, A. Verbruggen, R. Wellum, R. Eykens, F. Kehoe, H. Kühn, Y. Aregbe, Preparation and development of new Pu spike isotopic reference materials at IRMM, ESARDA Bulletin, No. 46, 2011

22 R. Jakopič, A. Verbruggen, R. Eykens, F. Kehoe, H. Kühn, Y. Kushigeta, U. Jacobsson, J. Bauwens, S. Richter, R. Wellum, Y. Aregbe, An inter-calibration campaign using various selected Pu spike isotopic reference materials, J. Radioanal. Nucl. Chem., 286, 449-454, 2010

23 R. Jakopič, Y. Aregbe, S. Richter, E. Zuleger, S. Mialle, S. D. Balsley, U. Repinc and J. Hiess, Verification measurements of the IRMM-1027 and the IAEA large-sized dried (LSD) spikes, J. Radioanal. Nucl. Chem., 311, 1781-1791, 2017

24 JCGM 200:2012, International vocabulary of metrology – Basic and general concepts and associated terms (VIM), 2012

25 R. Jakopič, J. Bauwens, R. Buják, R. Eykens, C. Hennessy, F. Kehoe, S. Mialle, C. Venchiarutti, S. Richter, Y. Aregbe, Preparation and certification of Large-Sized Dried (LSD) spike IRMM-1027p, EUR 26520 EN, 2014

26 H. Vesper, H. Emons, M. Gnezda, C. P. Jain, W. G. Miller, R. Rej, G. Schumann, J. Tate, L. Thienpont, J. E. Vaks, Characterization and Qualification of Commutable Reference Materials for Laboratory Medicine; Approved Guideline, CLSI document C53-A, Clinical and Laboratory Standards Institute, Wayne, PA, USA, 2010

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 phtalate
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}

List of figures

List of tables

Annexes

Annex 1 The certified masses of ^{235}U, ^{238}U and ^{239}Pu per unit (Vial No. 001 - 1074) of IRMM-1027t

Vial No.	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	38.112	0.013	9.2017	0.0067	1.7894	0.0011
002	CAB/DOP	38.075	0.013	9.1927	0.0067	1.7877	0.0011
003	CAB/DOP	38.096	0.013	9.1977	0.0067	1.7886	0.0011
004	CAB/DOP	38.012	0.013	9.1775	0.0067	1.7847	0.0011
005	CAB/DOP	38.127	0.013	9.2053	0.0067	1.7901	0.0011
006	CAB/DOP	37.995	0.013	9.1735	0.0067	1.7839	0.0011
007	CAB/DOP	38.096	0.013	9.1977	0.0067	1.7886	0.0011
008	CAB/DOP	38.042	0.013	9.1847	0.0067	1.7861	0.0011
009	CAB/DOP	38.007	0.013	9.1764	0.0067	1.7845	0.0011
010	CAB/DOP	38.118	0.013	9.2032	0.0067	1.7897	0.0011
011	CAB/DOP	38.061	0.013	9.1894	0.0067	1.7870	0.0011
012	CAB/DOP	38.046	0.013	9.1858	0.0067	1.7863	0.0011
013	CAB/DOP	38.027	0.013	9.1811	0.0067	1.7854	0.0011
014	CAB/DOP	38.052	0.013	9.1873	0.0067	1.7866	0.0011
015	CAB/DOP	38.111	0.013	9.2014	0.0067	1.7893	0.0011
016	CAB/DOP	38.046	0.013	9.1858	0.0067	1.7863	0.0011
017	CAB/DOP	38.061	0.013	9.1894	0.0067	1.7870	0.0011
018	CAB/DOP	38.055	0.013	9.1880	0.0067	1.7867	0.0011
019	CAB/DOP	38.049	0.013	9.1865	0.0067	1.7865	0.0011
020	CAB/DOP	38.072	0.013	9.1920	0.0067	1.7875	0.0011
021	CAB/DOP	38.012	0.013	9.1775	0.0067	1.7847	0.0011
022	CAB/DOP	38.106	0.013	9.2003	0.0067	1.7891	0.0011
023	CAB/DOP	38.027	0.013	9.1811	0.0067	1.7854	0.0011
024	CAB/DOP	38.094	0.013	9.1974	0.0067	1.7886	0.0011
025	CAB/DOP	38.007	0.013	9.1764	0.0067	1.7845	0.0011
026	CAB/DOP	38.072	0.013	9.1920	0.0067	1.7875	0.0011
027	CAB/DOP	38.099	0.013	9.1985	0.0067	1.7888	0.0011
028	CAB/DOP	38.034	0.013	9.1829	0.0067	1.7858	0.0011
029	CAB/DOP	38.051	0.013	9.1869	0.0067	1.7865	0.0011
030	CAB/DOP	38.031	0.013	9.1822	0.0067	1.7856	0.0011
031	CAB/DOP	38.093	0.013	9.1970	0.0067	1.7885	0.0011
032	CAB/DOP	38.036	0.013	9.1833	0.0067	1.7858	0.0011
033	CAB/DOP	38.096	0.013	9.1977	0.0067	1.7886	0.0011
034	CAB/DOP	37.995	0.013	9.1735	0.0067	1.7839	0.0011
035	CAB/DOP	38.118	0.013	9.2032	0.0067	1.7897	0.0011
036	CAB/DOP	38.031	0.013	9.1822	0.0067	1.7856	0.0011
037	CAB/DOP	38.084	0.013	9.1949	0.0067	1.7881	0.0011
038	CAB/DOP	38.036	0.013	9.1833	0.0067	1.7858	0.0011
039	CAB/DOP	38.070	0.013	9.1916	0.0067	1.7874	0.0011
040	CAB/DOP	38.066	0.013	9.1905	0.0067	1.7872	0.0011
041	CAB/DOP	38.028	0.013	9.1815	0.0067	1.7855	0.0011
042	CAB/DOP	38.069	0.013	9.1912	0.0067	1.7874	0.0011
043	CAB/DOP	38.045	0.013	9.1855	0.0067	1.7862	0.0011
044	CAB/DOP	38.022	0.013	9.1800	0.0067	1.7852	0.0011
045	CAB/DOP	38.103	0.013	9.1996	0.0067	1.7890	0.0011
046	CAB/DOP	38.030	0.013	9.1819	0.0067	1.7855	0.0011
047	CAB/DOP	38.087	0.013	9.1956	0.0067	1.7882	0.0011
048	CAB/DOP	38.031	0.013	9.1822	0.0067	1.7856	0.0011
049	CAB/DOP	38.028	0.013	9.1815	0.0067	1.7855	0.0011
050	CAB/DOP	38.106	0.013	9.2003	0.0067	1.7891	0.0011

Vial No.	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	CAB/DOP	38.051	0.013	9.1869	0.0067	1.7865	0.0011
052	CAB/DOP	38.057	0.013	9.1884	0.0067	1.7868	0.0011
053	CAB/DOP	38.069	0.013	9.1912	0.0067	1.7874	0.0011
054	CAB/DOP	38.022	0.013	9.1800	0.0067	1.7852	0.0011
055	CAB/DOP	38.051	0.013	9.1869	0.0067	1.7865	0.0011
056	CAB/DOP	38.084	0.013	9.1949	0.0067	1.7881	0.0011
057	CAB/DOP	38.094	0.013	9.1974	0.0067	1.7886	0.0011
058	CAB/DOP	38.009	0.013	9.1768	0.0067	1.7846	0.0011
059	CAB/DOP	38.099	0.013	9.1985	0.0067	1.7888	0.0011
060	CAB/DOP	38.033	0.013	9.1826	0.0067	1.7857	0.0011
061	CAB/DOP	38.085	0.013	9.1952	0.0067	1.7881	0.0011
062	CAB/DOP	38.078	0.013	9.1934	0.0067	1.7878	0.0011
063	CAB/DOP	38.036	0.013	9.1833	0.0067	1.7858	0.0011
064	CAB/DOP	37.985	0.013	9.1710	0.0067	1.7834	0.0011
065	CAB/DOP	38.142	0.013	9.2089	0.0067	1.7908	0.0011
066	CAB/DOP	38.102	0.013	9.1992	0.0067	1.7889	0.0011
067	CAB/DOP	38.067	0.013	9.1909	0.0067	1.7873	0.0011
068	CAB/DOP	37.995	0.013	9.1735	0.0067	1.7839	0.0011
069	CAB/DOP	38.121	0.013	9.2039	0.0067	1.7898	0.0011
070	CAB/DOP	37.972	0.013	9.1678	0.0067	1.7828	0.0011
071	CAB/DOP	38.193	0.013	9.2212	0.0067	1.7932	0.0011
072	CAB/DOP	38.025	0.013	9.1808	0.0067	1.7853	0.0011
073	CAB/DOP	38.049	0.013	9.1865	0.0067	1.7865	0.0011
074	CAB/DOP	38.025	0.013	9.1808	0.0067	1.7853	0.0011
075	CAB/DOP	38.078	0.013	9.1934	0.0067	1.7878	0.0011
076	CAB/DOP	38.063	0.013	9.1898	0.0067	1.7871	0.0011
077	CAB/DOP	38.067	0.013	9.1909	0.0067	1.7873	0.0011
078	CAB/DOP	38.094	0.013	9.1974	0.0067	1.7886	0.0011
079	CAB/DOP	38.013	0.013	9.1779	0.0067	1.7848	0.0011
080	CAB/DOP	38.094	0.013	9.1974	0.0067	1.7886	0.0011
081	CAB/DOP	38.045	0.013	9.1855	0.0067	1.7862	0.0011
082	CAB/DOP	38.027	0.013	9.1811	0.0067	1.7854	0.0011
083	CAB/DOP	38.090	0.013	9.1963	0.0067	1.7884	0.0011
084	CAB/DOP	38.048	0.013	9.1862	0.0067	1.7864	0.0011
085	CMC	38.087	0.013	9.1956	0.0067	1.7882	0.0011
086	CAB/DOP	38.054	0.013	9.1876	0.0067	1.7867	0.0011
087	CAB/DOP	38.001	0.013	9.1750	0.0067	1.7842	0.0011
088	CAB/DOP	38.025	0.013	9.1808	0.0067	1.7853	0.0011
089	CAB/DOP	38.076	0.013	9.1931	0.0067	1.7877	0.0011
090	CAB/DOP	38.082	0.013	9.1945	0.0067	1.7880	0.0011
091	CAB/DOP	38.016	0.013	9.1786	0.0067	1.7849	0.0011
092	CAB/DOP	38.006	0.013	9.1761	0.0067	1.7844	0.0011
093	CAB/DOP	38.049	0.013	9.1865	0.0067	1.7865	0.0011
094	CAB/DOP	38.079	0.013	9.1938	0.0067	1.7879	0.0011
095	CAB/DOP	37.994	0.013	9.1732	0.0067	1.7839	0.0011
096	CAB/DOP	38.097	0.013	9.1981	0.0067	1.7887	0.0011
097	CMC	37.968	0.013	9.1670	0.0067	1.7827	0.0011
098	CMC	38.079	0.013	9.1937	0.0067	1.7879	0.0011
099	CMC	38.009	0.013	9.1768	0.0067	1.7846	0.0011
100	CMC	38.006	0.013	9.1760	0.0067	1.7844	0.0011

Vial No.	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	CMC	38.070	0.013	9.1916	0.0067	1.7874	0.0011
102	CMC	37.980	0.013	9.1699	0.0067	1.7832	0.0011
103	CMC	38.064	0.013	9.1901	0.0067	1.7872	0.0011
104	CMC	38.042	0.013	9.1847	0.0067	1.7861	0.0011
105	CMC	38.067	0.013	9.1909	0.0067	1.7873	0.0011
106	CMC	38.004	0.013	9.1757	0.0067	1.7843	0.0011
107	CMC	38.013	0.013	9.1779	0.0067	1.7848	0.0011
108	CMC	38.040	0.013	9.1844	0.0067	1.7860	0.0011
109	CMC	37.952	0.013	9.1630	0.0067	1.7819	0.0011
110	CMC	38.070	0.013	9.1916	0.0067	1.7874	0.0011
111	CMC	38.037	0.013	9.1836	0.0067	1.7859	0.0011
112	CMC	37.992	0.013	9.1728	0.0067	1.7838	0.0011
113	CMC	38.057	0.013	9.1883	0.0067	1.7868	0.0011
114	CMC	38.003	0.013	9.1753	0.0067	1.7843	0.0011
115	CMC	37.983	0.013	9.1706	0.0067	1.7834	0.0011
116	CMC	38.088	0.013	9.1959	0.0067	1.7883	0.0011
117	CMC	37.971	0.013	9.1677	0.0067	1.7828	0.0011
118	CMC	38.013	0.013	9.1779	0.0067	1.7848	0.0011
119	CMC	38.049	0.013	9.1865	0.0067	1.7865	0.0011
120	CMC	38.028	0.013	9.1815	0.0067	1.7855	0.0011
121	CMC	37.995	0.013	9.1735	0.0067	1.7839	0.0011
122	CMC	38.042	0.013	9.1847	0.0067	1.7861	0.0011
123	CMC	37.953	0.013	9.1634	0.0067	1.7820	0.0011
124	CMC	38.033	0.013	9.1826	0.0067	1.7857	0.0011
125	CMC	38.018	0.013	9.1789	0.0067	1.7850	0.0011
126	CMC	38.009	0.013	9.1768	0.0067	1.7846	0.0011
127	CMC	38.000	0.013	9.1746	0.0067	1.7841	0.0011
128	CMC	37.973	0.013	9.1681	0.0067	1.7829	0.0011
129	CMC	38.013	0.013	9.1779	0.0067	1.7848	0.0011
130	CMC	38.013	0.013	9.1779	0.0067	1.7848	0.0011
131	CMC	37.979	0.013	9.1695	0.0067	1.7831	0.0011
132	CMC	37.971	0.013	9.1677	0.0067	1.7828	0.0011
133	CMC	38.006	0.013	9.1760	0.0067	1.7844	0.0011
134	CMC	38.021	0.013	9.1797	0.0067	1.7851	0.0011
135	CMC	38.015	0.013	9.1782	0.0067	1.7848	0.0011
136	CMC	38.046	0.013	9.1858	0.0067	1.7863	0.0011
137	CMC	37.898	0.013	9.1500	0.0067	1.7794	0.0011
138	CMC	38.024	0.013	9.1804	0.0067	1.7853	0.0011
139	CMC	37.888	0.013	9.1475	0.0067	1.7789	0.0011
140	CMC	37.955	0.013	9.1638	0.0067	1.7820	0.0011
141	CMC	37.955	0.013	9.1638	0.0067	1.7820	0.0011
142	CMC	37.977	0.013	9.1692	0.0067	1.7831	0.0011
143	CMC	37.876	0.013	9.1446	0.0067	1.7783	0.0011
144	CAB/DOP	38.105	0.013	9.1999	0.0067	1.7891	0.0011
145	CMC	38.030	0.013	9.1818	0.0067	1.7855	0.0011
146	CAB/DOP	37.958	0.013	9.1645	0.0067	1.7822	0.0011
147	CAB/DOP	37.924	0.013	9.1562	0.0067	1.7806	0.0011
148	CAB/DOP	38.010	0.013	9.1771	0.0067	1.7846	0.0011
149	CAB/DOP	38.046	0.013	9.1858	0.0067	1.7863	0.0011
150	CAB/DOP	37.986	0.013	9.1714	0.0067	1.7835	0.0011

Vial No.	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	37.937	0.013	9.1594	0.0067	1.7812	0.0011
152	CAB/DOP	37.930	0.013	9.1576	0.0067	1.7808	0.0011
153	CAB/DOP	37.924	0.013	9.1562	0.0067	1.7806	0.0011
154	CAB/DOP	38.087	0.013	9.1956	0.0067	1.7882	0.0011
155	CAB/DOP	38.033	0.013	9.1826	0.0067	1.7857	0.0011
156	CAB/DOP	37.948	0.013	9.1620	0.0067	1.7817	0.0011
157	CAB/DOP	37.936	0.013	9.1591	0.0067	1.7811	0.0011
158	CAB/DOP	37.948	0.013	9.1620	0.0067	1.7817	0.0011
159	CAB/DOP	38.085	0.013	9.1952	0.0067	1.7881	0.0011
160	CAB/DOP	37.976	0.013	9.1688	0.0067	1.7830	0.0011
161	CAB/DOP	37.892	0.013	9.1486	0.0067	1.7791	0.0011
162	CAB/DOP	38.085	0.013	9.1952	0.0067	1.7881	0.0011
163	CAB/DOP	38.024	0.013	9.1804	0.0067	1.7853	0.0011
164	CAB/DOP	37.994	0.013	9.1732	0.0067	1.7839	0.0011
165	CAB/DOP	37.977	0.013	9.1692	0.0067	1.7831	0.0011
166	CAB/DOP	37.864	0.013	9.1417	0.0067	1.7777	0.0011
167	CAB/DOP	38.133	0.013	9.2068	0.0067	1.7904	0.0011
168	CAB/DOP	37.921	0.013	9.1555	0.0067	1.7804	0.0011
169	CAB/DOP	38.058	0.013	9.1887	0.0067	1.7869	0.0011
170	CAB/DOP	37.883	0.013	9.1464	0.0067	1.7787	0.0011
171	CAB/DOP	38.003	0.013	9.1753	0.0067	1.7843	0.0011
172	CAB/DOP	37.967	0.013	9.1667	0.0067	1.7826	0.0011
173	CAB/DOP	38.069	0.013	9.1912	0.0067	1.7874	0.0011
174	CAB/DOP	37.994	0.013	9.1732	0.0067	1.7839	0.0011
175	CAB/DOP	37.971	0.013	9.1677	0.0067	1.7828	0.0011
176	CAB/DOP	38.010	0.013	9.1771	0.0067	1.7846	0.0011
177	CAB/DOP	37.998	0.013	9.1742	0.0067	1.7841	0.0011
178	CAB/DOP	38.010	0.013	9.1771	0.0067	1.7846	0.0011
179	CAB/DOP	37.977	0.013	9.1692	0.0067	1.7831	0.0011
180	CAB/DOP	38.018	0.013	9.1789	0.0067	1.7850	0.0011
181	CAB/DOP	37.971	0.013	9.1677	0.0067	1.7828	0.0011
182	CAB/DOP	37.946	0.013	9.1616	0.0067	1.7816	0.0011
183	CAB/DOP	38.055	0.013	9.1880	0.0067	1.7867	0.0011
184	CAB/DOP	37.979	0.013	9.1696	0.0067	1.7832	0.0011
185	CAB/DOP	38.003	0.013	9.1753	0.0067	1.7843	0.0011
186	CAB/DOP	37.977	0.013	9.1692	0.0067	1.7831	0.0011
187	CAB/DOP	38.000	0.013	9.1746	0.0067	1.7841	0.0011
188	CAB/DOP	37.989	0.013	9.1721	0.0067	1.7836	0.0011
189	CAB/DOP	37.970	0.013	9.1674	0.0067	1.7827	0.0011
190	CAB/DOP	37.974	0.013	9.1685	0.0067	1.7829	0.0011
191	CAB/DOP	37.921	0.013	9.1555	0.0067	1.7804	0.0011
192	CAB/DOP	38.084	0.013	9.1948	0.0067	1.7881	0.0011
193	CMC	38.022	0.013	9.1800	0.0067	1.7852	0.0011
194	CAB/DOP	37.998	0.013	9.1742	0.0067	1.7841	0.0011
195	CAB/DOP	37.970	0.013	9.1674	0.0067	1.7827	0.0011
196	CAB/DOP	37.938	0.013	9.1598	0.0067	1.7813	0.0011
197	CAB/DOP	38.022	0.013	9.1800	0.0067	1.7852	0.0011
198	CAB/DOP	37.997	0.013	9.1739	0.0067	1.7840	0.0011
199	CAB/DOP	37.977	0.013	9.1692	0.0067	1.7831	0.0011
200	CAB/DOP	37.977	0.013	9.1692	0.0067	1.7831	0.0011

Vial No.	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	38.019	0.013	9.1793	0.0067	1.7850	0.0011
202	CAB/DOP	37.991	0.013	9.1724	0.0067	1.7837	0.0011
203	CAB/DOP	37.989	0.013	9.1721	0.0067	1.7836	0.0011
204	CAB/DOP	37.994	0.013	9.1732	0.0067	1.7839	0.0011
205	CAB/DOP	37.997	0.013	9.1739	0.0067	1.7840	0.0011
206	CAB/DOP	38.000	0.013	9.1746	0.0067	1.7841	0.0011
207	CAB/DOP	37.991	0.013	9.1724	0.0067	1.7837	0.0011
208	CAB/DOP	38.015	0.013	9.1782	0.0067	1.7848	0.0011
209	CAB/DOP	37.998	0.013	9.1742	0.0067	1.7841	0.0011
210	CAB/DOP	37.977	0.013	9.1692	0.0067	1.7831	0.0011
211	CAB/DOP	37.995	0.013	9.1735	0.0067	1.7839	0.0011
212	CAB/DOP	38.018	0.013	9.1789	0.0067	1.7850	0.0011
213	CAB/DOP	37.977	0.013	9.1692	0.0067	1.7831	0.0011
214	CAB/DOP	38.027	0.013	9.1811	0.0067	1.7854	0.0011
215	CAB/DOP	37.989	0.013	9.1721	0.0067	1.7836	0.0011
216	CAB/DOP	38.018	0.013	9.1789	0.0067	1.7850	0.0011
217	CAB/DOP	37.989	0.013	9.1721	0.0067	1.7836	0.0011
218	CAB/DOP	38.018	0.013	9.1789	0.0067	1.7850	0.0011
219	CAB/DOP	37.997	0.013	9.1739	0.0067	1.7840	0.0011
220	CAB/DOP	38.003	0.013	9.1753	0.0067	1.7843	0.0011
221	CAB/DOP	37.985	0.013	9.1710	0.0067	1.7834	0.0011
222	CAB/DOP	37.982	0.013	9.1703	0.0067	1.7833	0.0011
223	CAB/DOP	38.030	0.013	9.1818	0.0067	1.7855	0.0011
224	CAB/DOP	37.983	0.013	9.1706	0.0067	1.7834	0.0011
225	CAB/DOP	38.001	0.013	9.1750	0.0067	1.7842	0.0011
226	CAB/DOP	37.986	0.013	9.1713	0.0067	1.7835	0.0011
227	CAB/DOP	38.033	0.013	9.1825	0.0067	1.7857	0.0011
228	CAB/DOP	37.980	0.013	9.1699	0.0067	1.7832	0.0011
229	CAB/DOP	37.955	0.013	9.1638	0.0067	1.7820	0.0011
230	CAB/DOP	38.001	0.013	9.1750	0.0067	1.7842	0.0011
231	CAB/DOP	38.018	0.013	9.1789	0.0067	1.7850	0.0011
232	CAB/DOP	37.985	0.013	9.1710	0.0067	1.7834	0.0011
233	CAB/DOP	38.030	0.013	9.1818	0.0067	1.7855	0.0011
234	CAB/DOP	38.015	0.013	9.1782	0.0067	1.7848	0.0011
235	CAB/DOP	38.009	0.013	9.1768	0.0067	1.7846	0.0011
236	CAB/DOP	37.976	0.013	9.1688	0.0067	1.7830	0.0011
237	CAB/DOP	38.006	0.013	9.1760	0.0067	1.7844	0.0011
238	CAB/DOP	37.985	0.013	9.1710	0.0067	1.7834	0.0011
239	CAB/DOP	38.000	0.013	9.1746	0.0067	1.7841	0.0011
240	CAB/DOP	38.006	0.013	9.1760	0.0067	1.7844	0.0011
241	CAB/DOP	38.006	0.013	9.1760	0.0067	1.7844	0.0011
242	CMC	38.016	0.013	9.1786	0.0067	1.7849	0.0011
243	CMC	38.010	0.013	9.1771	0.0067	1.7846	0.0011
244	CMC	37.973	0.013	9.1681	0.0067	1.7829	0.0011
245	CMC	38.028	0.013	9.1815	0.0067	1.7855	0.0011
246	CMC	37.989	0.013	9.1721	0.0067	1.7836	0.0011
247	CAB/DOP	38.007	0.013	9.1764	0.0067	1.7845	0.0011
248	CMC	38.022	0.013	9.1800	0.0067	1.7852	0.0011
249	CMC	37.997	0.013	9.1739	0.0067	1.7840	0.0011
250	CMC	38.022	0.013	9.1800	0.0067	1.7852	0.0011

Vial No.	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	37.994	0.013	9.1732	0.0067	1.7839	0.0011
252	CMC	38.025	0.013	9.1807	0.0067	1.7853	0.0011
253	CMC	37.989	0.013	9.1721	0.0067	1.7836	0.0011
254	CMC	38.036	0.013	9.1833	0.0067	1.7858	0.0011
255	CMC	37.991	0.013	9.1724	0.0067	1.7837	0.0011
256	CMC	38.028	0.013	9.1815	0.0067	1.7855	0.0011
257	CMC	38.009	0.013	9.1768	0.0067	1.7846	0.0011
258	CMC	37.995	0.013	9.1735	0.0067	1.7839	0.0011
259	CMC	38.003	0.013	9.1753	0.0067	1.7843	0.0011
260	CAB/DOP	37.962	0.013	9.1656	0.0067	1.7824	0.0011
261	CMC	37.998	0.013	9.1742	0.0067	1.7841	0.0011
262	CMC	38.033	0.013	9.1825	0.0067	1.7857	0.0011
263	CMC	38.015	0.013	9.1782	0.0067	1.7848	0.0011
264	CMC	37.998	0.013	9.1742	0.0067	1.7841	0.0011
265	CMC	38.016	0.013	9.1786	0.0067	1.7849	0.0011
266	CAB/DOP	38.009	0.013	9.1768	0.0067	1.7846	0.0011
267	CMC	38.004	0.013	9.1757	0.0067	1.7843	0.0011
268	CMC	38.033	0.013	9.1825	0.0067	1.7857	0.0011
269	CMC	38.012	0.013	9.1775	0.0067	1.7847	0.0011
270	CMC	38.009	0.013	9.1768	0.0067	1.7846	0.0011
271	CMC	38.013	0.013	9.1779	0.0067	1.7848	0.0011
272	CMC	38.007	0.013	9.1764	0.0067	1.7845	0.0011
273	CMC	38.024	0.013	9.1804	0.0067	1.7853	0.0011
274	CMC	38.009	0.013	9.1768	0.0067	1.7846	0.0011
275	CMC	38.018	0.013	9.1789	0.0067	1.7850	0.0011
276	CMC	38.013	0.013	9.1779	0.0067	1.7848	0.0011
277	CMC	38.004	0.013	9.1757	0.0067	1.7843	0.0011
278	CMC	38.013	0.013	9.1779	0.0067	1.7848	0.0011
279	CMC	38.015	0.013	9.1782	0.0067	1.7848	0.0011
280	CMC	38.006	0.013	9.1760	0.0067	1.7844	0.0011
281	CMC	38.034	0.013	9.1829	0.0067	1.7857	0.0011
282	CMC	38.028	0.013	9.1815	0.0067	1.7855	0.0011
283	CMC	37.998	0.013	9.1742	0.0067	1.7841	0.0011
284	CMC	38.016	0.013	9.1786	0.0067	1.7849	0.0011
285	CMC	38.016	0.013	9.1786	0.0067	1.7849	0.0011
286	CMC	38.006	0.013	9.1760	0.0067	1.7844	0.0011
287	CMC	38.022	0.013	9.1800	0.0067	1.7852	0.0011
288	CMC	38.028	0.013	9.1815	0.0067	1.7855	0.0011
289	CAB/DOP	37.983	0.013	9.1706	0.0067	1.7834	0.0011
290	CAB/DOP	38.033	0.013	9.1826	0.0067	1.7857	0.0011
291	CAB/DOP	38.022	0.013	9.1800	0.0067	1.7852	0.0011
292	CAB/DOP	38.015	0.013	9.1782	0.0067	1.7848	0.0011
293	CAB/DOP	37.988	0.013	9.1717	0.0067	1.7836	0.0011
294	CAB/DOP	38.000	0.013	9.1746	0.0067	1.7841	0.0011
295	CAB/DOP	38.013	0.013	9.1779	0.0067	1.7848	0.0011
296	CAB/DOP	38.037	0.013	9.1837	0.0067	1.7859	0.0011
297	CAB/DOP	37.948	0.013	9.1620	0.0067	1.7817	0.0011
298	CAB/DOP	38.036	0.013	9.1833	0.0067	1.7858	0.0011
299	CAB/DOP	37.972	0.013	9.1678	0.0067	1.7828	0.0011
300	CAB/DOP	38.052	0.013	9.1873	0.0067	1.7866	0.0011

Vial No.	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	38.016	0.013	9.1786	0.0067	1.7849	0.0011
302	CAB/DOP	38.030	0.013	9.1818	0.0067	1.7855	0.0011
303	CAB/DOP	38.013	0.013	9.1779	0.0067	1.7848	0.0011
304	CAB/DOP	38.031	0.013	9.1822	0.0067	1.7856	0.0011
305	CAB/DOP	38.022	0.013	9.1800	0.0067	1.7852	0.0011
306	CAB/DOP	37.994	0.013	9.1732	0.0067	1.7839	0.0011
307	CAB/DOP	38.037	0.013	9.1837	0.0067	1.7859	0.0011
308	CAB/DOP	38.037	0.013	9.1837	0.0067	1.7859	0.0011
309	CAB/DOP	38.019	0.013	9.1793	0.0067	1.7851	0.0011
310	CAB/DOP	38.007	0.013	9.1764	0.0067	1.7845	0.0011
311	CAB/DOP	38.012	0.013	9.1775	0.0067	1.7847	0.0011
312	CAB/DOP	38.007	0.013	9.1764	0.0067	1.7845	0.0011
313	CAB/DOP	38.018	0.013	9.1790	0.0067	1.7850	0.0011
314	CAB/DOP	38.027	0.013	9.1811	0.0067	1.7854	0.0011
315	CAB/DOP	38.031	0.013	9.1822	0.0067	1.7856	0.0011
316	CAB/DOP	38.009	0.013	9.1768	0.0067	1.7846	0.0011
317	CMC	38.028	0.013	9.1815	0.0067	1.7855	0.0011
318	CAB/DOP	38.019	0.013	9.1793	0.0067	1.7851	0.0011
319	CAB/DOP	38.034	0.013	9.1829	0.0067	1.7858	0.0011
320	CAB/DOP	37.995	0.013	9.1735	0.0067	1.7839	0.0011
321	CAB/DOP	38.013	0.013	9.1779	0.0067	1.7848	0.0011
322	CAB/DOP	38.004	0.013	9.1757	0.0067	1.7843	0.0011
323	CAB/DOP	38.006	0.013	9.1761	0.0067	1.7844	0.0011
324	CAB/DOP	38.013	0.013	9.1779	0.0067	1.7848	0.0011
325	CAB/DOP	38.043	0.013	9.1851	0.0067	1.7862	0.0011
326	CAB/DOP	38.001	0.013	9.1750	0.0067	1.7842	0.0011
327	CAB/DOP	38.003	0.013	9.1753	0.0067	1.7843	0.0011
328	CAB/DOP	38.015	0.013	9.1782	0.0067	1.7848	0.0011
329	CAB/DOP	38.010	0.013	9.1772	0.0067	1.7846	0.0011
330	CAB/DOP	38.021	0.013	9.1797	0.0067	1.7851	0.0011
331	CAB/DOP	37.997	0.013	9.1739	0.0067	1.7840	0.0011
332	CAB/DOP	38.019	0.013	9.1793	0.0067	1.7851	0.0011
333	CAB/DOP	37.989	0.013	9.1721	0.0067	1.7836	0.0011
334	CAB/DOP	38.024	0.013	9.1804	0.0067	1.7853	0.0011
335	CAB/DOP	37.985	0.013	9.1710	0.0067	1.7834	0.0011
336	CAB/DOP	37.995	0.013	9.1735	0.0067	1.7839	0.0011
337	CAB/DOP	37.970	0.013	9.1674	0.0067	1.7827	0.0011
338	CAB/DOP	38.009	0.013	9.1768	0.0067	1.7846	0.0011
339	CAB/DOP	38.004	0.013	9.1757	0.0067	1.7843	0.0011
340	CAB/DOP	37.964	0.013	9.1660	0.0067	1.7825	0.0011
341	CAB/DOP	38.015	0.013	9.1782	0.0067	1.7848	0.0011
342	CAB/DOP	37.980	0.013	9.1699	0.0067	1.7832	0.0011
343	CAB/DOP	38.003	0.013	9.1753	0.0067	1.7843	0.0011
344	CAB/DOP	37.986	0.013	9.1714	0.0067	1.7835	0.0011
345	CAB/DOP	38.004	0.013	9.1757	0.0067	1.7843	0.0011
346	CAB/DOP	37.992	0.013	9.1728	0.0067	1.7838	0.0011
347	CAB/DOP	37.980	0.013	9.1699	0.0067	1.7832	0.0011
348	CAB/DOP	37.991	0.013	9.1725	0.0067	1.7837	0.0011
349	CAB/DOP	37.976	0.013	9.1688	0.0067	1.7830	0.0011
350	CAB/DOP	38.003	0.013	9.1753	0.0067	1.7843	0.0011

Vial No.	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	37.998	0.013	9.1743	0.0067	1.7841	0.0011
352	CAB/DOP	38.030	0.013	9.1818	0.0067	1.7855	0.0011
353	CAB/DOP	37.948	0.013	9.1620	0.0067	1.7817	0.0011
354	CAB/DOP	38.003	0.013	9.1753	0.0067	1.7843	0.0011
355	CAB/DOP	37.979	0.013	9.1696	0.0067	1.7832	0.0011
356	CAB/DOP	37.995	0.013	9.1735	0.0067	1.7839	0.0011
357	CAB/DOP	38.009	0.013	9.1768	0.0067	1.7846	0.0011
358	CAB/DOP	37.983	0.013	9.1706	0.0067	1.7834	0.0011
359	CAB/DOP	38.004	0.013	9.1757	0.0067	1.7843	0.0011
360	CAB/DOP	37.963	0.013	9.1656	0.0067	1.7824	0.0011
361	CAB/DOP	38.019	0.013	9.1793	0.0067	1.7851	0.0011
362	CAB/DOP	38.010	0.013	9.1772	0.0067	1.7846	0.0011
363	CAB/DOP	38.004	0.013	9.1757	0.0067	1.7843	0.0011
364	CAB/DOP	38.001	0.013	9.1750	0.0067	1.7842	0.0011
365	CMC	38.016	0.013	9.1786	0.0067	1.7849	0.0011
366	CAB/DOP	37.986	0.013	9.1714	0.0067	1.7835	0.0011
367	CAB/DOP	38.009	0.013	9.1768	0.0067	1.7846	0.0011
368	CAB/DOP	38.007	0.013	9.1764	0.0067	1.7845	0.0011
369	CAB/DOP	38.000	0.013	9.1746	0.0067	1.7841	0.0011
370	CAB/DOP	38.007	0.013	9.1764	0.0067	1.7845	0.0011
371	CAB/DOP	38.015	0.013	9.1782	0.0067	1.7848	0.0011
372	CAB/DOP	38.004	0.013	9.1757	0.0067	1.7843	0.0011
373	CAB/DOP	38.009	0.013	9.1768	0.0067	1.7846	0.0011
374	CAB/DOP	37.997	0.013	9.1739	0.0067	1.7840	0.0011
375	CAB/DOP	38.016	0.013	9.1786	0.0067	1.7849	0.0011
376	CAB/DOP	38.004	0.013	9.1757	0.0067	1.7843	0.0011
377	CAB/DOP	38.006	0.013	9.1761	0.0067	1.7844	0.0011
378	CAB/DOP	38.016	0.013	9.1786	0.0067	1.7849	0.0011
379	CAB/DOP	38.009	0.013	9.1768	0.0067	1.7846	0.0011
380	CAB/DOP	38.013	0.013	9.1779	0.0067	1.7848	0.0011
381	CAB/DOP	37.995	0.013	9.1735	0.0067	1.7839	0.0011
382	CAB/DOP	38.010	0.013	9.1772	0.0067	1.7846	0.0011
383	CAB/DOP	37.983	0.013	9.1706	0.0067	1.7834	0.0011
384	CAB/DOP	38.006	0.013	9.1761	0.0067	1.7844	0.0011
385	CMC	37.989	0.013	9.1721	0.0067	1.7836	0.0011
386	CMC	37.985	0.013	9.1710	0.0067	1.7834	0.0011
387	CMC	37.982	0.013	9.1703	0.0067	1.7833	0.0011
388	CMC	37.997	0.013	9.1739	0.0067	1.7840	0.0011
389	CMC	37.988	0.013	9.1717	0.0067	1.7836	0.0011
390	CMC	37.956	0.013	9.1641	0.0067	1.7821	0.0011
391	CMC	37.980	0.013	9.1699	0.0067	1.7832	0.0011
392	CMC	37.992	0.013	9.1728	0.0067	1.7838	0.0011
393	CMC	37.995	0.013	9.1735	0.0067	1.7839	0.0011
394	CMC	37.995	0.013	9.1735	0.0067	1.7839	0.0011
395	CMC	37.976	0.013	9.1688	0.0067	1.7830	0.0011
396	CMC	37.983	0.013	9.1706	0.0067	1.7834	0.0011
397	CMC	37.994	0.013	9.1731	0.0067	1.7838	0.0011
398	CMC	37.971	0.013	9.1677	0.0067	1.7828	0.0011
399	CMC	37.971	0.013	9.1677	0.0067	1.7828	0.0011
400	CMC	37.997	0.013	9.1739	0.0067	1.7840	0.0011

Vial No.	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	37.970	0.013	9.1674	0.0067	1.7827	0.0011
402	CMC	37.973	0.013	9.1681	0.0067	1.7829	0.0011
403	CMC	37.980	0.013	9.1699	0.0067	1.7832	0.0011
404	CMC	37.988	0.013	9.1717	0.0067	1.7836	0.0011
405	CMC	37.965	0.013	9.1663	0.0067	1.7825	0.0011
406	CMC	38.006	0.013	9.1760	0.0067	1.7844	0.0011
407	CMC	37.968	0.013	9.1670	0.0067	1.7827	0.0011
408	CMC	37.992	0.013	9.1728	0.0067	1.7838	0.0011
409	CMC	37.973	0.013	9.1681	0.0067	1.7829	0.0011
410	CMC	37.988	0.013	9.1717	0.0067	1.7836	0.0011
411	CMC	37.985	0.013	9.1710	0.0067	1.7834	0.0011
412	CMC	37.965	0.013	9.1663	0.0067	1.7825	0.0011
413	CMC	37.977	0.013	9.1692	0.0067	1.7831	0.0011
414	CMC	37.955	0.013	9.1638	0.0067	1.7820	0.0011
415	CMC	37.992	0.013	9.1728	0.0067	1.7838	0.0011
416	CMC	37.992	0.013	9.1728	0.0067	1.7838	0.0011
417	CMC	37.944	0.013	9.1612	0.0067	1.7815	0.0011
418	CMC	38.006	0.013	9.1760	0.0067	1.7844	0.0011
419	CMC	38.002	0.013	9.1750	0.0067	1.7842	0.0011
420	CMC	37.997	0.013	9.1739	0.0067	1.7840	0.0011
421	CMC	37.984	0.013	9.1707	0.0067	1.7834	0.0011
422	CMC	38.019	0.013	9.1793	0.0067	1.7851	0.0011
423	CMC	38.025	0.013	9.1808	0.0067	1.7853	0.0011
424	CMC	38.025	0.013	9.1808	0.0067	1.7853	0.0011
425	CMC	38.008	0.013	9.1764	0.0067	1.7845	0.0011
426	CMC	38.043	0.013	9.1851	0.0067	1.7862	0.0011
427	CMC	37.991	0.013	9.1725	0.0067	1.7837	0.0011
428	CAB/DOP	38.061	0.013	9.1895	0.0067	1.7870	0.0011
429	CMC	37.993	0.013	9.1728	0.0067	1.7838	0.0011
430	CMC	38.046	0.013	9.1858	0.0067	1.7863	0.0011
431	CMC	37.985	0.013	9.1710	0.0067	1.7834	0.0011
432	CMC	38.018	0.013	9.1790	0.0067	1.7850	0.0011
433	CAB/DOP	38.024	0.013	9.1804	0.0067	1.7853	0.0011
434	CAB/DOP	38.037	0.013	9.1837	0.0067	1.7859	0.0011
435	CAB/DOP	37.999	0.013	9.1743	0.0067	1.7841	0.0011
436	CAB/DOP	38.005	0.013	9.1757	0.0067	1.7844	0.0011
437	CAB/DOP	38.024	0.013	9.1804	0.0067	1.7853	0.0011
438	CAB/DOP	38.045	0.013	9.1855	0.0067	1.7862	0.0011
439	CAB/DOP	38.019	0.013	9.1793	0.0067	1.7851	0.0011
440	CAB/DOP	38.028	0.013	9.1815	0.0067	1.7855	0.0011
441	CAB/DOP	37.993	0.013	9.1728	0.0067	1.7838	0.0011
442	CAB/DOP	38.011	0.013	9.1772	0.0067	1.7846	0.0011
443	CAB/DOP	38.033	0.013	9.1826	0.0067	1.7857	0.0011
444	CAB/DOP	38.013	0.013	9.1779	0.0067	1.7848	0.0011
445	CAB/DOP	38.013	0.013	9.1779	0.0067	1.7848	0.0011
446	CAB/DOP	38.021	0.013	9.1797	0.0067	1.7851	0.0011
447	CAB/DOP	38.045	0.013	9.1855	0.0067	1.7862	0.0011
448	CAB/DOP	38.025	0.013	9.1808	0.0067	1.7853	0.0011
449	CAB/DOP	38.000	0.013	9.1746	0.0067	1.7841	0.0011
450	CAB/DOP	38.033	0.013	9.1826	0.0067	1.7857	0.0011

Vial No.	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	CAB/DOP	38.030	0.013	9.1819	0.0067	1.7855	0.0011
452	CAB/DOP	38.019	0.013	9.1793	0.0067	1.7851	0.0011
453	CAB/DOP	38.016	0.013	9.1786	0.0067	1.7849	0.0011
454	CAB/DOP	38.000	0.013	9.1746	0.0067	1.7841	0.0011
455	CAB/DOP	38.018	0.013	9.1790	0.0067	1.7850	0.0011
456	CAB/DOP	38.005	0.013	9.1757	0.0067	1.7844	0.0011
457	CAB/DOP	38.040	0.013	9.1844	0.0067	1.7860	0.0011
458	CAB/DOP	38.006	0.013	9.1761	0.0067	1.7844	0.0011
459	CAB/DOP	38.012	0.013	9.1775	0.0067	1.7847	0.0011
460	CAB/DOP	38.019	0.013	9.1793	0.0067	1.7851	0.0011
461	CAB/DOP	38.018	0.013	9.1790	0.0067	1.7850	0.0011
462	CAB/DOP	37.999	0.013	9.1743	0.0067	1.7841	0.0011
463	CAB/DOP	38.040	0.013	9.1844	0.0067	1.7860	0.0011
464	CAB/DOP	38.005	0.013	9.1757	0.0067	1.7844	0.0011
465	CAB/DOP	38.042	0.013	9.1848	0.0067	1.7861	0.0011
466	CAB/DOP	38.009	0.013	9.1768	0.0067	1.7846	0.0011
467	CAB/DOP	37.993	0.013	9.1728	0.0067	1.7838	0.0011
468	CAB/DOP	38.025	0.013	9.1808	0.0067	1.7853	0.0011
469	CAB/DOP	38.025	0.013	9.1808	0.0067	1.7853	0.0011
470	CAB/DOP	38.006	0.013	9.1761	0.0067	1.7844	0.0011
471	CAB/DOP	38.011	0.013	9.1772	0.0067	1.7846	0.0011
472	CAB/DOP	38.039	0.013	9.1840	0.0067	1.7860	0.0011
473	CAB/DOP	37.984	0.013	9.1707	0.0067	1.7834	0.0011
474	CAB/DOP	38.036	0.013	9.1833	0.0067	1.7858	0.0011
475	CAB/DOP	37.972	0.013	9.1678	0.0067	1.7828	0.0011
476	CAB/DOP	38.025	0.013	9.1808	0.0067	1.7853	0.0011
477	CAB/DOP	38.049	0.013	9.1866	0.0067	1.7865	0.0011
478	CAB/DOP	37.985	0.013	9.1710	0.0067	1.7834	0.0011
479	CAB/DOP	38.025	0.013	9.1808	0.0067	1.7853	0.0011
480	CAB/DOP	38.000	0.013	9.1746	0.0067	1.7841	0.0011
481	CAB/DOP	38.072	0.013	9.1920	0.0067	1.7875	0.0011
482	CAB/DOP	37.957	0.013	9.1642	0.0067	1.7821	0.0011
483	CAB/DOP	38.042	0.013	9.1848	0.0067	1.7861	0.0011
484	CAB/DOP	37.963	0.013	9.1656	0.0067	1.7824	0.0011
485	CAB/DOP	38.011	0.013	9.1772	0.0067	1.7846	0.0011
486	CAB/DOP	38.039	0.013	9.1840	0.0067	1.7860	0.0011
487	CAB/DOP	37.985	0.013	9.1710	0.0067	1.7834	0.0011
488	CAB/DOP	38.020	0.013	9.1794	0.0067	1.7851	0.0011
489	CAB/DOP	38.015	0.013	9.1783	0.0067	1.7848	0.0011
490	CMC	38.045	0.013	9.1855	0.0067	1.7863	0.0011
491	CAB/DOP	38.046	0.013	9.1859	0.0067	1.7863	0.0011
492	CAB/DOP	38.009	0.013	9.1768	0.0067	1.7846	0.0011
493	CAB/DOP	38.012	0.013	9.1775	0.0067	1.7847	0.0011
494	CAB/DOP	38.009	0.013	9.1768	0.0067	1.7846	0.0011
495	CAB/DOP	38.021	0.013	9.1797	0.0067	1.7851	0.0011
496	CAB/DOP	38.000	0.013	9.1747	0.0067	1.7841	0.0011
497	CAB/DOP	38.012	0.013	9.1775	0.0067	1.7847	0.0011
498	CAB/DOP	38.014	0.013	9.1779	0.0067	1.7848	0.0011
499	CAB/DOP	38.043	0.013	9.1851	0.0067	1.7862	0.0011
500	CAB/DOP	38.033	0.013	9.1826	0.0067	1.7857	0.0011

Vial No.	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	37.999	0.013	9.1743	0.0067	1.7841	0.0011
502	CAB/DOP	38.000	0.013	9.1747	0.0067	1.7841	0.0011
503	CAB/DOP	38.055	0.013	9.1880	0.0067	1.7867	0.0011
504	CAB/DOP	38.021	0.013	9.1797	0.0067	1.7851	0.0011
505	CAB/DOP	38.042	0.013	9.1848	0.0067	1.7861	0.0011
506	CAB/DOP	37.979	0.013	9.1696	0.0067	1.7832	0.0011
507	CAB/DOP	38.045	0.013	9.1855	0.0067	1.7863	0.0011
508	CAB/DOP	38.017	0.013	9.1786	0.0067	1.7849	0.0011
509	CAB/DOP	38.034	0.013	9.1830	0.0067	1.7858	0.0011
510	CAB/DOP	37.999	0.013	9.1743	0.0067	1.7841	0.0011
511	CAB/DOP	38.026	0.013	9.1808	0.0067	1.7853	0.0011
512	CMC	38.029	0.013	9.1815	0.0067	1.7855	0.0011
513	CAB/DOP	38.032	0.013	9.1822	0.0067	1.7856	0.0011
514	CAB/DOP	37.991	0.013	9.1725	0.0067	1.7837	0.0011
515	CAB/DOP	38.042	0.013	9.1848	0.0067	1.7861	0.0011
516	CAB/DOP	38.002	0.013	9.1750	0.0067	1.7842	0.0011
517	CAB/DOP	38.079	0.013	9.1938	0.0067	1.7879	0.0011
518	CAB/DOP	37.985	0.013	9.1710	0.0067	1.7834	0.0011
519	CAB/DOP	38.026	0.013	9.1808	0.0067	1.7853	0.0011
520	CAB/DOP	38.005	0.013	9.1757	0.0067	1.7844	0.0011
521	CAB/DOP	38.040	0.013	9.1844	0.0067	1.7860	0.0011
522	CAB/DOP	37.970	0.013	9.1674	0.0067	1.7827	0.0011
523	CAB/DOP	37.993	0.013	9.1728	0.0067	1.7838	0.0011
524	CAB/DOP	38.009	0.013	9.1768	0.0067	1.7846	0.0011
525	CAB/DOP	38.017	0.013	9.1786	0.0067	1.7849	0.0011
526	CAB/DOP	38.002	0.013	9.1750	0.0067	1.7842	0.0011
527	CAB/DOP	38.043	0.013	9.1851	0.0067	1.7862	0.0011
528	CAB/DOP	37.964	0.013	9.1660	0.0067	1.7825	0.0011
529	CMC	38.024	0.013	9.1804	0.0067	1.7853	0.0011
530	CMC	38.014	0.013	9.1779	0.0067	1.7848	0.0011
531	CMC	38.032	0.013	9.1822	0.0067	1.7856	0.0011
532	CMC	37.969	0.013	9.1671	0.0067	1.7827	0.0011
533	CMC	38.060	0.013	9.1891	0.0067	1.7870	0.0011
534	CMC	37.961	0.013	9.1653	0.0067	1.7823	0.0011
535	CMC	38.027	0.013	9.1812	0.0067	1.7854	0.0011
536	CMC	38.005	0.013	9.1757	0.0067	1.7844	0.0011
537	CMC	37.994	0.013	9.1732	0.0067	1.7839	0.0011
538	CMC	38.049	0.013	9.1866	0.0067	1.7865	0.0011
539	CMC	37.987	0.013	9.1714	0.0067	1.7835	0.0011
540	CMC	38.045	0.013	9.1855	0.0067	1.7863	0.0011
541	CMC	38.003	0.013	9.1754	0.0067	1.7843	0.0011
542	CAB/DOP	38.032	0.013	9.1822	0.0067	1.7856	0.0011
543	CMC	37.988	0.013	9.1718	0.0067	1.7836	0.0011
544	CMC	38.014	0.013	9.1779	0.0067	1.7848	0.0011
545	CMC	38.042	0.013	9.1848	0.0067	1.7861	0.0011
546	CMC	38.012	0.013	9.1775	0.0067	1.7847	0.0011
547	CMC	38.018	0.013	9.1790	0.0067	1.7850	0.0011
548	CMC	38.043	0.013	9.1851	0.0067	1.7862	0.0011
549	CMC	38.014	0.013	9.1779	0.0067	1.7848	0.0011
550	CMC	37.991	0.013	9.1725	0.0067	1.7837	0.0011

Vial No.	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	CMC	38.020	0.013	9.1794	0.0067	1.7851	0.0011
552	CMC	37.978	0.013	9.1692	0.0067	1.7831	0.0011
553	CAB/DOP	38.020	0.013	9.1794	0.0067	1.7851	0.0011
554	CMC	38.027	0.013	9.1812	0.0067	1.7854	0.0011
555	CMC	38.018	0.013	9.1790	0.0067	1.7850	0.0011
556	CMC	38.032	0.013	9.1822	0.0067	1.7856	0.0011
557	CMC	37.991	0.013	9.1725	0.0067	1.7837	0.0011
558	CMC	38.002	0.013	9.1750	0.0067	1.7842	0.0011
559	CMC	38.002	0.013	9.1750	0.0067	1.7842	0.0011
560	CMC	38.020	0.013	9.1794	0.0067	1.7851	0.0011
561	CMC	38.049	0.013	9.1866	0.0067	1.7865	0.0011
562	CMC	37.985	0.013	9.1710	0.0067	1.7834	0.0011
563	CMC	37.990	0.013	9.1721	0.0067	1.7837	0.0011
564	CMC	37.997	0.013	9.1739	0.0067	1.7840	0.0011
565	CMC	38.021	0.013	9.1797	0.0067	1.7851	0.0011
566	CMC	38.040	0.013	9.1844	0.0067	1.7860	0.0011
567	CMC	37.976	0.013	9.1689	0.0067	1.7830	0.0011
568	CMC	38.018	0.013	9.1790	0.0067	1.7850	0.0011
569	CMC	38.006	0.013	9.1761	0.0067	1.7844	0.0011
570	CMC	38.032	0.013	9.1822	0.0067	1.7856	0.0011
571	CMC	38.002	0.013	9.1750	0.0067	1.7842	0.0011
572	CMC	37.984	0.013	9.1707	0.0067	1.7834	0.0011
573	CMC	38.017	0.013	9.1786	0.0067	1.7849	0.0011
574	CMC	38.033	0.013	9.1826	0.0067	1.7857	0.0011
575	CMC	38.005	0.013	9.1757	0.0067	1.7844	0.0011
576	CMC	38.015	0.013	9.1783	0.0067	1.7848	0.0011
577	CAB/DOP	38.004	0.013	9.1757	0.0067	1.7844	0.0011
578	CAB/DOP	37.970	0.013	9.1674	0.0067	1.7827	0.0011
579	CAB/DOP	38.028	0.013	9.1815	0.0067	1.7855	0.0011
580	CAB/DOP	37.973	0.013	9.1681	0.0067	1.7829	0.0011
581	CAB/DOP	38.037	0.013	9.1837	0.0067	1.7859	0.0011
582	CAB/DOP	37.991	0.013	9.1725	0.0067	1.7837	0.0011
583	CAB/DOP	37.991	0.013	9.1725	0.0067	1.7837	0.0011
584	CAB/DOP	38.048	0.013	9.1862	0.0067	1.7864	0.0011
585	CAB/DOP	38.012	0.013	9.1775	0.0067	1.7847	0.0011
586	CAB/DOP	37.999	0.013	9.1743	0.0067	1.7841	0.0011
587	CAB/DOP	37.999	0.013	9.1743	0.0067	1.7841	0.0011
588	CAB/DOP	37.970	0.013	9.1674	0.0067	1.7827	0.0011
589	CAB/DOP	37.976	0.013	9.1689	0.0067	1.7830	0.0011
590	CAB/DOP	38.034	0.013	9.1829	0.0067	1.7858	0.0011
591	CAB/DOP	37.979	0.013	9.1696	0.0067	1.7832	0.0011
592	CAB/DOP	37.979	0.013	9.1696	0.0067	1.7832	0.0011
593	CAB/DOP	38.054	0.013	9.1876	0.0067	1.7867	0.0011
594	CAB/DOP	37.988	0.013	9.1717	0.0067	1.7836	0.0011
595	CAB/DOP	37.975	0.013	9.1685	0.0067	1.7829	0.0011
596	CAB/DOP	38.022	0.013	9.1801	0.0067	1.7852	0.0011
597	CAB/DOP	37.958	0.013	9.1645	0.0067	1.7822	0.0011
598	CAB/DOP	38.027	0.013	9.1811	0.0067	1.7854	0.0011
599	CAB/DOP	38.046	0.013	9.1858	0.0067	1.7863	0.0011
600	CAB/DOP	37.988	0.013	9.1717	0.0067	1.7836	0.0011

Vial No.	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	38.024	0.013	9.1804	0.0067	1.7853	0.0011
602	CMC	37.994	0.013	9.1732	0.0067	1.7839	0.0011
603	CAB/DOP	38.013	0.013	9.1779	0.0067	1.7848	0.0011
604	CAB/DOP	37.994	0.013	9.1732	0.0067	1.7839	0.0011
605	CAB/DOP	38.006	0.013	9.1761	0.0067	1.7844	0.0011
606	CAB/DOP	38.003	0.013	9.1754	0.0067	1.7843	0.0011
607	CAB/DOP	37.969	0.013	9.1670	0.0067	1.7827	0.0011
608	CAB/DOP	38.054	0.013	9.1876	0.0067	1.7867	0.0011
609	CAB/DOP	38.007	0.013	9.1764	0.0067	1.7845	0.0011
610	CAB/DOP	38.021	0.013	9.1797	0.0067	1.7851	0.0011
611	CAB/DOP	37.978	0.013	9.1692	0.0067	1.7831	0.0011
612	CAB/DOP	38.054	0.013	9.1876	0.0067	1.7867	0.0011
613	CAB/DOP	38.001	0.013	9.1750	0.0067	1.7842	0.0011
614	CAB/DOP	37.988	0.013	9.1717	0.0067	1.7836	0.0011
615	CAB/DOP	37.996	0.013	9.1736	0.0067	1.7839	0.0011
616	CAB/DOP	38.031	0.013	9.1822	0.0067	1.7856	0.0011
617	CAB/DOP	38.022	0.013	9.1801	0.0067	1.7852	0.0011
618	CAB/DOP	37.972	0.013	9.1678	0.0067	1.7828	0.0011
619	CAB/DOP	38.045	0.013	9.1855	0.0067	1.7862	0.0011
620	CAB/DOP	37.961	0.013	9.1652	0.0067	1.7823	0.0011
621	CAB/DOP	38.025	0.013	9.1808	0.0067	1.7853	0.0011
622	CAB/DOP	38.025	0.013	9.1808	0.0067	1.7853	0.0011
623	CAB/DOP	37.957	0.013	9.1642	0.0067	1.7821	0.0011
624	CAB/DOP	38.013	0.013	9.1779	0.0067	1.7848	0.0011
625	CAB/DOP	38.013	0.013	9.1779	0.0067	1.7848	0.0011
626	CAB/DOP	37.984	0.013	9.1707	0.0067	1.7834	0.0011
627	CAB/DOP	38.013	0.013	9.1779	0.0067	1.7848	0.0011
628	CAB/DOP	38.034	0.013	9.1829	0.0067	1.7858	0.0011
629	CAB/DOP	37.948	0.013	9.1620	0.0067	1.7817	0.0011
630	CAB/DOP	38.025	0.013	9.1808	0.0067	1.7853	0.0011
631	CAB/DOP	37.966	0.013	9.1663	0.0067	1.7825	0.0011
632	CAB/DOP	37.996	0.013	9.1736	0.0067	1.7839	0.0011
633	CAB/DOP	38.015	0.013	9.1782	0.0067	1.7848	0.0011
634	CAB/DOP	38.022	0.013	9.1801	0.0067	1.7852	0.0011
635	CAB/DOP	37.984	0.013	9.1707	0.0067	1.7834	0.0011
636	CAB/DOP	38.057	0.013	9.1884	0.0067	1.7868	0.0011
637	CAB/DOP	37.997	0.013	9.1739	0.0067	1.7840	0.0011
638	CAB/DOP	38.004	0.013	9.1757	0.0067	1.7844	0.0011
639	CAB/DOP	38.009	0.013	9.1768	0.0067	1.7846	0.0011
640	CAB/DOP	38.036	0.013	9.1833	0.0067	1.7858	0.0011
641	CAB/DOP	37.961	0.013	9.1652	0.0067	1.7823	0.0011
642	CAB/DOP	38.028	0.013	9.1815	0.0067	1.7855	0.0011
643	CAB/DOP	38.025	0.013	9.1808	0.0067	1.7853	0.0011
644	CAB/DOP	38.015	0.013	9.1782	0.0067	1.7848	0.0011
645	CAB/DOP	37.948	0.013	9.1620	0.0067	1.7817	0.0011
646	CAB/DOP	38.061	0.013	9.1894	0.0067	1.7870	0.0011
647	CAB/DOP	38.013	0.013	9.1779	0.0067	1.7848	0.0011
648	CAB/DOP	37.913	0.013	9.1537	0.0067	1.7801	0.0011
649	CAB/DOP	38.016	0.013	9.1786	0.0067	1.7849	0.0011
650	CAB/DOP	38.009	0.013	9.1768	0.0067	1.7846	0.0011

Vial No.	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	38.000	0.013	9.1746	0.0067	1.7841	0.0011
652	CAB/DOP	38.054	0.013	9.1876	0.0067	1.7867	0.0011
653	CAB/DOP	37.952	0.013	9.1631	0.0067	1.7819	0.0011
654	CAB/DOP	38.043	0.013	9.1851	0.0067	1.7862	0.0011
655	CAB/DOP	37.970	0.013	9.1674	0.0067	1.7827	0.0011
656	CAB/DOP	38.069	0.013	9.1913	0.0067	1.7874	0.0011
657	CAB/DOP	37.981	0.013	9.1699	0.0067	1.7832	0.0011
658	CAB/DOP	37.978	0.013	9.1692	0.0067	1.7831	0.0011
659	CAB/DOP	38.004	0.013	9.1757	0.0067	1.7844	0.0011
660	CAB/DOP	38.048	0.013	9.1862	0.0067	1.7864	0.0011
661	CAB/DOP	37.963	0.013	9.1656	0.0067	1.7824	0.0011
662	CAB/DOP	38.024	0.013	9.1804	0.0067	1.7853	0.0011
663	CAB/DOP	37.988	0.013	9.1717	0.0067	1.7836	0.0011
664	CAB/DOP	38.018	0.013	9.1790	0.0067	1.7850	0.0011
665	CAB/DOP	38.022	0.013	9.1801	0.0067	1.7852	0.0011
666	CAB/DOP	37.955	0.013	9.1638	0.0067	1.7820	0.0011
667	CAB/DOP	38.039	0.013	9.1840	0.0067	1.7860	0.0011
668	CAB/DOP	38.004	0.013	9.1757	0.0067	1.7844	0.0011
669	CAB/DOP	37.997	0.013	9.1739	0.0067	1.7840	0.0011
670	CAB/DOP	38.004	0.013	9.1757	0.0067	1.7844	0.0011
671	CAB/DOP	38.006	0.013	9.1761	0.0067	1.7844	0.0011
672	CAB/DOP	37.994	0.013	9.1732	0.0067	1.7839	0.0011
673	CAB/DOP	38.018	0.013	9.1790	0.0067	1.7850	0.0011
674	CAB/DOP	37.997	0.013	9.1739	0.0067	1.7840	0.0011
675	CAB/DOP	38.000	0.013	9.1746	0.0067	1.7841	0.0011
676	CAB/DOP	38.014	0.013	9.1779	0.0067	1.7848	0.0011
677	CAB/DOP	37.955	0.013	9.1638	0.0067	1.7820	0.0011
678	CAB/DOP	38.014	0.013	9.1779	0.0067	1.7848	0.0011
679	CAB/DOP	38.006	0.013	9.1761	0.0067	1.7844	0.0011
680	CAB/DOP	37.990	0.013	9.1721	0.0067	1.7837	0.0011
681	CAB/DOP	38.061	0.013	9.1895	0.0067	1.7870	0.0011
682	CAB/DOP	38.001	0.013	9.1750	0.0067	1.7842	0.0011
683	CAB/DOP	38.024	0.013	9.1804	0.0067	1.7853	0.0011
684	CAB/DOP	38.070	0.013	9.1916	0.0067	1.7874	0.0011
685	CAB/DOP	37.988	0.013	9.1717	0.0067	1.7836	0.0011
686	CAB/DOP	38.022	0.013	9.1800	0.0067	1.7852	0.0011
687	CAB/DOP	37.997	0.013	9.1739	0.0067	1.7840	0.0011
688	CAB/DOP	38.004	0.013	9.1757	0.0067	1.7843	0.0011
689	CAB/DOP	38.036	0.013	9.1833	0.0067	1.7858	0.0011
690	CAB/DOP	37.954	0.013	9.1634	0.0067	1.7820	0.0011
691	CAB/DOP	38.037	0.013	9.1836	0.0067	1.7859	0.0011
692	CAB/DOP	38.036	0.013	9.1833	0.0067	1.7858	0.0011
693	CAB/DOP	38.018	0.013	9.1790	0.0067	1.7850	0.0011
694	CAB/DOP	38.057	0.013	9.1883	0.0067	1.7868	0.0011
695	CAB/DOP	38.016	0.013	9.1786	0.0067	1.7849	0.0011
696	CAB/DOP	38.043	0.013	9.1851	0.0067	1.7862	0.0011
697	CAB/DOP	38.004	0.013	9.1757	0.0067	1.7843	0.0011
698	CAB/DOP	37.998	0.013	9.1743	0.0067	1.7841	0.0011
699	CAB/DOP	38.037	0.013	9.1836	0.0067	1.7859	0.0011
700	CAB/DOP	38.049	0.013	9.1865	0.0067	1.7865	0.0011

Vial No.	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	CAB/DOP	37.998	0.013	9.1743	0.0067	1.7841	0.0011
702	CMC	38.021	0.013	9.1797	0.0067	1.7851	0.0011
703	CAB/DOP	38.004	0.013	9.1757	0.0067	1.7843	0.0011
704	CAB/DOP	38.030	0.013	9.1818	0.0067	1.7855	0.0011
705	CAB/DOP	38.016	0.013	9.1786	0.0067	1.7849	0.0011
706	CAB/DOP	38.022	0.013	9.1800	0.0067	1.7852	0.0011
707	CAB/DOP	38.088	0.013	9.1959	0.0067	1.7883	0.0011
708	CAB/DOP	37.985	0.013	9.1710	0.0067	1.7834	0.0011
709	CAB/DOP	37.992	0.013	9.1728	0.0067	1.7838	0.0011
710	CAB/DOP	38.060	0.013	9.1891	0.0067	1.7869	0.0011
711	CAB/DOP	38.009	0.013	9.1768	0.0067	1.7846	0.0011
712	CAB/DOP	38.010	0.013	9.1771	0.0067	1.7846	0.0011
713	CAB/DOP	38.040	0.013	9.1844	0.0067	1.7860	0.0011
714	CAB/DOP	37.967	0.013	9.1667	0.0067	1.7826	0.0011
715	CAB/DOP	38.066	0.013	9.1905	0.0067	1.7872	0.0011
716	CAB/DOP	37.979	0.013	9.1696	0.0067	1.7832	0.0011
717	CAB/DOP	38.049	0.013	9.1865	0.0067	1.7865	0.0011
718	CAB/DOP	38.036	0.013	9.1833	0.0067	1.7858	0.0011
719	CAB/DOP	38.018	0.013	9.1790	0.0067	1.7850	0.0011
720	CAB/DOP	38.006	0.013	9.1761	0.0067	1.7844	0.0011
721	CAB/DOP	38.000	0.013	9.1746	0.0067	1.7841	0.0011
722	CAB/DOP	38.042	0.013	9.1847	0.0067	1.7861	0.0011
723	CAB/DOP	38.000	0.013	9.1746	0.0067	1.7841	0.0011
724	CAB/DOP	37.971	0.013	9.1678	0.0067	1.7828	0.0011
725	CAB/DOP	38.037	0.013	9.1836	0.0067	1.7859	0.0011
726	CAB/DOP	38.001	0.013	9.1750	0.0067	1.7842	0.0011
727	CAB/DOP	38.058	0.013	9.1887	0.0067	1.7869	0.0011
728	CAB/DOP	37.966	0.013	9.1663	0.0067	1.7825	0.0011
729	CAB/DOP	38.028	0.013	9.1815	0.0067	1.7855	0.0011
730	CAB/DOP	38.006	0.013	9.1761	0.0067	1.7844	0.0011
731	CAB/DOP	38.031	0.013	9.1822	0.0067	1.7856	0.0011
732	CAB/DOP	37.997	0.013	9.1739	0.0067	1.7840	0.0011
733	CAB/DOP	38.040	0.013	9.1844	0.0067	1.7860	0.0011
734	CAB/DOP	38.013	0.013	9.1779	0.0067	1.7848	0.0011
735	CAB/DOP	37.945	0.013	9.1612	0.0067	1.7815	0.0011
736	CAB/DOP	38.072	0.013	9.1920	0.0067	1.7875	0.0011
737	CAB/DOP	38.019	0.013	9.1793	0.0067	1.7850	0.0011
738	CAB/DOP	37.961	0.013	9.1652	0.0067	1.7823	0.0011
739	CAB/DOP	38.057	0.013	9.1883	0.0067	1.7868	0.0011
740	CAB/DOP	38.025	0.013	9.1808	0.0067	1.7853	0.0011
741	CAB/DOP	37.943	0.013	9.1609	0.0067	1.7815	0.0011
742	CAB/DOP	38.076	0.013	9.1930	0.0067	1.7877	0.0011
743	CAB/DOP	38.028	0.013	9.1815	0.0067	1.7855	0.0011
744	CAB/DOP	38.027	0.013	9.1811	0.0067	1.7854	0.0011
745	CAB/DOP	37.927	0.013	9.1569	0.0067	1.7807	0.0011
746	CAB/DOP	38.034	0.013	9.1829	0.0067	1.7858	0.0011
747	CAB/DOP	38.031	0.013	9.1822	0.0067	1.7856	0.0011
748	CAB/DOP	37.991	0.013	9.1724	0.0067	1.7837	0.0011
749	CAB/DOP	37.974	0.013	9.1685	0.0067	1.7829	0.0011
750	CAB/DOP	38.027	0.013	9.1811	0.0067	1.7854	0.0011

Vial No.	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	38.001	0.013	9.1750	0.0067	1.7842	0.0011
752	CAB/DOP	38.030	0.013	9.1818	0.0067	1.7855	0.0011
753	CAB/DOP	37.985	0.013	9.1710	0.0067	1.7834	0.0011
754	CAB/DOP	38.006	0.013	9.1761	0.0067	1.7844	0.0011
755	CAB/DOP	37.986	0.013	9.1714	0.0067	1.7835	0.0011
756	CAB/DOP	38.040	0.013	9.1844	0.0067	1.7860	0.0011
757	CAB/DOP	38.006	0.013	9.1761	0.0067	1.7844	0.0011
758	CAB/DOP	37.976	0.013	9.1688	0.0067	1.7830	0.0011
759	CAB/DOP	38.036	0.013	9.1833	0.0067	1.7858	0.0011
760	CAB/DOP	38.022	0.013	9.1800	0.0067	1.7852	0.0011
761	CAB/DOP	38.021	0.013	9.1797	0.0067	1.7851	0.0011
762	CAB/DOP	37.971	0.013	9.1678	0.0067	1.7828	0.0011
763	CAB/DOP	38.028	0.013	9.1815	0.0067	1.7855	0.0011
764	CAB/DOP	38.037	0.013	9.1836	0.0067	1.7859	0.0011
765	CAB/DOP	37.961	0.013	9.1652	0.0067	1.7823	0.0011
766	CAB/DOP	38.040	0.013	9.1844	0.0067	1.7860	0.0011
767	CAB/DOP	37.991	0.013	9.1724	0.0067	1.7837	0.0011
768	CAB/DOP	38.034	0.013	9.1829	0.0067	1.7858	0.0011
769	CAB/DOP	38.000	0.013	9.1746	0.0067	1.7841	0.0011
770	CAB/DOP	38.013	0.013	9.1779	0.0067	1.7848	0.0011
771	CAB/DOP	38.030	0.013	9.1818	0.0067	1.7855	0.0011
772	CAB/DOP	37.988	0.013	9.1717	0.0067	1.7836	0.0011
773	CAB/DOP	37.991	0.013	9.1724	0.0067	1.7837	0.0011
774	CAB/DOP	38.025	0.013	9.1808	0.0067	1.7853	0.0011
775	CAB/DOP	37.973	0.013	9.1681	0.0067	1.7829	0.0011
776	CAB/DOP	38.049	0.013	9.1865	0.0067	1.7865	0.0011
777	CAB/DOP	38.027	0.013	9.1811	0.0067	1.7854	0.0011
778	CAB/DOP	38.012	0.013	9.1775	0.0067	1.7847	0.0011
779	CAB/DOP	37.976	0.013	9.1688	0.0067	1.7830	0.0011
780	CAB/DOP	38.031	0.013	9.1822	0.0067	1.7856	0.0011
781	CAB/DOP	38.003	0.013	9.1753	0.0067	1.7843	0.0011
782	CAB/DOP	38.000	0.013	9.1746	0.0067	1.7841	0.0011
783	CAB/DOP	38.021	0.013	9.1797	0.0067	1.7851	0.0011
784	CAB/DOP	38.028	0.013	9.1815	0.0067	1.7855	0.0011
785	CAB/DOP	37.955	0.013	9.1638	0.0067	1.7820	0.0011
786	CAB/DOP	38.057	0.013	9.1883	0.0067	1.7868	0.0011
787	CAB/DOP	38.021	0.013	9.1797	0.0067	1.7851	0.0011
788	CAB/DOP	37.964	0.013	9.1659	0.0067	1.7824	0.0011
789	CAB/DOP	38.024	0.013	9.1804	0.0067	1.7853	0.0011
790	CAB/DOP	38.042	0.013	9.1847	0.0067	1.7861	0.0011
791	CAB/DOP	38.030	0.013	9.1818	0.0067	1.7855	0.0011
792	CAB/DOP	37.997	0.013	9.1739	0.0067	1.7840	0.0011
793	CAB/DOP	37.965	0.013	9.1663	0.0067	1.7825	0.0011
794	CAB/DOP	38.042	0.013	9.1847	0.0067	1.7861	0.0011
795	CAB/DOP	37.985	0.013	9.1710	0.0067	1.7834	0.0011
796	CAB/DOP	38.037	0.013	9.1836	0.0067	1.7859	0.0011
797	CAB/DOP	38.027	0.013	9.1811	0.0067	1.7854	0.0011
798	CAB/DOP	38.016	0.013	9.1786	0.0067	1.7849	0.0011
799	CAB/DOP	38.000	0.013	9.1746	0.0067	1.7841	0.0011
800	CAB/DOP	37.988	0.013	9.1717	0.0067	1.7836	0.0011

Vial No.	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	CAB/DOP	37.986	0.013	9.1714	0.0067	1.7835	0.0011
802	CAB/DOP	38.022	0.013	9.1800	0.0067	1.7852	0.0011
803	CAB/DOP	38.030	0.013	9.1818	0.0067	1.7855	0.0011
804	CAB/DOP	37.965	0.013	9.1663	0.0067	1.7825	0.0011
805	CAB/DOP	37.951	0.013	9.1627	0.0067	1.7818	0.0011
806	CAB/DOP	38.060	0.013	9.1891	0.0067	1.7869	0.0011
807	CAB/DOP	38.021	0.013	9.1797	0.0067	1.7851	0.0011
808	CAB/DOP	37.971	0.013	9.1677	0.0067	1.7828	0.0011
809	CAB/DOP	38.042	0.013	9.1847	0.0067	1.7861	0.0011
810	CAB/DOP	38.001	0.013	9.1750	0.0067	1.7842	0.0011
811	CAB/DOP	37.954	0.013	9.1634	0.0067	1.7820	0.0011
812	CAB/DOP	38.054	0.013	9.1876	0.0067	1.7867	0.0011
813	CAB/DOP	37.974	0.013	9.1685	0.0067	1.7829	0.0011
814	CAB/DOP	38.036	0.013	9.1833	0.0067	1.7858	0.0011
815	CAB/DOP	38.031	0.013	9.1822	0.0067	1.7856	0.0011
816	CAB/DOP	38.021	0.013	9.1797	0.0067	1.7851	0.0011
817	CMC	37.951	0.013	9.1627	0.0067	1.7818	0.0011
818	CMC	38.042	0.013	9.1847	0.0067	1.7861	0.0011
819	CMC	38.015	0.013	9.1782	0.0067	1.7848	0.0011
820	CMC	38.007	0.013	9.1764	0.0067	1.7845	0.0011
821	CMC	38.007	0.013	9.1764	0.0067	1.7845	0.0011
822	CMC	38.012	0.013	9.1775	0.0067	1.7847	0.0011
823	CMC	37.970	0.013	9.1674	0.0067	1.7827	0.0011
824	CMC	38.022	0.013	9.1800	0.0067	1.7852	0.0011
825	CMC	38.039	0.013	9.1840	0.0067	1.7860	0.0011
826	CAB/DOP	37.983	0.013	9.1706	0.0067	1.7834	0.0011
827	CMC	37.995	0.013	9.1735	0.0067	1.7839	0.0011
828	CMC	38.019	0.013	9.1793	0.0067	1.7850	0.0011
829	CMC	37.957	0.013	9.1641	0.0067	1.7821	0.0011
830	CMC	38.022	0.013	9.1800	0.0067	1.7852	0.0011
831	CMC	38.040	0.013	9.1844	0.0067	1.7860	0.0011
832	CMC	37.952	0.013	9.1631	0.0067	1.7819	0.0011
833	CMC	38.019	0.013	9.1793	0.0067	1.7850	0.0011
834	CMC	37.979	0.013	9.1696	0.0067	1.7832	0.0011
835	CMC	37.982	0.013	9.1703	0.0067	1.7833	0.0011
836	CMC	38.048	0.013	9.1862	0.0067	1.7864	0.0011
837	CMC	38.025	0.013	9.1808	0.0067	1.7853	0.0011
838	CMC	37.967	0.013	9.1667	0.0067	1.7826	0.0011
839	CMC	38.034	0.013	9.1829	0.0067	1.7858	0.0011
840	CMC	38.025	0.013	9.1808	0.0067	1.7853	0.0011
841	CMC	37.967	0.013	9.1667	0.0067	1.7826	0.0011
842	CMC	38.039	0.013	9.1840	0.0067	1.7860	0.0011
843	CMC	38.034	0.013	9.1829	0.0067	1.7858	0.0011
844	CMC	38.010	0.013	9.1771	0.0067	1.7846	0.0011
845	CMC	37.991	0.013	9.1724	0.0067	1.7837	0.0011
846	CMC	38.034	0.013	9.1829	0.0067	1.7858	0.0011
847	CMC	37.970	0.013	9.1674	0.0067	1.7827	0.0011
848	CMC	38.043	0.013	9.1851	0.0067	1.7862	0.0011
849	CMC	38.027	0.013	9.1811	0.0067	1.7854	0.0011
850	CMC	38.022	0.013	9.1800	0.0067	1.7852	0.0011

Vial No.	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	38.006	0.013	9.1761	0.0067	1.7844	0.0011
852	CMC	37.977	0.013	9.1692	0.0067	1.7831	0.0011
853	CMC	38.037	0.013	9.1836	0.0067	1.7859	0.0011
854	CMC	38.024	0.013	9.1804	0.0067	1.7853	0.0011
855	CMC	37.985	0.013	9.1710	0.0067	1.7834	0.0011
856	CMC	38.037	0.013	9.1836	0.0067	1.7859	0.0011
857	CMC	38.016	0.013	9.1786	0.0067	1.7849	0.0011
858	CMC	37.979	0.013	9.1696	0.0067	1.7832	0.0011
859	CMC	38.019	0.013	9.1793	0.0067	1.7850	0.0011
860	CMC	38.036	0.013	9.1833	0.0067	1.7858	0.0011
861	CMC	38.019	0.013	9.1793	0.0067	1.7850	0.0011
862	CMC	37.986	0.013	9.1714	0.0067	1.7835	0.0011
863	CMC	38.055	0.013	9.1880	0.0067	1.7867	0.0011
864	CMC	37.946	0.013	9.1616	0.0067	1.7816	0.0011
865	CMC	38.054	0.013	9.1876	0.0067	1.7867	0.0011
866	CMC	38.019	0.013	9.1793	0.0067	1.7850	0.0011
867	CMC	38.001	0.013	9.1750	0.0067	1.7842	0.0011
868	CMC	38.019	0.013	9.1793	0.0067	1.7850	0.0011
869	CAB/DOP	37.986	0.013	9.1714	0.0067	1.7835	0.0011
870	CMC	37.964	0.013	9.1659	0.0067	1.7824	0.0011
871	CMC	38.034	0.013	9.1829	0.0067	1.7857	0.0011
872	CMC	38.033	0.013	9.1826	0.0067	1.7857	0.0011
873	CMC	38.022	0.013	9.1800	0.0067	1.7852	0.0011
874	CMC	37.967	0.013	9.1667	0.0067	1.7826	0.0011
875	CMC	38.039	0.013	9.1840	0.0067	1.7860	0.0011
876	CMC	38.015	0.013	9.1782	0.0067	1.7848	0.0011
877	CMC	38.012	0.013	9.1775	0.0067	1.7847	0.0011
878	CMC	38.025	0.013	9.1807	0.0067	1.7853	0.0011
879	CMC	37.958	0.013	9.1645	0.0067	1.7822	0.0011
880	CMC	38.018	0.013	9.1789	0.0067	1.7850	0.0011
881	CMC	38.009	0.013	9.1768	0.0067	1.7846	0.0011
882	CMC	38.027	0.013	9.1811	0.0067	1.7854	0.0011
883	CMC	37.982	0.013	9.1703	0.0067	1.7833	0.0011
884	CMC	38.034	0.013	9.1829	0.0067	1.7857	0.0011
885	CMC	38.030	0.013	9.1818	0.0067	1.7855	0.0011
886	CMC	37.940	0.013	9.1602	0.0067	1.7813	0.0011
887	CMC	38.073	0.013	9.1923	0.0067	1.7876	0.0011
888	CMC	37.988	0.013	9.1717	0.0067	1.7836	0.0011
889	CMC	38.001	0.013	9.1750	0.0067	1.7842	0.0011
890	CMC	38.025	0.013	9.1807	0.0067	1.7853	0.0011
891	CMC	38.013	0.013	9.1779	0.0067	1.7848	0.0011
892	CMC	38.025	0.013	9.1807	0.0067	1.7853	0.0011
893	CMC	38.028	0.013	9.1815	0.0067	1.7855	0.0011
894	CMC	37.991	0.013	9.1724	0.0067	1.7837	0.0011
895	CMC	38.019	0.013	9.1793	0.0067	1.7850	0.0011
896	CMC	38.039	0.013	9.1840	0.0067	1.7860	0.0011
897	CMC	37.942	0.013	9.1605	0.0067	1.7814	0.0011
898	CMC	38.043	0.013	9.1851	0.0067	1.7862	0.0011
899	CMC	38.025	0.013	9.1807	0.0067	1.7853	0.0011
900	CMC	38.024	0.013	9.1804	0.0067	1.7853	0.0011

Vial No.	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	37.959	0.013	9.1648	0.0067	1.7822	0.0011
902	CMC	38.034	0.013	9.1829	0.0067	1.7857	0.0011
903	CMC	38.033	0.013	9.1826	0.0067	1.7857	0.0011
904	CMC	38.027	0.013	9.1811	0.0067	1.7854	0.0011
905	CMC	37.937	0.013	9.1594	0.0067	1.7812	0.0011
906	CMC	38.057	0.013	9.1883	0.0067	1.7868	0.0011
907	CMC	38.024	0.013	9.1804	0.0067	1.7853	0.0011
908	CMC	38.025	0.013	9.1807	0.0067	1.7853	0.0011
909	CMC	37.970	0.013	9.1674	0.0067	1.7827	0.0011
910	CMC	38.018	0.013	9.1789	0.0067	1.7850	0.0011
911	CMC	38.034	0.013	9.1829	0.0067	1.7857	0.0011
912	CMC	38.012	0.013	9.1775	0.0067	1.7847	0.0011
913	CAB/DOP	37.973	0.013	9.1681	0.0067	1.7829	0.0011
914	CAB/DOP	38.034	0.013	9.1829	0.0067	1.7857	0.0011
915	CAB/DOP	38.031	0.013	9.1822	0.0067	1.7856	0.0011
916	CAB/DOP	38.027	0.013	9.1811	0.0067	1.7854	0.0011
917	CAB/DOP	37.971	0.013	9.1677	0.0067	1.7828	0.0011
918	CAB/DOP	38.039	0.013	9.1840	0.0067	1.7860	0.0011
919	CAB/DOP	38.001	0.013	9.1750	0.0067	1.7842	0.0011
920	CAB/DOP	38.027	0.013	9.1811	0.0067	1.7854	0.0011
921	CMC	38.036	0.013	9.1833	0.0067	1.7858	0.0011
922	CAB/DOP	37.998	0.013	9.1742	0.0067	1.7841	0.0011
923	CAB/DOP	37.944	0.013	9.1612	0.0067	1.7815	0.0011
924	CAB/DOP	38.061	0.013	9.1894	0.0067	1.7870	0.0011
925	CAB/DOP	38.031	0.013	9.1822	0.0067	1.7856	0.0011
926	CAB/DOP	37.970	0.013	9.1674	0.0067	1.7827	0.0011
927	CAB/DOP	38.028	0.013	9.1815	0.0067	1.7855	0.0011
928	CAB/DOP	38.019	0.013	9.1793	0.0067	1.7850	0.0011
929	CAB/DOP	38.034	0.013	9.1829	0.0067	1.7857	0.0011
930	CAB/DOP	38.022	0.013	9.1800	0.0067	1.7852	0.0011
931	CAB/DOP	37.952	0.013	9.1630	0.0067	1.7819	0.0011
932	CAB/DOP	38.007	0.013	9.1764	0.0067	1.7845	0.0011
933	CAB/DOP	38.033	0.013	9.1826	0.0067	1.7857	0.0011
934	CAB/DOP	38.001	0.013	9.1750	0.0067	1.7842	0.0011
935	CAB/DOP	37.961	0.013	9.1652	0.0067	1.7823	0.0011
936	CAB/DOP	38.030	0.013	9.1818	0.0067	1.7855	0.0011
937	CAB/DOP	38.016	0.013	9.1786	0.0067	1.7849	0.0011
938	CAB/DOP	38.028	0.013	9.1815	0.0067	1.7855	0.0011
939	CAB/DOP	38.022	0.013	9.1800	0.0067	1.7852	0.0011
940	CAB/DOP	38.012	0.013	9.1775	0.0067	1.7847	0.0011
941	CAB/DOP	37.971	0.013	9.1677	0.0067	1.7828	0.0011
942	CAB/DOP	38.030	0.013	9.1818	0.0067	1.7855	0.0011
943	CAB/DOP	38.016	0.013	9.1786	0.0067	1.7849	0.0011
944	CAB/DOP	38.016	0.013	9.1786	0.0067	1.7849	0.0011
945	CAB/DOP	38.019	0.013	9.1793	0.0067	1.7850	0.0011
946	CAB/DOP	38.012	0.013	9.1775	0.0067	1.7847	0.0011
947	CAB/DOP	38.021	0.013	9.1797	0.0067	1.7851	0.0011
948	CAB/DOP	38.033	0.013	9.1826	0.0067	1.7857	0.0011
949	CAB/DOP	37.949	0.013	9.1623	0.0067	1.7817	0.0011
950	CAB/DOP	38.043	0.013	9.1851	0.0067	1.7862	0.0011

Vial No.	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	CAB/DOP	38.039	0.013	9.1840	0.0067	1.7860	0.0011
952	CAB/DOP	37.931	0.013	9.1580	0.0067	1.7809	0.0011
953	CAB/DOP	38.021	0.013	9.1797	0.0067	1.7851	0.0011
954	CAB/DOP	38.070	0.013	9.1916	0.0067	1.7874	0.0011
955	CAB/DOP	37.970	0.013	9.1674	0.0067	1.7827	0.0011
956	CAB/DOP	38.039	0.013	9.1840	0.0067	1.7860	0.0011
957	CAB/DOP	38.033	0.013	9.1826	0.0067	1.7857	0.0011
958	CAB/DOP	38.028	0.013	9.1815	0.0067	1.7855	0.0011
959	CAB/DOP	38.001	0.013	9.1750	0.0067	1.7842	0.0011
960	CAB/DOP	38.010	0.013	9.1771	0.0067	1.7846	0.0011
961	CMC	38.012	0.013	9.1775	0.0067	1.7847	0.0011
962	CMC	37.993	0.013	9.1728	0.0067	1.7838	0.0011
963	CMC	38.039	0.013	9.1840	0.0067	1.7860	0.0011
964	CMC	37.930	0.013	9.1577	0.0067	1.7808	0.0011
965	CAB/DOP	38.066	0.013	9.1905	0.0067	1.7872	0.0011
966	CMC	37.982	0.013	9.1703	0.0067	1.7833	0.0011
967	CMC	38.014	0.013	9.1779	0.0067	1.7848	0.0011
968	CMC	37.979	0.013	9.1696	0.0067	1.7832	0.0011
969	CMC	38.021	0.013	9.1797	0.0067	1.7851	0.0011
970	CMC	37.999	0.013	9.1743	0.0067	1.7841	0.0011
971	CMC	38.012	0.013	9.1775	0.0067	1.7847	0.0011
972	CMC	38.021	0.013	9.1797	0.0067	1.7851	0.0011
973	CMC	37.990	0.013	9.1721	0.0067	1.7836	0.0011
974	CMC	37.999	0.013	9.1743	0.0067	1.7841	0.0011
975	CMC	38.025	0.013	9.1808	0.0067	1.7853	0.0011
976	CMC	37.993	0.013	9.1728	0.0067	1.7838	0.0011
977	CMC	38.043	0.013	9.1851	0.0067	1.7862	0.0011
978	CMC	37.937	0.013	9.1595	0.0067	1.7812	0.0011
979	CMC	38.040	0.013	9.1844	0.0067	1.7860	0.0011
980	CMC	38.027	0.013	9.1811	0.0067	1.7854	0.0011
981	CMC	37.957	0.013	9.1642	0.0067	1.7821	0.0011
982	CMC	38.003	0.013	9.1754	0.0067	1.7843	0.0011
983	CMC	38.028	0.013	9.1815	0.0067	1.7855	0.0011
984	CMC	37.964	0.013	9.1660	0.0067	1.7825	0.0011
985	CMC	38.031	0.013	9.1822	0.0067	1.7856	0.0011
986	CMC	37.996	0.013	9.1736	0.0067	1.7839	0.0011
987	CMC	38.043	0.013	9.1851	0.0067	1.7862	0.0011
988	CMC	37.970	0.013	9.1674	0.0067	1.7827	0.0011
989	CMC	38.054	0.013	9.1877	0.0067	1.7867	0.0011
990	CMC	37.943	0.013	9.1609	0.0067	1.7815	0.0011
991	CMC	38.033	0.013	9.1826	0.0067	1.7857	0.0011
992	CMC	38.031	0.013	9.1822	0.0067	1.7856	0.0011
993	CMC	38.016	0.013	9.1786	0.0067	1.7849	0.0011
994	CMC	37.996	0.013	9.1736	0.0067	1.7839	0.0011
995	CMC	37.922	0.013	9.1559	0.0067	1.7805	0.0011
996	CMC	38.005	0.013	9.1757	0.0067	1.7844	0.0011
997	CMC	38.034	0.013	9.1830	0.0067	1.7858	0.0011
998	CMC	38.000	0.013	9.1746	0.0067	1.7841	0.0011
999	CMC	38.058	0.013	9.1887	0.0067	1.7869	0.0011
1000	CMC	38.031	0.013	9.1822	0.0067	1.7856	0.0011

Vial No.	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	CMC	37.991	0.013	9.1725	0.0067	1.7837	0.0011
1002	CMC	37.984	0.013	9.1707	0.0067	1.7834	0.0011
1003	CMC	38.039	0.013	9.1840	0.0067	1.7860	0.0011
1004	CMC	38.009	0.013	9.1768	0.0067	1.7846	0.0011
1005	CMC	37.994	0.013	9.1732	0.0067	1.7839	0.0011
1006	CMC	37.949	0.013	9.1624	0.0067	1.7818	0.0011
1007	CMC	38.042	0.013	9.1848	0.0067	1.7861	0.0011
1008	CMC	38.036	0.013	9.1833	0.0067	1.7858	0.0011
1009	CAB/DOP	38.034	0.013	9.1830	0.0067	1.7858	0.0011
1010	CAB/DOP	38.015	0.013	9.1783	0.0067	1.7848	0.0011
1011	CAB/DOP	37.945	0.013	9.1613	0.0067	1.7815	0.0011
1012	CAB/DOP	38.049	0.013	9.1866	0.0067	1.7865	0.0011
1013	CAB/DOP	38.021	0.013	9.1797	0.0067	1.7851	0.0011
1014	CAB/DOP	38.006	0.013	9.1761	0.0067	1.7844	0.0011
1015	CAB/DOP	38.011	0.013	9.1772	0.0067	1.7846	0.0011
1016	CAB/DOP	38.034	0.013	9.1830	0.0067	1.7858	0.0011
1017	CAB/DOP	37.991	0.013	9.1725	0.0067	1.7837	0.0011
1018	CAB/DOP	37.975	0.013	9.1685	0.0067	1.7829	0.0011
1019	CAB/DOP	38.040	0.013	9.1844	0.0067	1.7860	0.0011
1020	CAB/DOP	38.024	0.013	9.1804	0.0067	1.7853	0.0011
1021	CAB/DOP	37.978	0.013	9.1692	0.0067	1.7831	0.0011
1022	CAB/DOP	38.033	0.013	9.1826	0.0067	1.7857	0.0011
1023	CAB/DOP	38.018	0.013	9.1790	0.0067	1.7850	0.0011
1024	CAB/DOP	38.009	0.013	9.1768	0.0067	1.7846	0.0011
1025	CMC	37.990	0.013	9.1721	0.0067	1.7836	0.0011
1026	CAB/DOP	37.978	0.013	9.1692	0.0067	1.7831	0.0011
1027	CAB/DOP	38.058	0.013	9.1887	0.0067	1.7869	0.0011
1028	CAB/DOP	38.002	0.013	9.1750	0.0067	1.7842	0.0011
1029	CAB/DOP	38.016	0.013	9.1786	0.0067	1.7849	0.0011
1030	CAB/DOP	38.027	0.013	9.1811	0.0067	1.7854	0.0011
1031	CAB/DOP	38.011	0.013	9.1772	0.0067	1.7846	0.0011
1032	CAB/DOP	37.955	0.013	9.1638	0.0067	1.7820	0.0011
1033	CAB/DOP	38.034	0.013	9.1830	0.0067	1.7858	0.0011
1034	CAB/DOP	37.952	0.013	9.1631	0.0067	1.7819	0.0011
1035	CAB/DOP	38.040	0.013	9.1844	0.0067	1.7860	0.0011
1036	CAB/DOP	38.019	0.013	9.1793	0.0067	1.7851	0.0011
1037	CAB/DOP	38.025	0.013	9.1808	0.0067	1.7853	0.0011
1038	CAB/DOP	37.997	0.013	9.1739	0.0067	1.7840	0.0011
1039	CAB/DOP	37.949	0.013	9.1624	0.0067	1.7818	0.0011
1040	CAB/DOP	38.049	0.013	9.1866	0.0067	1.7865	0.0011
1041	CAB/DOP	38.037	0.013	9.1837	0.0067	1.7859	0.0011
1042	CAB/DOP	37.955	0.013	9.1638	0.0067	1.7820	0.0011
1043	CAB/DOP	38.052	0.013	9.1873	0.0067	1.7866	0.0011
1044	CAB/DOP	38.015	0.013	9.1783	0.0067	1.7848	0.0011
1045	CAB/DOP	37.973	0.013	9.1681	0.0067	1.7829	0.0011
1046	CAB/DOP	37.976	0.013	9.1689	0.0067	1.7830	0.0011
1047	CAB/DOP	38.028	0.013	9.1815	0.0067	1.7855	0.0011
1048	CAB/DOP	38.033	0.013	9.1826	0.0067	1.7857	0.0011
1049	CAB/DOP	37.975	0.013	9.1685	0.0067	1.7829	0.0011
1050	CMC	38.018	0.013	9.1790	0.0067	1.7850	0.0011

Vial No.	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]
1051	CAB/DOP	38.028	0.013	9.1815	0.0067	1.7855	0.0011
1052	CAB/DOP	37.993	0.013	9.1728	0.0067	1.7838	0.0011
1053	CAB/DOP	38.037	0.013	9.1837	0.0067	1.7859	0.0011
1054	CAB/DOP	37.987	0.013	9.1714	0.0067	1.7835	0.0011
1055	CAB/DOP	38.016	0.013	9.1786	0.0067	1.7849	0.0011
1056	CAB/DOP	38.016	0.013	9.1786	0.0067	1.7849	0.0011
1057	CMC	38.033	0.013	9.1826	0.0067	1.7857	0.0011
1058	CMC	37.994	0.013	9.1732	0.0067	1.7839	0.0011
1059	CMC	37.990	0.013	9.1721	0.0067	1.7837	0.0011
1060	CMC	38.021	0.013	9.1797	0.0067	1.7851	0.0011
1061	CMC	37.954	0.013	9.1635	0.0067	1.7820	0.0011
1062	CMC	38.049	0.013	9.1866	0.0067	1.7865	0.0011
1063	CMC	37.979	0.013	9.1696	0.0067	1.7832	0.0011
1064	CMC	38.032	0.013	9.1822	0.0067	1.7856	0.0011
1065	CMC	37.994	0.013	9.1732	0.0067	1.7839	0.0011
1066	CMC	38.011	0.013	9.1772	0.0067	1.7846	0.0011
1067	CMC	37.978	0.013	9.1692	0.0067	1.7831	0.0011
1068	CMC	38.023	0.013	9.1801	0.0067	1.7852	0.0011
1069	CMC	37.978	0.013	9.1692	0.0067	1.7831	0.0011
1070	CMC	38.006	0.013	9.1761	0.0067	1.7844	0.0011
1071	CMC	37.943	0.013	9.1609	0.0067	1.7815	0.0011
1072	CMC	38.048	0.013	9.1862	0.0067	1.7864	0.0011
1073	CMC	37.988	0.013	9.1718	0.0067	1.7836	0.0011
1074	CMC	38.041	0.013	9.1844	0.0067	1.7860	0.0011

[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, 2017.

[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 Wang et al. (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).

Annex 2 The certificate of EC NRM 101 uranium metal

Certified Nuclear Reference Material

Certificate of Analysis

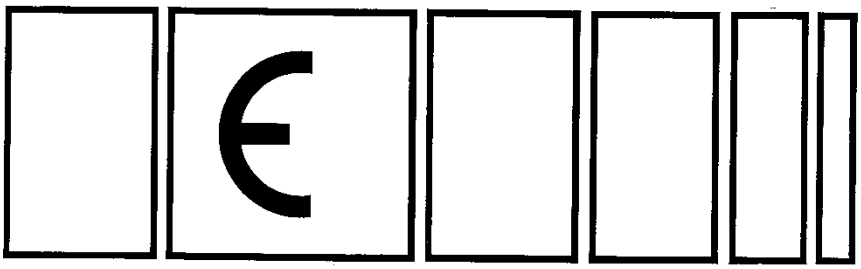
EC NUCLEAR REFERENCE MATERIAL NO. 101

MATERIAL : URANIUM METAL

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

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

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



Annex 3 The certificate of NBL CRM 116-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

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 4 The certificate of CETAMA MP2 plutonium metal

CETAMA

COMMISSARIAT A L'ENERGIE ATOMIQUE

COMMISSION D'ETABLISSEMENT DES METHODES D'ANALYSE

cea

REFERENCE MATERIAL CERTIFICATE

PLUTONIUM METAL
"MP2"

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

(For X and x values see list page 4)

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

99.90 ± 0.04 %

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

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

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

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

CETAMA CRM manager

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

ISO 9001 BUREAU VERITAS Certification

Version : 10.2007

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

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

UTILISATION

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

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

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

ADDITIONAL INFORMATION

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

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

IRMM

Institute for Reference Materials and Measurements

CERTIFICATE OF ISOTOPIC COMPOSITION

Geel, 30 May 2001

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

2. Sample Identification: MP2 (Pu metal)

3. Isotopic composition:

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

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

molar mass: 239.074 888(11) g·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 5 The certificate of isotopic 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)
$n(^{242}Pu)/\ n(^{238}Pu)$	0.000 075 70(78)

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

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

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

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

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

Uncertainty budget :

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

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

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

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

André Verbruggen
Group leader Nuclear Chemistry

Stephan Richter
Group leader Nuclear Mass Spectrometry

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

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

Annex 6 The certificate of isotopic composition of EC NRM 101

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 7 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

Neither JRC, its subsidiaries, its contractors nor any person acting on their behalf,
(a) make any warranty or representation, express or implied that the use of any information, material, pparatus, method or process disclosed in this document does not infringe any privately owned intellectual property rights; or
(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 8 Results of the process control measurements (6 blends, 2-3 replicates) for ^{235}U, ^{238}U and ^{239}Pu amount content in the mother solution of IRMM-1027t

Figure 11 The amount content of ^{235}U in the mother solution of IRMM-1027t measured by ID-TIMS using IRMM-046c (blue diamonds) spike CRM expressed as the relative difference from the gravimetric value. 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

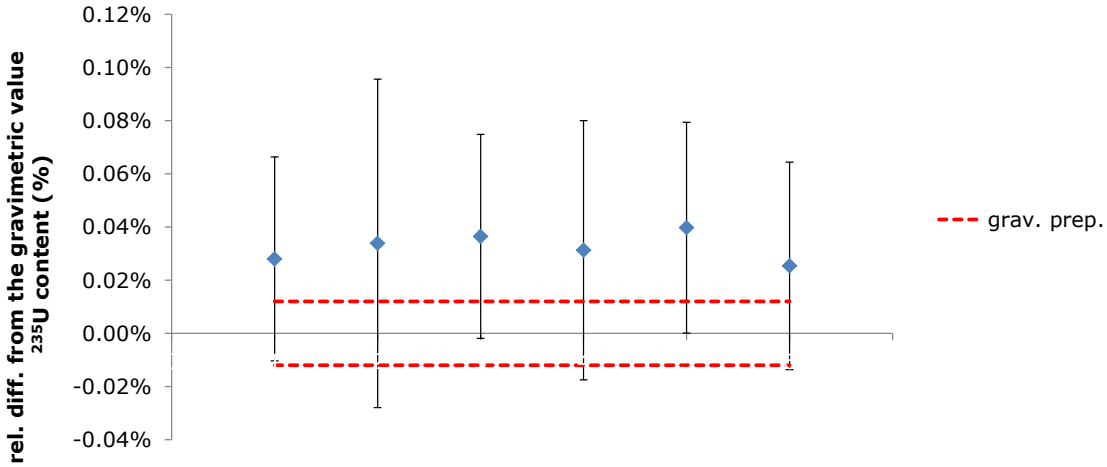


Figure 12 The amount content of ^{238}U in the mother solution of IRMM-1027t measured by ID-TIMS using IRMM-046c (blue diamonds) spike CRM expressed as the relative difference from the gravimetric value. Error bars show the relative expanded uncertainties (coverage factor k = 2). Red dotted lines show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

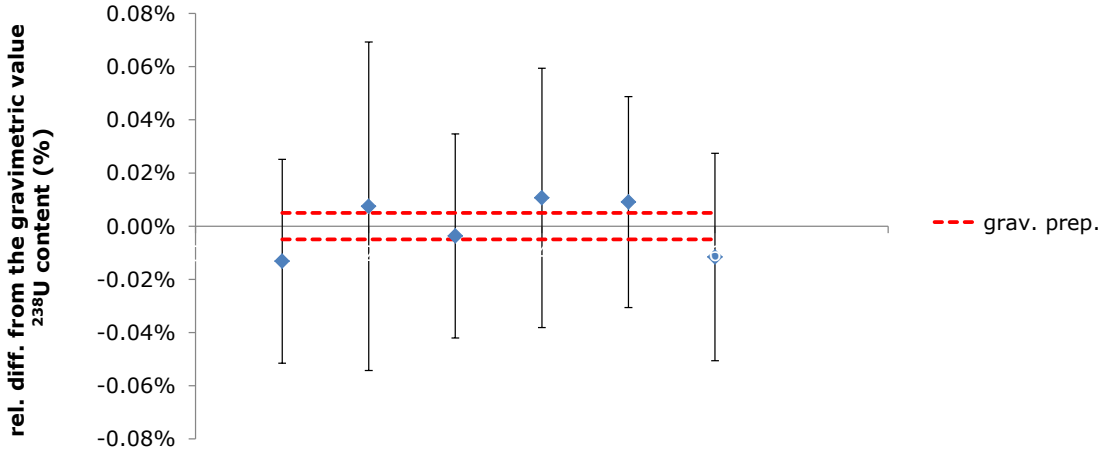
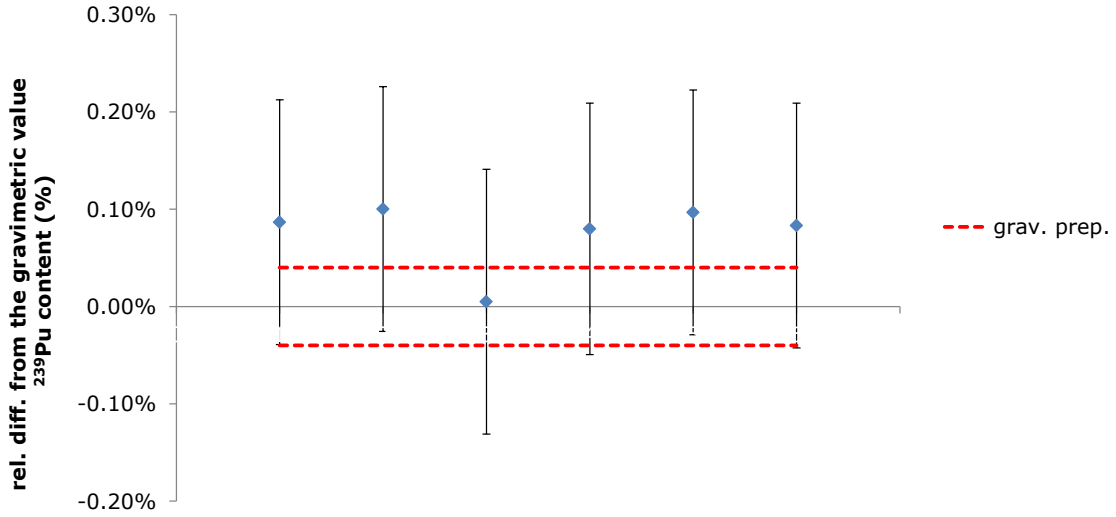


Figure 13 The amount content of ^{239}Pu in the mother solution of IRMM-1027t measured by ID-TIMS using IRMM-046c (blue diamonds) spike CRM expressed as the relative difference from the gravimetric value. Error bars show the relative expanded uncertainties (coverage factor k = 2). Red dotted lines show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



Annex 9 Results of the process control measurements (4 aliquots, 3 replicates) for the uranium and plutonium isotope amount ratios in the mother solution of IRMM-1027t

Figure 14 The $n(^{234}U)/n(^{238}U)$ amount ratio in the solution of IRMM-1027t 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)

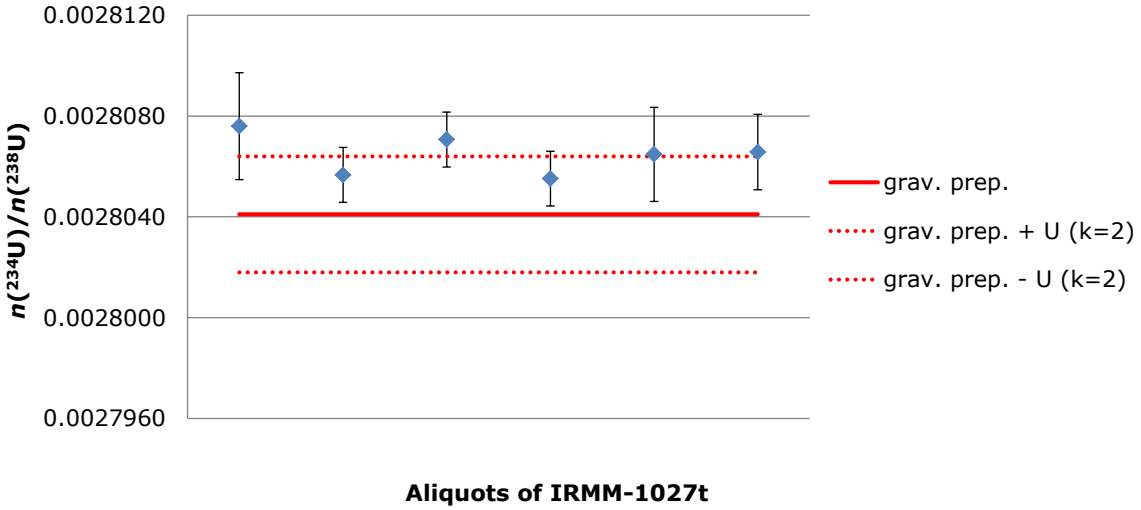


Figure 15 The $n(^{235}U)/n(^{238}U)$ amount ratio in the solution of IRMM-1027t prepared by gravimetric mixing compared with the measured values by TIMS (individual aliquots with blue diamonds and the average value with a green diamond). Error bars show the expanded uncertainties (coverage factor k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

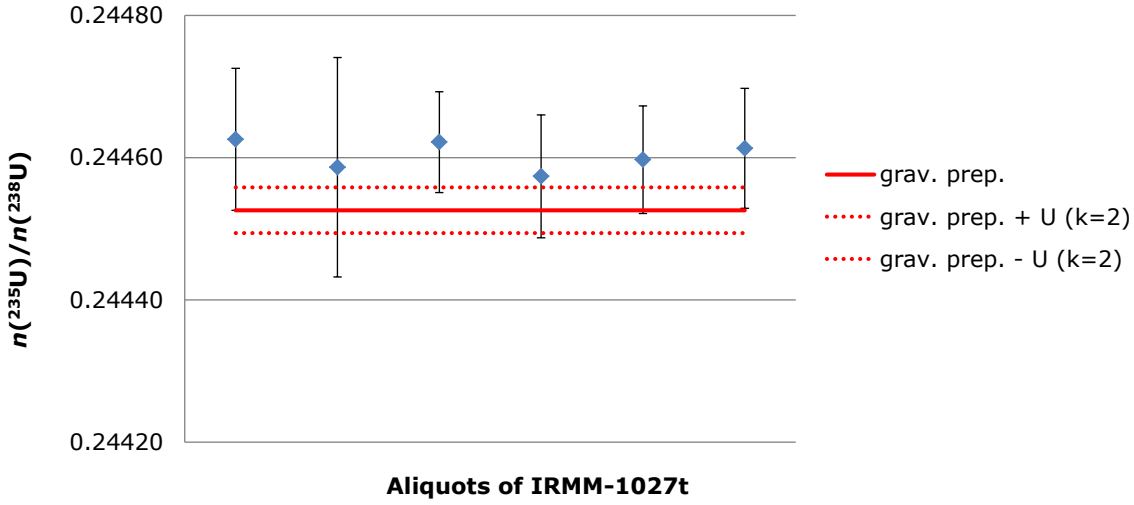


Figure 16 The $n(^{236}U)/n(^{238}U)$ amount ratio in the solution of IRMM-1027t prepared by gravimetric mixing compared with the measured values by TIMS (individual aliquots with blue diamonds and the average value with a green diamond). Error bars show the expanded uncertainties (coverage factor k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

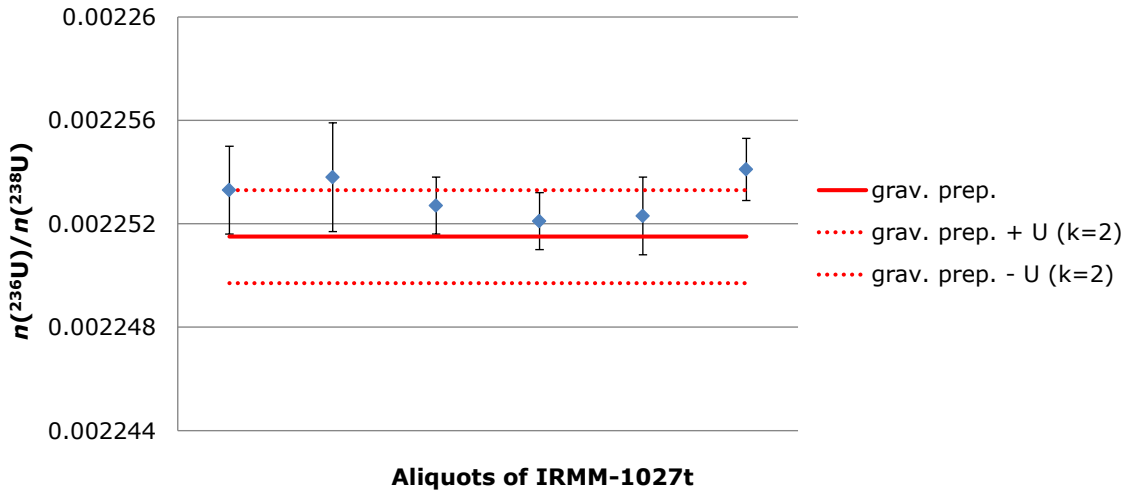


Figure 17 The $n(^{238}Pu)/n(^{239}Pu)$ amount ratio in the solution of IRMM-1027t prepared by gravimetric mixing compared with the measured values by TIMS (blue diamonds). Error bars show the expanded uncertainties (coverage factor k = 2)

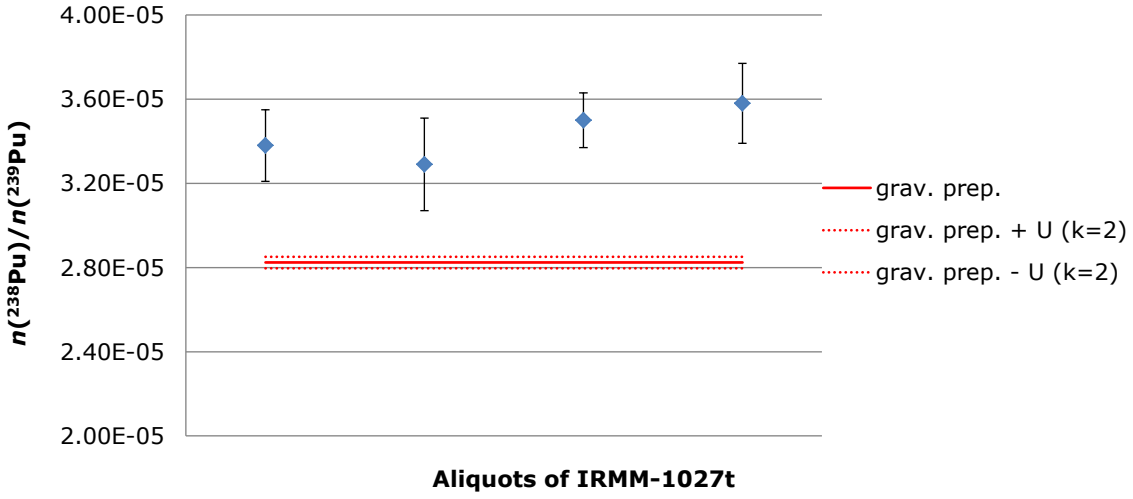


Figure 18 The $n(^{240}Pu)/n(^{239}Pu)$ amount ratio in the solution of IRMM-1027t prepared by gravimetric mixing compared with the measured values by TIMS (blue diamonds). Error bars show the expanded uncertainties (coverage factor k = 2)

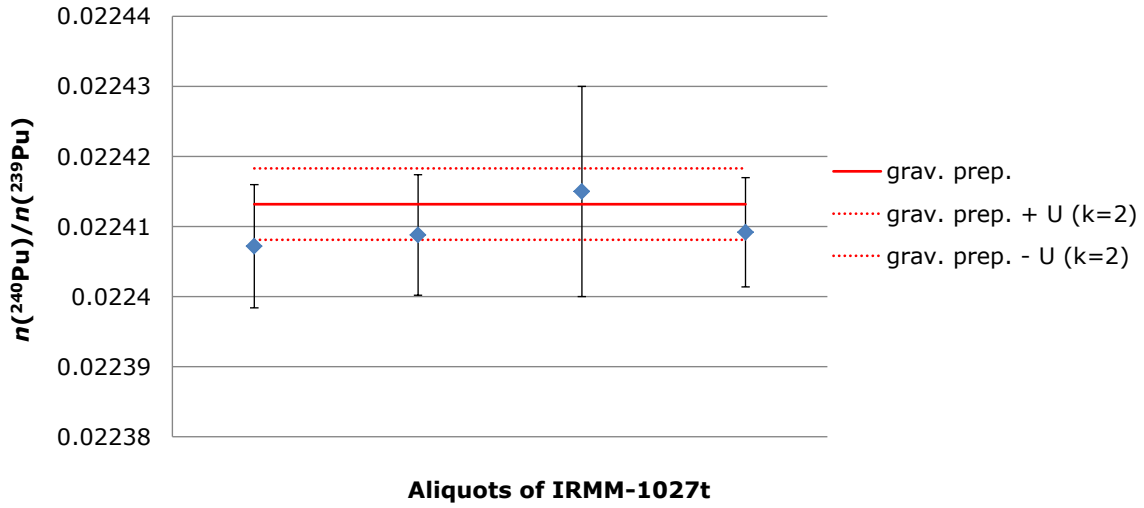


Figure 19 The $n(^{241}Pu)/n(^{239}Pu)$ amount ratio in the solution of IRMM-1027t prepared by gravimetric mixing compared with the measured values by TIMS (blue diamonds). Error bars show the expanded uncertainties (coverage factor k = 2)

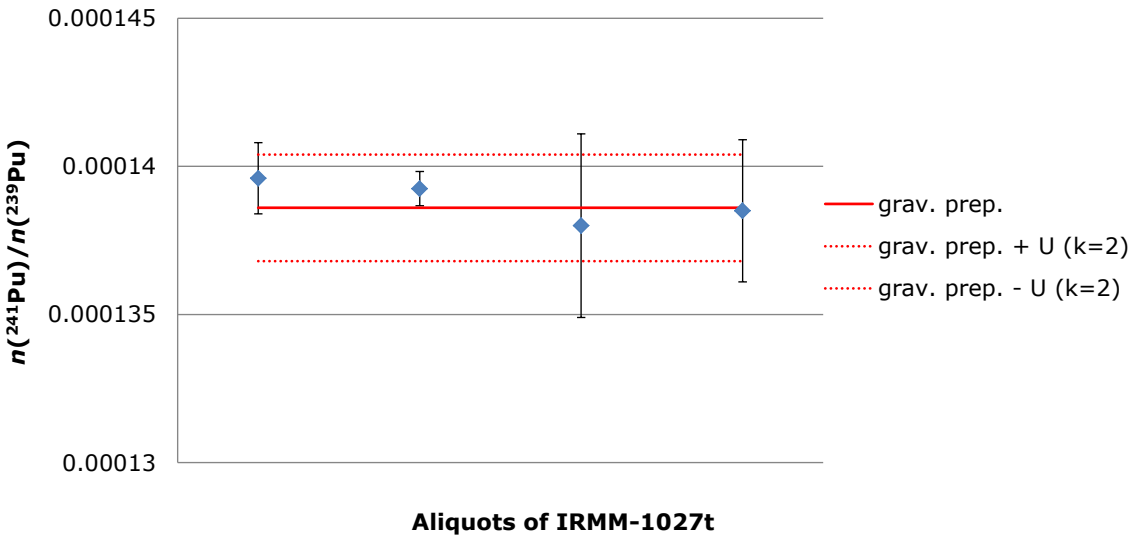
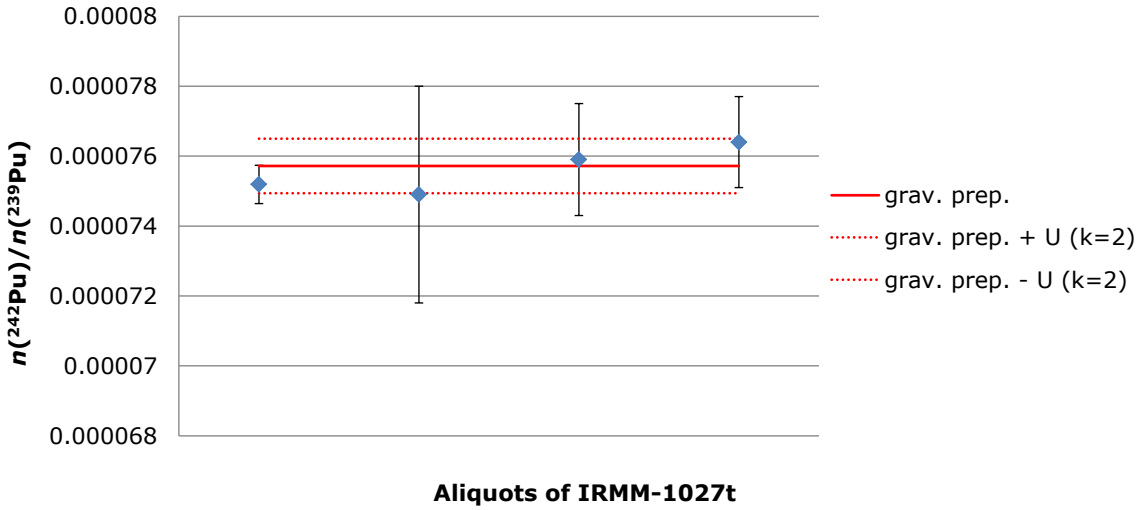


Figure 20 The $n(^{242}Pu)/n(^{239}Pu)$ amount ratio in the solution of IRMM-1027t prepared by gravimetric mixing compared with the measured values by TIMS (blue diamonds). Error bars show the expanded uncertainties (coverage factor k = 2)



Annex 10 Results of the homogeneity assessment for IRMM-1027t

Figure 21 The amount content of ^{235}U from homogeneity study for the 42 replicate measurements (15 selected units, 2-3 replicates each) are shown as a function of the analytical sequence

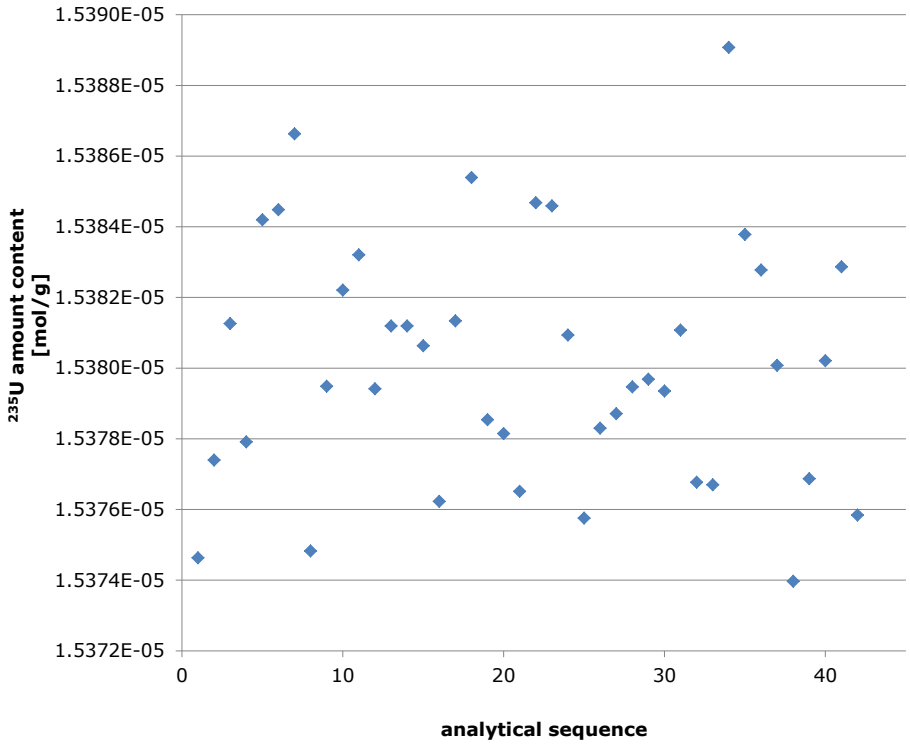


Figure 22 Mean amount contents of ^{235}U from homogeneity study as a function of the units (filling sequence). The unit means are plotted with 95 % CI of the means

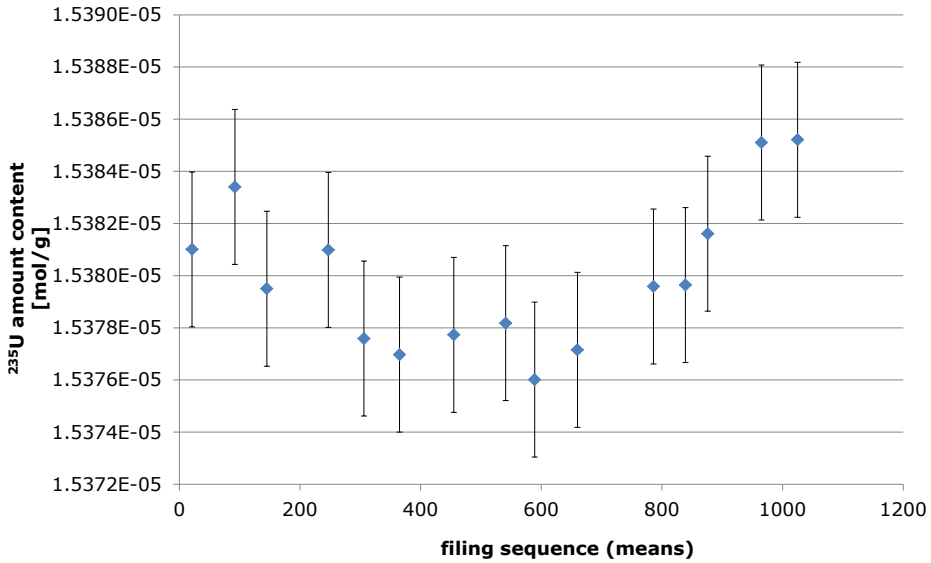


Figure 23 The amount content of ^{238}U from homogeneity study for the 42 replicate measurements (15 selected units, 2-3 replicates each) are shown as a function of the analytical sequence

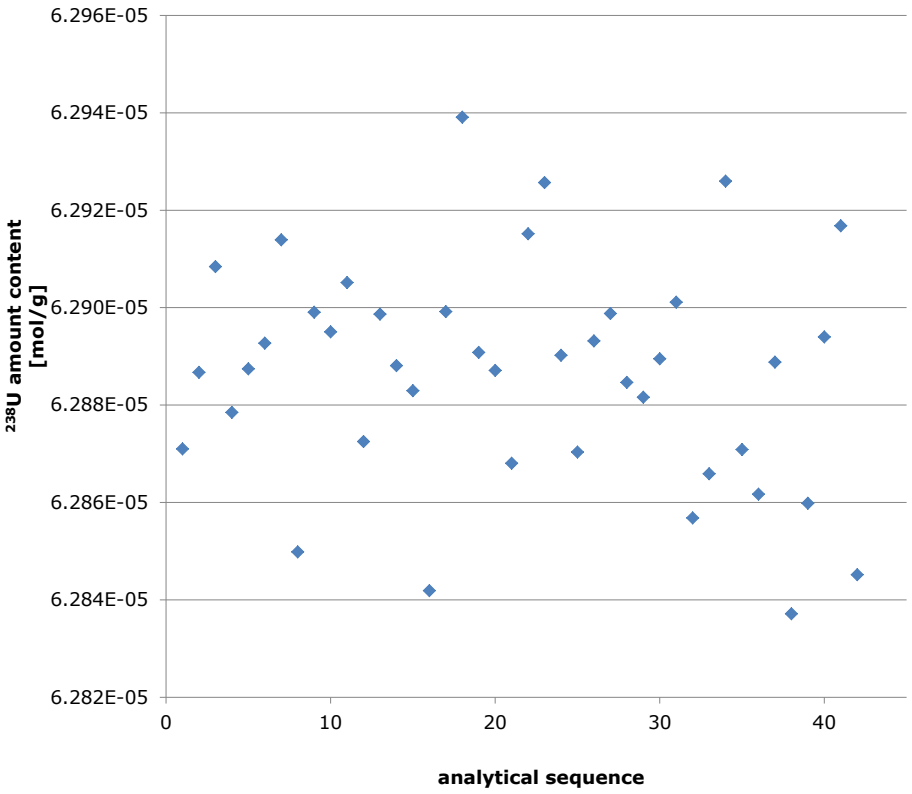


Figure 24 Mean amount contents of ^{238}U from homogeneity study as a function of the units (filling sequence). The unit means are plotted with 95 % CI of the means.

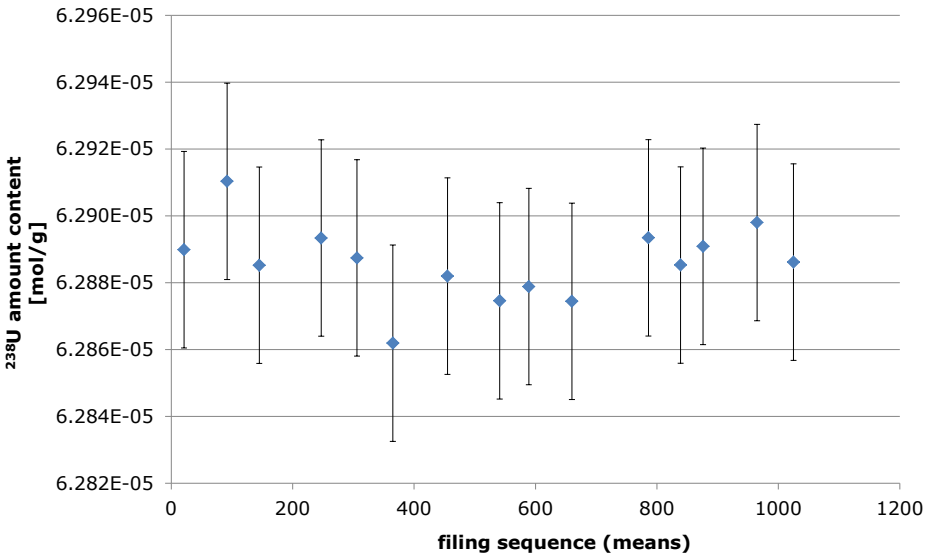


Figure 25 The amount content (normalised) of ^{239}Pu from homogeneity study for the 41 replicate measurements (15 selected units, 2-3 replicates each) are shown as a function of the analytical sequence

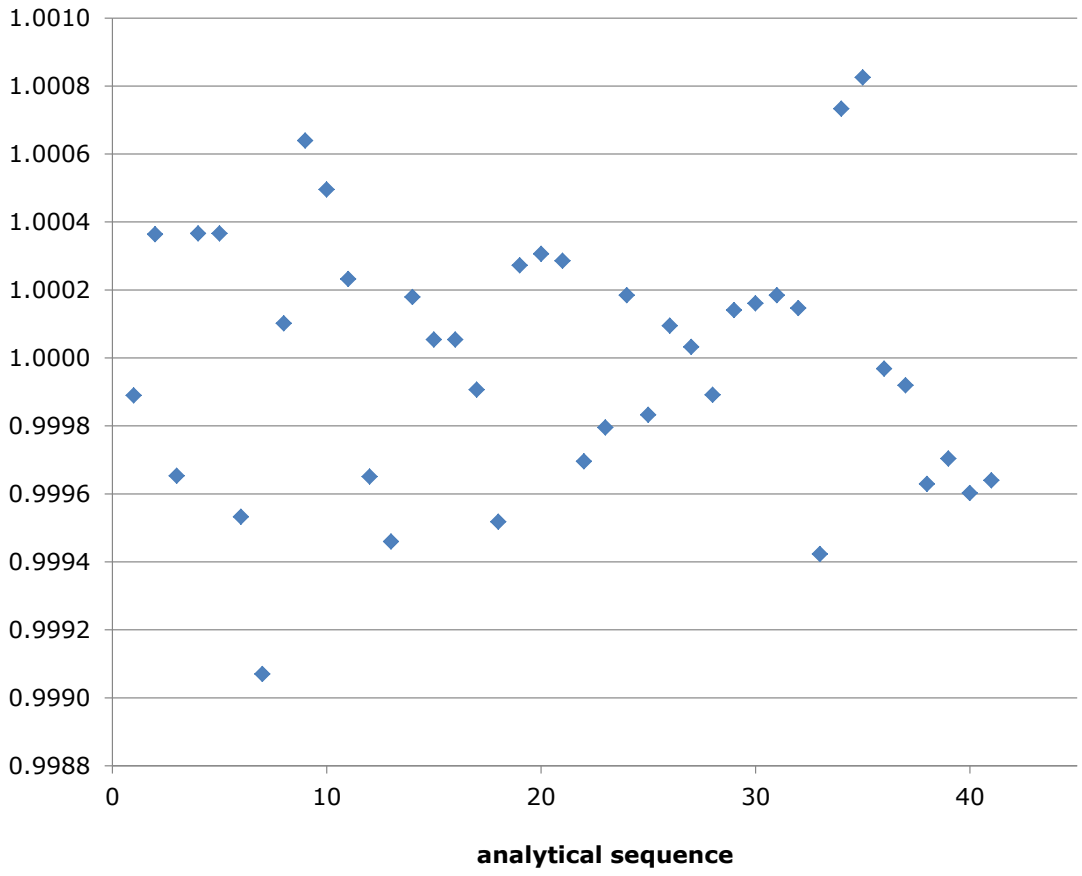
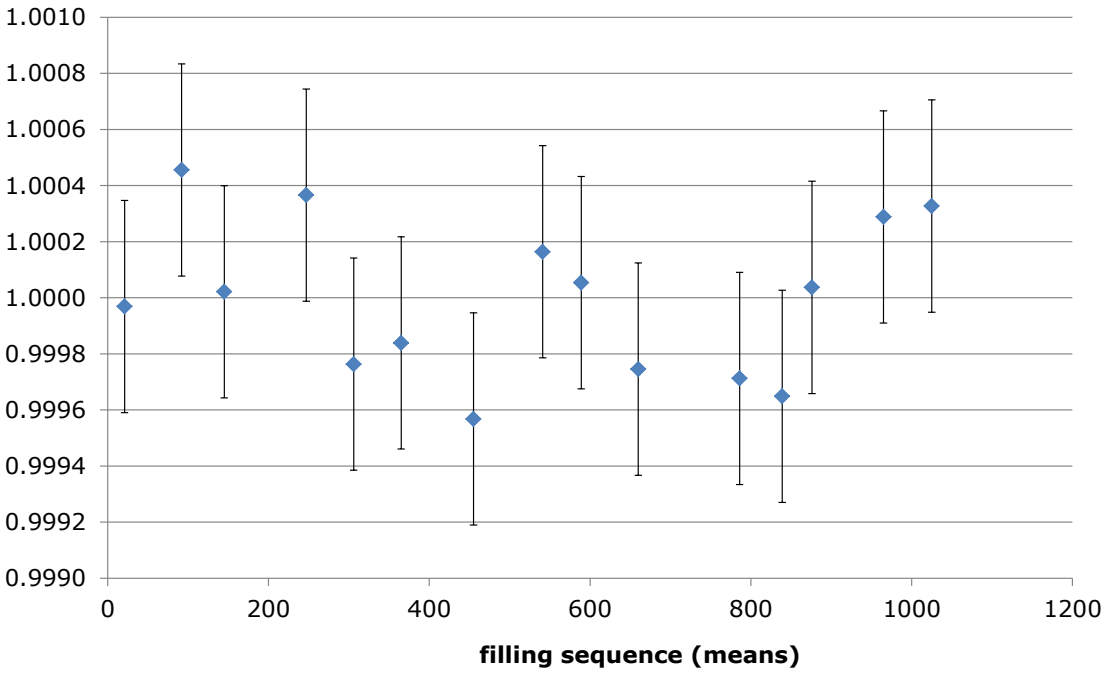


Figure 26 Mean amount contents (normalised) of ^{239}Pu from homogeneity study as a function of the units (filling sequence). The unit means are plotted with 95 % CI of the means



Annex 11 The weighing certificate of the aliquots of dispensed solution of IRMM-1027t per unit before drying

Joint Research Centre

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

Certificate of weighing

E.3908 **Issued date**: 26/09/2018 **Page** 1 **of** 7

Applicant:	R. Jakopič	**Unit**: SN3S
Project:	Preparation and certification of IRMM-1027t LSD spikes	
Description:	Dispensing of IRMM-1027t U/Pu nitrate solution into individual vials	
Weighing date:	9-13 April 2018	

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 installed in the dispensing robot box with inventory No. 2006 00290 17.

Traceability:
The certified masses are traceable to the International Kilogram Prototype via regular calibrations of the principal kilogram at JRC Geel. 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 is expanded uncertainties $U = k \cdot u_c$ where u_c is the combined standard uncertainty calculated according to the ISO/IEC Guide to the Expression of Uncertainty in Measurement. The coverage factor $k = 2$ corresponds to a coverage probability of about 95%.

Nuclear Chemistry Laboratory Responsible — R. Jakopič

Analyst — J. Bauwens

Retieseweg, B-2440 Geel, Belgium; Tel.: +32-(0)14-571 617

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

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
001	2.5490	051	2.5449	101	2.5462	151	2.5373
002	2.5465	052	2.5453	102	2.5402	152	2.5368
003	2.5479	053	2.5461	103	2.5458	153	2.5364
004	2.5423	054	2.5430	104	2.5443	154	2.5473
005	2.5500	055	2.5449	105	2.5460	155	2.5437
006	2.5412	056	2.5471	106	2.5418	156	2.5380
007	2.5479	057	2.5478	107	2.5424	157	2.5372
008	2.5443	058	2.5421	108	2.5442	158	2.5380
009	2.5420	059	2.5481	109	2.5383	159	2.5472
010	2.5494	060	2.5437	110	2.5462	160	2.5399
011	2.5456	061	2.5472	111	2.5440	161	2.5343
012	2.5446	062	2.5467	112	2.5410	162	2.5472
013	2.5433	063	2.5439	113	2.5453	163	2.5431
014	2.5450	064	2.5405	114	2.5417	164	2.5411
015	2.5489	065	2.5510	115	2.5404	165	2.5400
016	2.5446	066	2.5483	116	2.5474	166	2.5324
017	2.5456	067	2.5460	117	2.5396	167	2.5504
018	2.5452	068	2.5412	118	2.5424	168	2.5362
019	2.5448	069	2.5496	119	2.5448	169	2.5454
020	2.5463	070	2.5396	120	2.5434	170	2.5337
021	2.5423	071	2.5544	121	2.5412	171	2.5417
022	2.5486	072	2.5432	122	2.5443	172	2.5393
023	2.5433	073	2.5448	123	2.5384	173	2.5461
024	2.5478	074	2.5432	124	2.5437	174	2.5411
025	2.5420	075	2.5467	125	2.5427	175	2.5396
026	2.5463	076	2.5457	126	2.5421	176	2.5422
027	2.5481	077	2.5460	127	2.5415	177	2.5414
028	2.5438	078	2.5478	128	2.5397	178	2.5422
029	2.5449	079	2.5424	129	2.5424	179	2.5400
030	2.5436	080	2.5478	130	2.5424	180	2.5427
031	2.5477	081	2.5445	131	2.5401	181	2.5396
032	2.5439	082	2.5433	132	2.5396	182	2.5379
033	2.5479	083	2.5475	133	2.5419	183	2.5452
034	2.5412	084	2.5447	134	2.5429	184	2.5401
035	2.5494	085	2.5473	135	2.5425	185	2.5417
036	2.5436	086	2.5451	136	2.5446	186	2.5400
037	2.5471	087	2.5416	137	2.5347	187	2.5415
038	2.5439	088	2.5432	138	2.5431	188	2.5408
039	2.5462	089	2.5466	139	2.5340	189	2.5395
040	2.5459	090	2.5470	140	2.5385	190	2.5398
041	2.5434	091	2.5426	141	2.5385	191	2.5362
042	2.5461	092	2.5419	142	2.5400	192	2.5471
043	2.5445	093	2.5448	143	2.5332	193	2.5430
044	2.5430	094	2.5468	144	2.5485	194	2.5414
045	2.5484	095	2.5411	145	2.5435	195	2.5395
046	2.5435	096	2.5480	146	2.5387	196	2.5374
047	2.5473	097	2.5394	147	2.5364	197	2.5430
048	2.5436	098	2.5468	148	2.5422	198	2.5413
049	2.5434	099	2.5421	149	2.5446	199	2.5400
050	2.5486	100	2.5419	150	2.5406	200	2.5400

Retieseweg, B-2440 Geel, Belgium; Tel.: +32-(0)14-571 617

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

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
201	2.5428	251	2.5411	301	2.5426	351	2.5414
202	2.5409	252	2.5432	302	2.5435	352	2.5435
203	2.5408	253	2.5408	303	2.5424	353	2.5380
204	2.5411	254	2.5439	304	2.5436	354	2.5417
205	2.5413	255	2.5409	305	2.5430	355	2.5401
206	2.5415	256	2.5434	306	2.5411	356	2.5412
207	2.5409	257	2.5421	307	2.5440	357	2.5421
208	2.5425	258	2.5412	308	2.5440	358	2.5404
209	2.5414	259	2.5417	309	2.5428	359	2.5418
210	2.5400	260	2.5390	310	2.5420	360	2.5390
211	2.5412	261	2.5414	311	2.5423	361	2.5428
212	2.5427	262	2.5437	312	2.5420	362	2.5422
213	2.5400	263	2.5425	313	2.5427	363	2.5418
214	2.5433	264	2.5414	314	2.5433	364	2.5416
215	2.5408	265	2.5426	315	2.5436	365	2.5426
216	2.5427	266	2.5421	316	2.5421	366	2.5406
217	2.5408	267	2.5418	317	2.5434	367	2.5421
218	2.5427	268	2.5437	318	2.5428	368	2.5420
219	2.5413	269	2.5423	319	2.5438	369	2.5415
220	2.5417	270	2.5421	320	2.5412	370	2.5420
221	2.5405	271	2.5424	321	2.5424	371	2.5425
222	2.5403	272	2.5420	322	2.5418	372	2.5418
223	2.5435	273	2.5431	323	2.5419	373	2.5421
224	2.5404	274	2.5421	324	2.5424	374	2.5413
225	2.5416	275	2.5427	325	2.5444	375	2.5426
226	2.5406	276	2.5424	326	2.5416	376	2.5418
227	2.5437	277	2.5418	327	2.5417	377	2.5419
228	2.5402	278	2.5424	328	2.5425	378	2.5426
229	2.5385	279	2.5425	329	2.5422	379	2.5421
230	2.5416	280	2.5419	330	2.5429	380	2.5424
231	2.5427	281	2.5438	331	2.5413	381	2.5412
232	2.5405	282	2.5434	332	2.5428	382	2.5422
233	2.5435	283	2.5414	333	2.5408	383	2.5404
234	2.5425	284	2.5426	334	2.5431	384	2.5419
235	2.5421	285	2.5426	335	2.5405	385	2.5408
236	2.5399	286	2.5419	336	2.5412	386	2.5405
237	2.5419	287	2.5430	337	2.5395	387	2.5403
238	2.5405	288	2.5434	338	2.5421	388	2.5413
239	2.5415	289	2.5404	339	2.5418	389	2.5407
240	2.5419	290	2.5437	340	2.5391	390	2.5386
241	2.5419	291	2.5430	341	2.5425	391	2.5402
242	2.5426	292	2.5425	342	2.5402	392	2.5410
243	2.5422	293	2.5407	343	2.5417	393	2.5412
244	2.5397	294	2.5415	344	2.5406	394	2.5412
245	2.5434	295	2.5424	345	2.5418	395	2.5399
246	2.5408	296	2.5440	346	2.5410	396	2.5404
247	2.5420	297	2.5380	347	2.5402	397	2.5411
248	2.5430	298	2.5439	348	2.5409	398	2.5396
249	2.5413	299	2.5396	349	2.5399	399	2.5396
250	2.5430	300	2.5450	350	2.5417	400	2.5413

Retieseweg, B-2440 Geel, Belgium; Tel.: +32-(0)14-571 617

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

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
401	2.5395	451	2.5435	501	2.5414	551	2.5428
402	2.5397	452	2.5428	502	2.5415	552	2.5400
403	2.5402	453	2.5426	503	2.5452	553	2.5428
404	2.5407	454	2.5415	504	2.5429	554	2.5433
405	2.5392	455	2.5427	505	2.5443	555	2.5427
406	2.5419	456	2.5418	506	2.5401	556	2.5436
407	2.5394	457	2.5442	507	2.5445	557	2.5409
408	2.5410	458	2.5419	508	2.5426	558	2.5416
409	2.5397	459	2.5423	509	2.5438	559	2.5416
410	2.5407	460	2.5428	510	2.5414	560	2.5428
411	2.5405	461	2.5427	511	2.5432	561	2.5448
412	2.5392	462	2.5414	512	2.5434	562	2.5405
413	2.5400	463	2.5442	513	2.5436	563	2.5408
414	2.5385	464	2.5418	514	2.5409	564	2.5413
415	2.5410	465	2.5443	515	2.5443	565	2.5429
416	2.5410	466	2.5421	516	2.5416	566	2.5442
417	2.5378	467	2.5410	517	2.5468	567	2.5399
418	2.5419	468	2.5432	518	2.5405	568	2.5427
419	2.5416	469	2.5432	519	2.5432	569	2.5419
420	2.5413	470	2.5419	520	2.5418	570	2.5436
421	2.5404	471	2.5422	521	2.5442	571	2.5416
422	2.5428	472	2.5441	522	2.5395	572	2.5404
423	2.5432	473	2.5404	523	2.5410	573	2.5426
424	2.5432	474	2.5439	524	2.5421	574	2.5437
425	2.5420	475	2.5396	525	2.5426	575	2.5418
426	2.5444	476	2.5432	526	2.5416	576	2.5425
427	2.5409	477	2.5448	527	2.5444	577	2.5418
428	2.5456	478	2.5405	528	2.5391	578	2.5395
429	2.5410	479	2.5432	529	2.5431	579	2.5434
430	2.5446	480	2.5415	530	2.5424	580	2.5397
431	2.5405	481	2.5463	531	2.5436	581	2.5440
432	2.5427	482	2.5386	532	2.5394	582	2.5409
433	2.5431	483	2.5443	533	2.5455	583	2.5409
434	2.5440	484	2.5390	534	2.5389	584	2.5447
435	2.5414	485	2.5422	535	2.5433	585	2.5423
436	2.5418	486	2.5441	536	2.5418	586	2.5414
437	2.5431	487	2.5405	537	2.5411	587	2.5414
438	2.5445	488	2.5428	538	2.5448	588	2.5395
439	2.5428	489	2.5425	539	2.5406	589	2.5399
440	2.5434	490	2.5445	540	2.5445	590	2.5438
441	2.5410	491	2.5446	541	2.5417	591	2.5401
442	2.5422	492	2.5421	542	2.5436	592	2.5401
443	2.5437	493	2.5423	543	2.5407	593	2.5451
444	2.5424	494	2.5421	544	2.5424	594	2.5407
445	2.5424	495	2.5429	545	2.5443	595	2.5398
446	2.5429	496	2.5415	546	2.5423	596	2.5430
447	2.5445	497	2.5423	547	2.5427	597	2.5387
448	2.5432	498	2.5424	548	2.5444	598	2.5433
449	2.5415	499	2.5444	549	2.5424	599	2.5446
450	2.5437	500	2.5437	550	2.5409	600	2.5407

Retieseweg, B-2440 Geel, Belgium; Tel.: +32-(0)14-571 617

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

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
601	2.5431	651	2.5415	701	2.5414	751	2.5416
602	2.5411	652	2.5451	702	2.5429	752	2.5435
603	2.5424	653	2.5383	703	2.5418	753	2.5405
604	2.5411	654	2.5444	704	2.5435	754	2.5419
605	2.5419	655	2.5395	705	2.5426	755	2.5406
606	2.5417	656	2.5461	706	2.5430	756	2.5442
607	2.5394	657	2.5402	707	2.5474	757	2.5419
608	2.5451	658	2.5400	708	2.5405	758	2.5399
609	2.5420	659	2.5418	709	2.5410	759	2.5439
610	2.5429	660	2.5447	710	2.5455	760	2.5430
611	2.5400	661	2.5390	711	2.5421	761	2.5429
612	2.5451	662	2.5431	712	2.5422	762	2.5396
613	2.5416	663	2.5407	713	2.5442	763	2.5434
614	2.5407	664	2.5427	714	2.5393	764	2.5440
615	2.5412	665	2.5430	715	2.5459	765	2.5389
616	2.5436	666	2.5385	716	2.5401	766	2.5442
617	2.5430	667	2.5441	717	2.5448	767	2.5409
618	2.5396	668	2.5418	718	2.5439	768	2.5438
619	2.5445	669	2.5413	719	2.5427	769	2.5415
620	2.5389	670	2.5418	720	2.5419	770	2.5424
621	2.5432	671	2.5419	721	2.5415	771	2.5435
622	2.5432	672	2.5411	722	2.5443	772	2.5407
623	2.5386	673	2.5427	723	2.5415	773	2.5409
624	2.5424	674	2.5413	724	2.5396	774	2.5432
625	2.5424	675	2.5415	725	2.5440	775	2.5397
626	2.5404	676	2.5424	726	2.5416	776	2.5448
627	2.5424	677	2.5385	727	2.5454	777	2.5433
628	2.5438	678	2.5424	728	2.5392	778	2.5423
629	2.5380	679	2.5419	729	2.5434	779	2.5399
630	2.5432	680	2.5408	730	2.5419	780	2.5436
631	2.5392	681	2.5456	731	2.5436	781	2.5417
632	2.5412	682	2.5416	732	2.5413	782	2.5415
633	2.5425	683	2.5431	733	2.5442	783	2.5429
634	2.5430	684	2.5462	734	2.5424	784	2.5434
635	2.5404	685	2.5407	735	2.5378	785	2.5385
636	2.5453	686	2.5430	736	2.5463	786	2.5453
637	2.5413	687	2.5413	737	2.5428	787	2.5429
638	2.5418	688	2.5418	738	2.5389	788	2.5391
639	2.5421	689	2.5439	739	2.5453	789	2.5431
640	2.5439	690	2.5384	740	2.5432	790	2.5443
641	2.5389	691	2.5440	741	2.5377	791	2.5435
642	2.5434	692	2.5439	742	2.5466	792	2.5413
643	2.5432	693	2.5427	743	2.5434	793	2.5392
644	2.5425	694	2.5453	744	2.5433	794	2.5443
645	2.5380	695	2.5426	745	2.5366	795	2.5405
646	2.5456	696	2.5444	746	2.5438	796	2.5440
647	2.5424	697	2.5418	747	2.5436	797	2.5433
648	2.5357	698	2.5414	748	2.5409	798	2.5426
649	2.5426	699	2.5440	749	2.5398	799	2.5415
650	2.5421	700	2.5448	750	2.5433	800	2.5407

Retieseweg, B-2440 Geel, Belgium; Tel.: +32-(0)14-571 617

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

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
801	2.5406	851	2.5419	901	2.5388	951	2.5441
802	2.5430	852	2.5400	902	2.5438	952	2.5369
803	2.5435	853	2.5440	903	2.5437	953	2.5429
804	2.5392	854	2.5431	904	2.5433	954	2.5462
805	2.5382	855	2.5405	905	2.5373	955	2.5395
806	2.5455	856	2.5440	906	2.5453	956	2.5441
807	2.5429	857	2.5426	907	2.5431	957	2.5437
808	2.5396	858	2.5401	908	2.5432	958	2.5434
809	2.5443	859	2.5428	909	2.5395	959	2.5416
810	2.5416	860	2.5439	910	2.5427	960	2.5422
811	2.5384	861	2.5428	911	2.5438	961	2.5423
812	2.5451	862	2.5406	912	2.5423	962	2.5410
813	2.5398	863	2.5452	913	2.5397	963	2.5441
814	2.5439	864	2.5379	914	2.5438	964	2.5368
815	2.5436	865	2.5451	915	2.5436	965	2.5459
816	2.5429	866	2.5428	916	2.5433	966	2.5403
817	2.5382	867	2.5416	917	2.5396	967	2.5424
818	2.5443	868	2.5428	918	2.5441	968	2.5401
819	2.5425	869	2.5406	919	2.5416	969	2.5429
820	2.5420	870	2.5391	920	2.5433	970	2.5414
821	2.5420	871	2.5438	921	2.5439	971	2.5423
822	2.5423	872	2.5437	922	2.5414	972	2.5429
823	2.5395	873	2.5430	923	2.5378	973	2.5408
824	2.5430	874	2.5393	924	2.5456	974	2.5414
825	2.5441	875	2.5441	925	2.5436	975	2.5432
826	2.5404	876	2.5425	926	2.5395	976	2.5410
827	2.5412	877	2.5423	927	2.5434	977	2.5444
828	2.5428	878	2.5432	928	2.5428	978	2.5373
829	2.5386	879	2.5387	929	2.5438	979	2.5442
830	2.5430	880	2.5427	930	2.5430	980	2.5433
831	2.5442	881	2.5421	931	2.5383	981	2.5386
832	2.5383	882	2.5433	932	2.5420	982	2.5417
833	2.5428	883	2.5403	933	2.5437	983	2.5434
834	2.5401	884	2.5438	934	2.5416	984	2.5391
835	2.5403	885	2.5435	935	2.5389	985	2.5436
836	2.5447	886	2.5375	936	2.5435	986	2.5412
837	2.5432	887	2.5464	937	2.5426	987	2.5444
838	2.5393	888	2.5407	938	2.5434	988	2.5395
839	2.5438	889	2.5416	939	2.5430	989	2.5451
840	2.5432	890	2.5432	940	2.5423	990	2.5377
841	2.5393	891	2.5424	941	2.5396	991	2.5437
842	2.5441	892	2.5432	942	2.5435	992	2.5436
843	2.5438	893	2.5434	943	2.5426	993	2.5426
844	2.5422	894	2.5409	944	2.5426	994	2.5412
845	2.5409	895	2.5428	945	2.5428	995	2.5363
846	2.5438	896	2.5441	946	2.5423	996	2.5418
847	2.5395	897	2.5376	947	2.5429	997	2.5438
848	2.5444	898	2.5444	948	2.5437	998	2.5415
849	2.5433	899	2.5432	949	2.5381	999	2.5454
850	2.5430	900	2.5431	950	2.5444	1000	2.5436

Retieseweg, B-2440 Geel, Belgium; Tel.: +32-(0)14-571 617

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

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
1001	2.5409	1051	2.5434				
1002	2.5404	1052	2.5410				
1003	2.5441	1053	2.5440				
1004	2.5421	1054	2.5406				
1005	2.5411	1055	2.5426				
1006	2.5381	1056	2.5426				
1007	2.5443	1057	2.5437				
1008	2.5439	1058	2.5411				
1009	2.5438	1059	2.5408				
1010	2.5425	1060	2.5429				
1011	2.5378	1061	2.5384				
1012	2.5448	1062	2.5448				
1013	2.5429	1063	2.5401				
1014	2.5419	1064	2.5436				
1015	2.5422	1065	2.5411				
1016	2.5438	1066	2.5422				
1017	2.5409	1067	2.5400				
1018	2.5398	1068	2.5430				
1019	2.5442	1069	2.5400				
1020	2.5431	1070	2.5419				
1021	2.5400	1071	2.5377				
1022	2.5437	1072	2.5447				
1023	2.5427	1073	2.5407				
1024	2.5421	1074	2.5442				
1025	2.5408						
1026	2.5400						
1027	2.5454						
1028	2.5416						
1029	2.5426						
1030	2.5433						
1031	2.5422						
1032	2.5385						
1033	2.5438						
1034	2.5383						
1035	2.5442						
1036	2.5428						
1037	2.5432						
1038	2.5413						
1039	2.5381						
1040	2.5448						
1041	2.5440						
1042	2.5385						
1043	2.5450						
1044	2.5425						
1045	2.5397						
1046	2.5399						
1047	2.5434						
1048	2.5437						
1049	2.5398						
1050	2.5427						

Retieseweg, B-2440 Geel, Belgium; Tel.: +32-(0)14-571 617

Annex 12 The weighing certificate for the preparation of the mother solution of IRMM-1027t

Joint Research Centre

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

Certificate of weighing

Reg. No. E.3904 **Issued date**: 25 September 2018 **Page** 1 of 1

Applicant:	R. Jakopič	**Unit**: SN3S	
Project:	Preparation and certification of IRMM-1027t LSD spikes		
Description:	Preparation of U/Pu nitrate solution for IRMM-1027t		
Date of request:	N/A	**Weighing date**:	December 2017/January 2018

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

	Mass [g]	Uncertainty [g]
Mass of Pu metal (MP2)	2.13568	0.00007
Mass of enriched U metal (CRM 116-A)	11.16901	0.00013
Mass of natural U metal (EC 101)	44.18372	0.00014
Mass of IRMM-1027t U/Pu nitrate solution	2969.547	0.025

Observations:
Masses were determined by substitution weighing on balances AT 261 and AT 201 with inventory No. 1999003727 and 19960054773 and balance PR 5002 with inventory No. 9800298.

Traceability:
The certified mass values are traceable to the International Kilogram Prototype via regular calibrations of the principal kilogram at JRC Geel. The sets of working mass standards M3 and M10 were used as reference in the mass determination.

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

Rožle Jakopič
Nuclear Chemistry Laboratory Responsible

Jeroen Bauwens,
Analyst

Retieseweg 111, B-2440 Geel, Belgium; Tel.: +32-(0)14-571 211 • Fax: +32-(0)14-571 978

Annex 13 Uncertainty budget for the uranium gravimetric mixture of IRMM-1027t

Uranium gravimetric mixture for IRMM-1027t

Author: Jakopic

Author: Rozle Jakopic

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

Input parameters: a) masses of the metals and the nitrate solution (E3904) b) purity of the metals (metal certificates) c) uranium isotope amount ratios of the metals (certificate) d) 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 until 1 November 2017 (reference date for IRMM-1027t)

Model Equation:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$\gamma_{Umixture}=(m_{UCRM116A}*\eta_{purityCRM116A}+m_{UEC101}*\eta_{purityEC101}+m_{UMP2})/m_{solution1027t}$;

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

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

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

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

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

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

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

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

{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
$w_{Umixture}$	g/g	U mass fraction in IRMM-1027t
$w_{235Umixture}$	g/g	^{235}U mass fraction in IRMM-1027t
$w_{238Umixture}$	g/g	^{238}U mass fraction in IRMM-1027t
$c_{Umixture}$	mol/g	U amount content in IRMM-1027t
$c_{235Umixture}$	mol/g	^{235}U amount content in IRMM-1027t
$c_{238Umixture}$	mol/g	^{238}U amount content in IRMM-1027t
M_U	g/mol	Molar mass of U in IRMM-1027t
$R_{233U/238U}$	mol/mol	^{233}U/^{238}U amount ratio in IRMM-1027t
$R_{234U/238U}$	mol/mol	^{234}U/^{238}U amount ratio in IRMM-1027t
$R_{235U/238U}$	mol/mol	^{235}U/^{238}U amount ratio in IRMM-1027t
$R_{236U/238U}$	mol/mol	^{236}U/^{238}U amount ratio in IRMM-1027t
f_{233U}	mol/mol	^{233}U amount fraction in IRMM-1027t
f_{234U}	mol/mol	^{234}U amount fraction in IRMM-1027t
f_{235U}	mol/mol	^{235}U amount fraction in IRMM-1027t
f_{236U}	mol/mol	^{236}U amount fraction in IRMM-1027t
f_{238U}	mol/mol	^{238}U amount fraction in IRMM-1027t
w_{233U}	g/g	^{233}U mass fraction in IRMM-1027t
w_{234U}	g/g	^{234}U mass fraction in IRMM-1027t
w_{235U}	g/g	^{235}U mass fraction in IRMM-1027t
w_{236U}	g/g	^{236}U mass fraction in IRMM-1027t
w_{238U}	g/g	^{238}U mass fraction in IRMM-1027t
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
$m_{solution1027t}$	g	Mass of gravimetric mixture, IRMM-1027t
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

Quantity	Unit	Definition
$R_{233U/235Ub}$	mol/mol	$^{233}U/^{235}U$ amount ratio in NBL CRM 116-A
$R_{234U/235Ub}$	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-1027t
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
$m_{235Uvial1}$	g	mass of ^{235}U in vial 1
$m_{aliquot1}$	g	mass of dispensed mother solution of IRMM-1027t 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)

$m_{solution1027t}$: Type B normal distribution
Value: 2969.547 g
Expanded Uncertainty: 0.025 g
Coverage Factor: 2

E3904

m_{UEC101}: Type B normal distribution
Value: 44.18372 g
Expanded Uncertainty: 0.00014 g
Coverage Factor: 2

E3904

$\eta_{purityEC101}$: 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: 11.16901 g
Expanded Uncertainty: 0.00013 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 from Pu MP2_23_02_2018.smu
Symbol: n_{234U}Total

$n_{235.c}$: Import
Filename: U ingrowth from Pu MP2_23_02_2018.smu
Symbol: n_{235U}Total

$n_{236.c}$: Import
Filename: U ingrowth from Pu MP2_23_02_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 from Pu MP2_23_02_2018.smu
Symbol: n_{238U}Total

m_{UMP2}: Import
Filename: U ingrowth from Pu MP2_01_11_2017.smu
Symbol: m_UTotal

$m_{aliquot1}$: Type B normal distribution
Value: 2.5490 g
Expanded Uncertainty: 0.0006 g
Coverage Factor: 2

E3908

Input Correlation:

	$n_{234.c}$	$n_{235.c}$	$n_{236.c}$	$n_{238.c}$
$n_{234.c}$	1	0.2104	0.1461	0.0026
$n_{235.c}$	0.2104	1	0.6387	0.0115
$n_{236.c}$	0.1461	0.6387	1	0.0080
$n_{238.c}$	0.0026	0.0115	0.0080	1

Interim Results:

Quantity	Value	Standard Uncertainty
f_{233U}	$73.363 \cdot 10^{-9}$ mol/mol	$495 \cdot 10^{-12}$ mol/mol
w_{233U}	$72.000 \cdot 10^{-9}$ g/g	$486 \cdot 10^{-12}$ g/g
n_{233U}	$17.099 \cdot 10^{-9}$ mol	$115 \cdot 10^{-12}$ mol
n_{234U}	$523.014 \cdot 10^{-6}$ mol	$216 \cdot 10^{-9}$ mol
n_{236U}	$419.950 \cdot 10^{-6}$ mol	$171 \cdot 10^{-9}$ mol
n_{238U}	0.18651739 mol	$4.71 \cdot 10^{-6}$ mol
M_{Ua}	238.02889667 g/mol	$5.58 \cdot 10^{-6}$ g/mol
f_{234Ua}	$55.077 \cdot 10^{-6}$ mol/mol	$109 \cdot 10^{-9}$ mol/mol
f_{235Ua}	$7.20658 \cdot 10^{-3}$ mol/mol	$1.77 \cdot 10^{-6}$ mol/mol
f_{236Ua}	$149.9 \cdot 10^{-9}$ mol/mol	$19.9 \cdot 10^{-9}$ mol/mol
f_{238Ua}	0.99273819 mol/mol	$1.78 \cdot 10^{-6}$ mol/mol
M_{Ub}	235.1857225 g/mol	$55.1 \cdot 10^{-6}$ g/mol
f_{233Ub}	$360.24 \cdot 10^{-9}$ mol/mol	$2.43 \cdot 10^{-9}$ mol/mol
f_{234Ub}	0.01080225 mol/mol	$4.48 \cdot 10^{-6}$ mol/mol
f_{235Ub}	0.9325468 mol/mol	$18.6 \cdot 10^{-6}$ mol/mol
f_{236Ub}	$8.83243 \cdot 10^{-3}$ mol/mol	$3.56 \cdot 10^{-6}$ mol/mol
f_{238Ub}	0.0478182 mol/mol	$18.2 \cdot 10^{-6}$ mol/mol
$n_{234.a}$	$10.2221 \cdot 10^{-6}$ mol	$20.3 \cdot 10^{-9}$ mol
$n_{235.a}$	$1.337510 \cdot 10^{-3}$ mol	$331 \cdot 10^{-9}$ mol
$n_{236.a}$	$27.82 \cdot 10^{-9}$ mol	$3.68 \cdot 10^{-9}$ mol
$n_{238.a}$	0.18424774 mol	$4.63 \cdot 10^{-6}$ mol
$n_{233.b}$	$17.099 \cdot 10^{-9}$ mol	$115 \cdot 10^{-12}$ mol
$n_{234.b}$	$512.718 \cdot 10^{-6}$ mol	$215 \cdot 10^{-9}$ mol
$n_{235.b}$	0.04426245 mol	$2.75 \cdot 10^{-6}$ mol
$n_{236.b}$	$419.223 \cdot 10^{-6}$ mol	$171 \cdot 10^{-9}$ mol
$n_{238.b}$	$2.269645 \cdot 10^{-3}$ mol	$874 \cdot 10^{-9}$ mol
ΣR_U	1.2495822 mol/mol	$16.5 \cdot 10^{-6}$ mol/mol
ΣR_{Ua}	1.00731493 mol/mol	$1.80 \cdot 10^{-6}$ mol/mol
ΣR_{Ub}	1.0723323 mol/mol	$21.4 \cdot 10^{-6}$ mol/mol
w_{234Ua}	$54.154 \cdot 10^{-6}$ g/g	$107 \cdot 10^{-9}$ g/g
w_{235Ua}	$7.11621 \cdot 10^{-3}$ g/g	$1.75 \cdot 10^{-6}$ g/g
w_{236Ua}	$148.7 \cdot 10^{-9}$ g/g	$19.7 \cdot 10^{-9}$ g/g
w_{238Ua}	0.99282949 g/g	$1.76 \cdot 10^{-6}$ g/g
w_{233Ub}	$356.96 \cdot 10^{-9}$ g/g	$2.41 \cdot 10^{-9}$ g/g
w_{234Ub}	0.01074967 g/g	$4.46 \cdot 10^{-6}$ g/g
w_{235Ub}	0.9319845 g/g	$18.8 \cdot 10^{-6}$ g/g

Quantity	Value	Standard Uncertainty
w_{236Ub}	$8.86472 \cdot 10^{-3}$ g/g	$3.58 \cdot 10^{-6}$ g/g
w_{238Ub}	0.0484007 g/g	$18.4 \cdot 10^{-6}$ g/g

Uncertainty Budgets:

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

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
M_{233U}	233.03963440 g/mol	$2.40 \cdot 10^{-6}$ g/mol	normal	$-5.4 \cdot 10^{-12}$	$-13 \cdot 10^{-18}$ g/g	0.0 %
M_{234U}	234.04095040 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$-160 \cdot 10^{-9}$	$-190 \cdot 10^{-15}$ g/g	0.0 %
M_{235U}	235.04392820 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$1.5 \cdot 10^{-6}$	$1.8 \cdot 10^{-12}$ g/g	0.0 %
M_{236U}	236.04556620 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$-130 \cdot 10^{-9}$	$-160 \cdot 10^{-15}$ g/g	0.0 %
M_{238U}	238.05078700 g/mol	$1.60 \cdot 10^{-6}$ g/mol	normal	$-1.2 \cdot 10^{-6}$	$-1.8 \cdot 10^{-12}$ g/g	0.0 %
$m_{solution1027t}$	2969.5470 g	0.0125 g	normal	$-1.2 \cdot 10^{-6}$	$-15 \cdot 10^{-9}$ g/g	0.5 %
m_{UEC101}	44.1837200 g	$70.0 \cdot 10^{-6}$ g	normal	$2.4 \cdot 10^{-6}$	$170 \cdot 10^{-12}$ g/g	0.0 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0 \cdot 10^{-6}$ g/g	normal	$110 \cdot 10^{-6}$	$2.6 \cdot 10^{-9}$ g/g	0.0 %
$m_{UCRM116A}$	11.1690100 g	$65.0 \cdot 10^{-6}$ g	normal	$310 \cdot 10^{-6}$	$20 \cdot 10^{-9}$ g/g	0.9 %
$\eta_{purityCRM116A}$	0.9994500 g/g	$58.3 \cdot 10^{-6}$ g/g	normal	$3.5 \cdot 10^{-3}$	$200 \cdot 10^{-9}$ g/g	86.8 %
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	normal	0.0	0.0 g/g	0.0 %
$R_{234U/238Ua}$	$55.480 \cdot 10^{-6}$ mol/mol	$110 \cdot 10^{-9}$ mol/mol	normal	$-100 \cdot 10^{-6}$	$-11 \cdot 10^{-12}$ g/g	0.0 %
$R_{235U/238Ua}$	$7.25930 \cdot 10^{-3}$ mol/mol	$1.80 \cdot 10^{-6}$ mol/mol	normal	0.014	$26 \cdot 10^{-9}$ g/g	1.4 %
$R_{236U/238Ua}$	$151.0 \cdot 10^{-9}$ mol/mol	$20.0 \cdot 10^{-9}$ mol/mol	normal	$-100 \cdot 10^{-6}$	$-2.1 \cdot 10^{-12}$ g/g	0.0 %
$R_{233U/235Ub}$	$386.30 \cdot 10^{-9}$ mol/mol	$2.61 \cdot 10^{-9}$ mol/mol	normal	$-3.2 \cdot 10^{-3}$	$-8.4 \cdot 10^{-12}$ g/g	0.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	$4.85 \cdot 10^{-6}$ mol/mol	normal	$-3.3 \cdot 10^{-3}$	$-16 \cdot 10^{-9}$ g/g	0.5 %
$R_{238U/235Ub}$	0.0512770 mol/mol	$20.5 \cdot 10^{-6}$ mol/mol	normal	$-3.3 \cdot 10^{-3}$	$-68 \cdot 10^{-9}$ g/g	9.5 %
$R_{236U/235Ub}$	$9.47130 \cdot 10^{-3}$ mol/mol	$3.85 \cdot 10^{-6}$ mol/mol	normal	$-3.3 \cdot 10^{-3}$	$-13 \cdot 10^{-9}$ g/g	0.3 %
$n_{234.c}$	$73.591 \cdot 10^{-9}$ mol	$121 \cdot 10^{-12}$ mol		-0.015	$-1.8 \cdot 10^{-12}$ g/g	0.0 %
$n_{235.c}$	$8.48119 \cdot 10^{-6}$ mol	$3.10 \cdot 10^{-9}$ mol		0.064	$200 \cdot 10^{-12}$ g/g	0.0 %
$n_{236.c}$	$699.668 \cdot 10^{-9}$ mol	$369 \cdot 10^{-12}$ mol		-0.015	$-5.7 \cdot 10^{-12}$ g/g	0.0 %
$n_{233.c}$	0.0 mol	0.0 mol	normal	0.0	0.0 g/g	0.0 %
$n_{238.c}$	$14.737 \cdot 10^{-12}$ mol	$141 \cdot 10^{-15}$ mol		-0.016	$-2.2 \cdot 10^{-15}$ g/g	0.0 %
m_{UMP2}	$2.155770 \cdot 10^{-3}$ g	$791 \cdot 10^{-9}$ g		$65 \cdot 10^{-6}$	$52 \cdot 10^{-12}$ g/g	0.0 %
$\gamma_{235Umixture}$	$3.609972 \cdot 10^{-3}$ g/g	$219 \cdot 10^{-9}$ g/g				

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

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
M_{233U}	233.03963440 g/mol	$2.40 \cdot 10^{-6}$ g/mol	normal	$-280 \cdot 10^{-15}$	$-670 \cdot 10^{-21}$ g/g	0.0 %
M_{234U}	234.04095040 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$-12 \cdot 10^{-9}$	$-14 \cdot 10^{-15}$ g/g	0.0 %
M_{235U}	235.04392820 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$-1.2 \cdot 10^{-6}$	$-1.4 \cdot 10^{-12}$ g/g	0.0 %
M_{236U}	236.04556620 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$-7.0 \cdot 10^{-9}$	$-8.4 \cdot 10^{-15}$ g/g	0.0 %
M_{238U}	238.05078700 g/mol	$1.60 \cdot 10^{-6}$ g/mol	normal	$1.2 \cdot 10^{-6}$	$1.9 \cdot 10^{-12}$ g/g	0.0 %
$m_{solution1027t}$	2969.5470 g	0.0125 g	normal	$-5.0 \cdot 10^{-6}$	$-63 \cdot 10^{-9}$ g/g	2.7 %
m_{UEC101}	44.1837200 g	$70.0 \cdot 10^{-6}$ g	normal	$330 \cdot 10^{-6}$	$23 \cdot 10^{-9}$ g/g	0.4 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0 \cdot 10^{-6}$ g/g	normal	0.015	$370 \cdot 10^{-9}$ g/g	93.1 %
$m_{UCRM116A}$	11.1690100 g	$65.0 \cdot 10^{-6}$ g	normal	$16 \cdot 10^{-6}$	$1.1 \cdot 10^{-9}$ g/g	0.0 %
$\eta_{purityCRM116A}$	0.9994500 g/g	$58.3 \cdot 10^{-6}$ g/g	normal	$180 \cdot 10^{-6}$	$11 \cdot 10^{-9}$ g/g	0.0 %
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	normal	0.0	0.0 g/g	0.0 %
$R_{234U/238Ua}$	$55.480 \cdot 10^{-6}$ mol/mol	$110 \cdot 10^{-9}$ mol/mol	normal	-0.014	$-1.6 \cdot 10^{-9}$ g/g	0.0 %
$R_{235U/238Ua}$	$7.25930 \cdot 10^{-3}$ mol/mol	$1.80 \cdot 10^{-6}$ mol/mol	normal	-0.014	$-26 \cdot 10^{-9}$ g/g	0.5 %
$R_{236U/238Ua}$	$151.0 \cdot 10^{-9}$ mol/mol	$20.0 \cdot 10^{-9}$ mol/mol	normal	-0.015	$-290 \cdot 10^{-12}$ g/g	0.0 %
$R_{233U/235Ub}$	$386.30 \cdot 10^{-9}$ mol/mol	$2.61 \cdot 10^{-9}$ mol/mol	normal	$-170 \cdot 10^{-6}$	$-440 \cdot 10^{-15}$ g/g	0.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	$4.85 \cdot 10^{-6}$ mol/mol	normal	$-170 \cdot 10^{-6}$	$-820 \cdot 10^{-12}$ g/g	0.0 %
$R_{238U/235Ub}$	0.0512770 mol/mol	$20.5 \cdot 10^{-6}$ mol/mol	normal	$3.4 \cdot 10^{-3}$	$69 \cdot 10^{-9}$ g/g	3.3 %
$R_{236U/235Ub}$	$9.47130 \cdot 10^{-3}$ mol/mol	$3.85 \cdot 10^{-6}$ mol/mol	normal	$-170 \cdot 10^{-6}$	$-660 \cdot 10^{-12}$ g/g	0.0 %
$n_{234.c}$	$73.591 \cdot 10^{-9}$ mol	$121 \cdot 10^{-12}$ mol		-0.063	$-7.6 \cdot 10^{-12}$ g/g	0.0 %
$n_{235.c}$	$8.48119 \cdot 10^{-6}$ mol	$3.10 \cdot 10^{-9}$ mol		-0.064	$-200 \cdot 10^{-12}$ g/g	0.0 %
$n_{236.c}$	$699.668 \cdot 10^{-9}$ mol	$369 \cdot 10^{-12}$ mol		-0.064	$-24 \cdot 10^{-12}$ g/g	0.0 %
$n_{233.c}$	0.0 mol	0.0 mol	normal	0.0	0.0 g/g	0.0 %
$n_{238.c}$	$14.737 \cdot 10^{-12}$ mol	$141 \cdot 10^{-15}$ mol		0.016	$2.2 \cdot 10^{-15}$ g/g	0.0 %
m_{UMP2}	$2.155770 \cdot 10^{-3}$ g	$791 \cdot 10^{-9}$ g		$270 \cdot 10^{-6}$	$210 \cdot 10^{-12}$ g/g	0.0 %
$\gamma_{238Umixture}$	0.014951976 g/g	$383 \cdot 10^{-9}$ g/g				

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

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
M_{233U}	233.03963440 g/mol	$2.40 \cdot 10^{-6}$ g/mol	normal	$-4.2 \cdot 10^{-12}$	$-10 \cdot 10^{-18}$ mol/mol	0.0 %
M_{234U}	234.04095040 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$-120 \cdot 10^{-9}$	$-150 \cdot 10^{-15}$ mol/mol	0.0 %
M_{235U}	235.04392820 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$-11 \cdot 10^{-6}$	$-13 \cdot 10^{-12}$ mol/mol	0.0 %
M_{236U}	236.04556620 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$-100 \cdot 10^{-9}$	$-120 \cdot 10^{-15}$ mol/mol	0.0 %
M_{238U}	238.05078700 g/mol	$1.60 \cdot 10^{-6}$ g/mol	normal	$11 \cdot 10^{-6}$	$17 \cdot 10^{-12}$ mol/mol	0.0 %
m_{UEC101}	44.1837200 g	$70.0 \cdot 10^{-6}$ g	normal	$-61 \cdot 10^{-6}$	$-4.3 \cdot 10^{-9}$ mol/mol	0.0 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0 \cdot 10^{-6}$ g/g	normal	$-2.7 \cdot 10^{-3}$	$-68 \cdot 10^{-9}$ mol/mol	0.3 %
$m_{UCRM116A}$	11.1690100 g	$65.0 \cdot 10^{-6}$ g	normal	$240 \cdot 10^{-6}$	$16 \cdot 10^{-9}$ mol/mol	0.0 %
$\eta_{purityCRM116A}$	0.9994500 g/g	$58.3 \cdot 10^{-6}$ g/g	normal	$2.7 \cdot 10^{-3}$	$160 \cdot 10^{-9}$ mol/mol	1.9 %
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	normal	0.0	0.0 mol/mol	0.0 %
$R_{234U/238Ua}$	$55.480 \cdot 10^{-6}$ mol/mol	$110 \cdot 10^{-9}$ mol/mol	normal	0.99	$110 \cdot 10^{-9}$ mol/mol	0.9 %
$R_{235U/238Ua}$	$7.25930 \cdot 10^{-3}$ mol/mol	$1.80 \cdot 10^{-6}$ mol/mol	normal	$2.7 \cdot 10^{-3}$	$4.8 \cdot 10^{-9}$ mol/mol	0.0 %
$R_{236U/238Ua}$	$151.0 \cdot 10^{-9}$ mol/mol	$20.0 \cdot 10^{-9}$ mol/mol	normal	$2.7 \cdot 10^{-3}$	$53 \cdot 10^{-12}$ mol/mol	0.0 %
$R_{233U/235Ub}$	$386.30 \cdot 10^{-9}$ mol/mol	$2.61 \cdot 10^{-9}$ mol/mol	normal	$-2.5 \cdot 10^{-3}$	$-6.5 \cdot 10^{-12}$ mol/mol	0.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	$4.85 \cdot 10^{-6}$ mol/mol	normal	0.23	$1.1 \cdot 10^{-6}$ mol/mol	96.5 %
$R_{238U/235Ub}$	0.0512770 mol/mol	$20.5 \cdot 10^{-6}$ mol/mol	normal	$-3.2 \cdot 10^{-3}$	$-66 \cdot 10^{-9}$ mol/mol	0.3 %
$R_{236U/235Ub}$	$9.47130 \cdot 10^{-3}$ mol/mol	$3.85 \cdot 10^{-6}$ mol/mol	normal	$-2.5 \cdot 10^{-3}$	$-9.8 \cdot 10^{-9}$ mol/mol	0.0 %
$n_{234.c}$	$73.591 \cdot 10^{-9}$ mol	$121 \cdot 10^{-12}$ mol		5.4	$650 \cdot 10^{-12}$ mol/mol	0.0 %
$n_{238.c}$	$14.737 \cdot 10^{-12}$ mol	$141 \cdot 10^{-15}$ mol		-0.015	$-2.1 \cdot 10^{-15}$ mol/mol	0.0 %
$R_{234U/238U}$	$2.80410 \cdot 10^{-3}$ mol/mol	$1.16 \cdot 10^{-6}$ mol/mol				

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

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
M_{233U}	233.03963440 g/mol	$2.40 \cdot 10^{-6}$ g/mol	normal	$-360 \cdot 10^{-12}$	$-860 \cdot 10^{-18}$ mol/mol	0.0 %
M_{234U}	234.04095040 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$-11 \cdot 10^{-6}$	$-13 \cdot 10^{-12}$ mol/mol	0.0 %
M_{235U}	235.04392820 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$-920 \cdot 10^{-6}$	$-1.1 \cdot 10^{-9}$ mol/mol	0.0 %
M_{236U}	236.04556620 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$-8.8 \cdot 10^{-6}$	$-11 \cdot 10^{-12}$ mol/mol	0.0 %
M_{238U}	238.05078700 g/mol	$1.60 \cdot 10^{-6}$ g/mol	normal	$930 \cdot 10^{-6}$	$1.5 \cdot 10^{-9}$ mol/mol	0.0 %
m_{UEC101}	44.1837200 g	$70.0 \cdot 10^{-6}$ g	normal	$-5.3 \cdot 10^{-3}$	$-370 \cdot 10^{-9}$ mol/mol	0.0 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0 \cdot 10^{-6}$ g/g	normal	-0.23	$-5.9 \cdot 10^{-6}$ mol/mol	13.1 %
$m_{UCRM116A}$	11.1690100 g	$65.0 \cdot 10^{-6}$ g	normal	0.021	$1.4 \cdot 10^{-6}$ mol/mol	0.7 %
$\eta_{purityCRM116A}$	0.9994500 g/g	$58.3 \cdot 10^{-6}$ g/g	normal	0.23	$14 \cdot 10^{-6}$ mol/mol	71.2 %
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	normal	0.0	0.0 mol/mol	0.0 %
$R_{234U/238Ua}$	$55.480 \cdot 10^{-6}$ mol/mol	$110 \cdot 10^{-9}$ mol/mol	normal	0.23	$25 \cdot 10^{-9}$ mol/mol	0.0 %
$R_{235U/238Ua}$	$7.25930 \cdot 10^{-3}$ mol/mol	$1.80 \cdot 10^{-6}$ mol/mol	normal	1.2	$2.2 \cdot 10^{-6}$ mol/mol	1.8 %
$R_{236U/238Ua}$	$151.0 \cdot 10^{-9}$ mol/mol	$20.0 \cdot 10^{-9}$ mol/mol	normal	0.23	$4.6 \cdot 10^{-9}$ mol/mol	0.0 %
$R_{233U/235Ub}$	$386.30 \cdot 10^{-9}$ mol/mol	$2.61 \cdot 10^{-9}$ mol/mol	normal	-0.22	$-560 \cdot 10^{-12}$ mol/mol	0.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	$4.85 \cdot 10^{-6}$ mol/mol	normal	-0.22	$-1.1 \cdot 10^{-6}$ mol/mol	0.4 %
$R_{238U/235Ub}$	0.0512770 mol/mol	$20.5 \cdot 10^{-6}$ mol/mol	normal	-0.28	$-5.7 \cdot 10^{-6}$ mol/mol	12.5 %
$R_{236U/235Ub}$	$9.47130 \cdot 10^{-3}$ mol/mol	$3.85 \cdot 10^{-6}$ mol/mol	normal	-0.22	$-840 \cdot 10^{-9}$ mol/mol	0.3 %
$n_{235.c}$	$8.48119 \cdot 10^{-5}$ mol	$3.10 \cdot 10^{-9}$ mol		5.4	$17 \cdot 10^{-9}$ mol/mol	0.0 %
$n_{238.c}$	$14.737 \cdot 10^{-12}$ mol	$141 \cdot 10^{-15}$ mol		-1.3	$-180 \cdot 10^{-15}$ mol/mol	0.0 %
$R_{235U/238U}$	0.2445265 mol/mol	$16.2 \cdot 10^{-6}$ mol/mol				

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

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
M_{233U}	233.03963440 g/mol	$2.40 \cdot 10^{-6}$ g/mol	normal	$-3.4 \cdot 10^{-12}$	$-8.2 \cdot 10^{-18}$ mol/mol	0.0 %
M_{234U}	234.04095040 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$-100 \cdot 10^{-9}$	$-120 \cdot 10^{-15}$ mol/mol	0.0 %
M_{235U}	235.04392820 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$-8.7 \cdot 10^{-6}$	$-10 \cdot 10^{-12}$ mol/mol	0.0 %
M_{236U}	236.04556620 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$-83 \cdot 10^{-9}$	$-100 \cdot 10^{-15}$ mol/mol	0.0 %
M_{238U}	238.05078700 g/mol	$1.60 \cdot 10^{-6}$ g/mol	normal	$8.8 \cdot 10^{-6}$	$14 \cdot 10^{-12}$ mol/mol	0.0 %
m_{UEC101}	44.1837200 g	$70.0 \cdot 10^{-6}$ g	normal	$-50 \cdot 10^{-6}$	$-3.5 \cdot 10^{-9}$ mol/mol	0.0 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0 \cdot 10^{-6}$ g/g	normal	$-2.2 \cdot 10^{-3}$	$-56 \cdot 10^{-9}$ mol/mol	0.4 %
$m_{UCRM116A}$	11.1690100 g	$65.0 \cdot 10^{-6}$ g	normal	$200 \cdot 10^{-6}$	$13 \cdot 10^{-9}$ mol/mol	0.0 %
$\eta_{purityCRM116A}$	0.9994500 g/g	$58.3 \cdot 10^{-6}$ g/g	normal	$2.2 \cdot 10^{-3}$	$130 \cdot 10^{-9}$ mol/mol	2.0 %
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	normal	0.0	0.0 mol/mol	0.0 %
$R_{234U/238Ua}$	$55.480 \cdot 10^{-6}$ mol/mol	$110 \cdot 10^{-9}$ mol/mol	normal	$2.2 \cdot 10^{-3}$	$240 \cdot 10^{-12}$ mol/mol	0.0 %
$R_{235U/238Ua}$	$7.25930 \cdot 10^{-3}$ mol/mol	$1.80 \cdot 10^{-6}$ mol/mol	normal	$2.2 \cdot 10^{-3}$	$3.9 \cdot 10^{-9}$ mol/mol	0.0 %
$R_{236U/238Ua}$	$151.0 \cdot 10^{-9}$ mol/mol	$20.0 \cdot 10^{-9}$ mol/mol	normal	0.99	$20 \cdot 10^{-9}$ mol/mol	0.0 %
$R_{233U/235Ub}$	$386.30 \cdot 10^{-9}$ mol/mol	$2.61 \cdot 10^{-9}$ mol/mol	normal	$-2.1 \cdot 10^{-3}$	$-5.3 \cdot 10^{-12}$ mol/mol	0.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	$4.85 \cdot 10^{-6}$ mol/mol	normal	$-2.1 \cdot 10^{-3}$	$-10 \cdot 10^{-9}$ mol/mol	0.0 %
$R_{238U/235Ub}$	0.0512770 mol/mol	$20.5 \cdot 10^{-6}$ mol/mol	normal	$-2.6 \cdot 10^{-3}$	$-54 \cdot 10^{-9}$ mol/mol	0.3 %
$R_{236U/235Ub}$	$9.47130 \cdot 10^{-3}$ mol/mol	$3.85 \cdot 10^{-6}$ mol/mol	normal	0.24	$910 \cdot 10^{-9}$ mol/mol	97.2 %
$n_{236.c}$	$699.668 \cdot 10^{-9}$ mol	$369 \cdot 10^{-12}$ mol		5.4	$2.0 \cdot 10^{-9}$ mol/mol	0.0 %
$n_{238.c}$	$14.737 \cdot 10^{-12}$ mol	$141 \cdot 10^{-15}$ mol		-0.012	$-1.7 \cdot 10^{-15}$ mol/mol	0.0 %
$R_{236U/238U}$	$2.251535 \cdot 10^{-3}$ mol/mol	$919 \cdot 10^{-9}$ 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	$2.40 \cdot 10^{-6}$ g/mol	normal	$-14 \cdot 10^{-12}$	$-33 \cdot 10^{-18}$ g	0.0 %
M_{234U}	234.04095040 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$-410 \cdot 10^{-9}$	$-490 \cdot 10^{-15}$ g	0.0 %
M_{235U}	235.04392820 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$3.7 \cdot 10^{-6}$	$4.5 \cdot 10^{-12}$ g	0.0 %
M_{236U}	236.04556620 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$-340 \cdot 10^{-9}$	$-400 \cdot 10^{-15}$ g	0.0 %
M_{238U}	238.05078700 g/mol	$1.60 \cdot 10^{-6}$ g/mol	normal	$-2.9 \cdot 10^{-6}$	$-4.7 \cdot 10^{-12}$ g	0.0 %
$m_{solution1027t}$	2969.5470 g	0.0125 g	normal	$-3.1 \cdot 10^{-6}$	$-39 \cdot 10^{-9}$ g	0.1 %
m_{UEC101}	44.1837200 g	$70.0 \cdot 10^{-6}$ g	normal	$6.1 \cdot 10^{-6}$	$430 \cdot 10^{-12}$ g	0.0 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0 \cdot 10^{-6}$ g/g	normal	$270 \cdot 10^{-6}$	$6.7 \cdot 10^{-9}$ g	0.0 %
$m_{UCRM116A}$	11.1690100 g	$65.0 \cdot 10^{-6}$ g	normal	$800 \cdot 10^{-6}$	$52 \cdot 10^{-9}$ g	0.2 %
$\eta_{purityCRM116A}$	0.9994500 g/g	$58.3 \cdot 10^{-6}$ g/g	normal	$8.9 \cdot 10^{-3}$	$520 \cdot 10^{-9}$ g	18.3 %
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	normal	0.0	0.0 g	0.0 %
$R_{234U/238Ua}$	$55.480 \cdot 10^{-6}$ mol/mol	$110 \cdot 10^{-9}$ mol/mol	normal	$-260 \cdot 10^{-6}$	$-29 \cdot 10^{-12}$ g	0.0 %
$R_{236U/238Ua}$	$7.25930 \cdot 10^{-3}$ mol/mol	$1.80 \cdot 10^{-6}$ mol/mol	normal	0.037	$66 \cdot 10^{-9}$ g	0.3 %
$R_{236U/238Ua}$	$151.0 \cdot 10^{-9}$ mol/mol	$20.0 \cdot 10^{-9}$ mol/mol	normal	$-270 \cdot 10^{-6}$	$-5.3 \cdot 10^{-12}$ g	0.0 %
$R_{233U/235Ub}$	$386.30 \cdot 10^{-9}$ mol/mol	$2.61 \cdot 10^{-9}$ mol/mol	normal	$-8.3 \cdot 10^{-3}$	$-22 \cdot 10^{-12}$ g	0.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	$4.85 \cdot 10^{-6}$ mol/mol	normal	$-8.3 \cdot 10^{-3}$	$-40 \cdot 10^{-9}$ g	0.1 %
$R_{238U/235Ub}$	0.0512770 mol/mol	$20.5 \cdot 10^{-6}$ mol/mol	normal	$-8.4 \cdot 10^{-3}$	$-170 \cdot 10^{-9}$ g	2.0 %
$R_{236U/235Ub}$	$9.47130 \cdot 10^{-3}$ mol/mol	$3.85 \cdot 10^{-6}$ mol/mol	normal	$-8.4 \cdot 10^{-3}$	$-32 \cdot 10^{-9}$ g	0.0 %
$n_{234.c}$	$73.591 \cdot 10^{-9}$ mol	$121 \cdot 10^{-12}$ mol		-0.039	$-4.7 \cdot 10^{-12}$ g	0.0 %
$n_{235.c}$	$8.48119 \cdot 10^{-6}$ mol	$3.10 \cdot 10^{-9}$ mol		0.16	$510 \cdot 10^{-12}$ g	0.0 %
$n_{236.c}$	$699.668 \cdot 10^{-9}$ mol	$369 \cdot 10^{-12}$ mol		-0.039	$-14 \cdot 10^{-12}$ g	0.0 %
$n_{233.c}$	0.0 mol	0.0 mol	normal	0.0	0.0 g	0.0 %
$n_{238.c}$	$14.737 \cdot 10^{-12}$ mol	$141 \cdot 10^{-15}$ mol		-0.040	$-5.6 \cdot 10^{-15}$ g	0.0 %
m_{UMP2}	$2.155770 \cdot 10^{-3}$ g	$791 \cdot 10^{-9}$ g		$170 \cdot 10^{-6}$	$130 \cdot 10^{-12}$ g	0.0 %
$m_{aliquot1}$	2.549000 g	$300 \cdot 10^{-6}$ g	normal	$3.6 \cdot 10^{-3}$	$1.1 \cdot 10^{-6}$ g	78.9 %
$m_{235Uvial1}$	$9.20182 \cdot 10^{-3}$ g	$1.22 \cdot 10^{-6}$ 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	$2.40 \cdot 10^{-6}$ g/mol	normal	$-710 \cdot 10^{-15}$	$-1.7 \cdot 10^{-18}$ g	0.0 %
M_{234U}	234.04095040 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$-30 \cdot 10^{-9}$	$-36 \cdot 10^{-15}$ g	0.0 %
M_{235U}	235.04392820 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$-3.0 \cdot 10^{-6}$	$-3.6 \cdot 10^{-12}$ g	0.0 %
M_{236U}	236.04556620 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$-18 \cdot 10^{-9}$	$-22 \cdot 10^{-15}$ g	0.0 %
M_{238U}	238.05078700 g/mol	$1.60 \cdot 10^{-6}$ g/mol	normal	$3.0 \cdot 10^{-6}$	$4.8 \cdot 10^{-12}$ g	0.0 %
$m_{solution1027t}$	2969.5470 g	0.0125 g	normal	$-13 \cdot 10^{-6}$	$-160 \cdot 10^{-9}$ g	0.1 %
m_{UEC101}	44.1837200 g	$70.0 \cdot 10^{-6}$ g	normal	$850 \cdot 10^{-6}$	$60 \cdot 10^{-9}$ g	0.0 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0 \cdot 10^{-6}$ g/g	normal	0.038	$940 \cdot 10^{-9}$ g	4.2 %
$m_{UCRM116A}$	11.1690100 g	$65.0 \cdot 10^{-6}$ g	normal	$42 \cdot 10^{-6}$	$2.7 \cdot 10^{-9}$ g	0.0 %
$\eta_{purityCRM116A}$	0.9994500 g/g	$58.3 \cdot 10^{-6}$ g/g	normal	$460 \cdot 10^{-6}$	$27 \cdot 10^{-9}$ g	0.0 %
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	normal	0.0	0.0 g	0.0 %
$R_{234U/238Ua}$	$55.480 \cdot 10^{-6}$ mol/mol	$110 \cdot 10^{-9}$ mol/mol	normal	-0.037	$-4.0 \cdot 10^{-9}$ g	0.0 %
$R_{235U/238Ua}$	$7.25930 \cdot 10^{-3}$ mol/mol	$1.80 \cdot 10^{-6}$ mol/mol	normal	-0.037	$-66 \cdot 10^{-9}$ g	0.0 %
$R_{236U/238Ua}$	$151.0 \cdot 10^{-9}$ mol/mol	$20.0 \cdot 10^{-9}$ mol/mol	normal	-0.037	$-740 \cdot 10^{-12}$ g	0.0 %
$R_{233U/235Ub}$	$386.30 \cdot 10^{-9}$ mol/mol	$2.61 \cdot 10^{-9}$ mol/mol	normal	$-430 \cdot 10^{-6}$	$-1.1 \cdot 10^{-12}$ g	0.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	$4.85 \cdot 10^{-6}$ mol/mol	normal	$-430 \cdot 10^{-6}$	$-2.1 \cdot 10^{-9}$ g	0.0 %
$R_{238U/235Ub}$	0.0512770 mol/mol	$20.5 \cdot 10^{-6}$ mol/mol	normal	$8.6 \cdot 10^{-3}$	$180 \cdot 10^{-9}$ g	0.1 %
$R_{236U/235Ub}$	$9.47130 \cdot 10^{-3}$ mol/mol	$3.85 \cdot 10^{-6}$ mol/mol	normal	$-430 \cdot 10^{-6}$	$-1.7 \cdot 10^{-9}$ g	0.0 %
$n_{234,c}$	$73.591 \cdot 10^{-9}$ mol	$121 \cdot 10^{-12}$ mol		-0.16	$-19 \cdot 10^{-12}$ g	0.0 %
$n_{235,c}$	$8.48119 \cdot 10^{-6}$ mol	$3.10 \cdot 10^{-9}$ mol		-0.16	$-500 \cdot 10^{-12}$ g	0.0 %
$n_{236,c}$	$699.668 \cdot 10^{-9}$ mol	$369 \cdot 10^{-12}$ mol		-0.16	$-60 \cdot 10^{-12}$ g	0.0 %
$n_{233,c}$	0.0 mol	0.0 mol	normal	0.0	0.0 g	0.0 %
$n_{238,c}$	$14.737 \cdot 10^{-12}$ mol	$141 \cdot 10^{-15}$ mol		0.040	$5.7 \cdot 10^{-15}$ g	0.0 %
m_{UMP2}	$2.155770 \cdot 10^{-3}$ g	$791 \cdot 10^{-9}$ g		$690 \cdot 10^{-6}$	$540 \cdot 10^{-12}$ g	0.0 %
$m_{aliquot1}$	2.549000 g	$300 \cdot 10^{-6}$ g	normal	0.015	$4.5 \cdot 10^{-6}$ g	95.5 %
$m_{238Uvial1}$	0.03811259 g	$4.59 \cdot 10^{-6}$ g				

Results:

Quantity	Value	Expanded Uncertainty	Coverage factor	Coverage
$y_{Umixture}$	0.01863655 g/g	$880 \cdot 10^{-9}$ g/g	2.00	manual
$y_{235Umixture}$	$3.60997 \cdot 10^{-3}$ g/g	$440 \cdot 10^{-9}$ g/g	2.00	manual
$y_{238Umixture}$	0.01495198 g/g	$770 \cdot 10^{-9}$ g/g	2.00	manual
$c_{Umixture}$	$78.4863 \cdot 10^{-6}$ mol/g	$3.7 \cdot 10^{-9}$ mol/g	2.00	manual
$c_{235Umixture}$	$15.3587 \cdot 10^{-6}$ mol/g	$1.9 \cdot 10^{-9}$ mol/g	2.00	manual
$c_{238Umixture}$	$62.8100 \cdot 10^{-6}$ mol/g	$3.2 \cdot 10^{-9}$ mol/g	2.00	manual
M_U	237.449773 g/mol	$64 \cdot 10^{-6}$ g/mol	2.00	manual
$R_{233U/238U}$	$91.7 \cdot 10^{-9}$ mol/mol	$1.2 \cdot 10^{-9}$ mol/mol	2.00	manual
$R_{234U/238U}$	$2.8041 \cdot 10^{-3}$ mol/mol	0.041 % (relative)	1.00	manual
$R_{235U/238U}$	0.244526 mol/mol	$16 \cdot 10^{-6}$ mol/mol	1.00	manual
$R_{236U/238U}$	$2.25153 \cdot 10^{-3}$ mol/mol	0.041 % (relative)	1.00	manual
f_{234U}	$2.2440 \cdot 10^{-3}$ mol/mol	$1.8 \cdot 10^{-6}$ mol/mol	2.00	manual
f_{235U}	0.195687 mol/mol	$21 \cdot 10^{-6}$ mol/mol	2.00	manual
f_{236U}	$1.8018 \cdot 10^{-3}$ mol/mol	$1.5 \cdot 10^{-6}$ mol/mol	2.00	manual
f_{238U}	0.800267 mol/mol	$21 \cdot 10^{-6}$ mol/mol	2.00	manual
w_{234U}	$2.2118 \cdot 10^{-3}$ g/g	$1.8 \cdot 10^{-6}$ g/g	2.00	manual
w_{235U}	0.193704 g/g	$21 \cdot 10^{-6}$ g/g	2.00	manual
w_{236U}	$1.7912 \cdot 10^{-3}$ g/g	$1.5 \cdot 10^{-6}$ g/g	2.00	manual
w_{238U}	0.802293 g/g	$21 \cdot 10^{-6}$ g/g	2.00	manual
n_{235U}	0.0456084 mol	$5.5 \cdot 10^{-6}$ mol	2.00	manual
$m_{235Uvial1}$	$9.2018 \cdot 10^{-3}$ g	$2.4 \cdot 10^{-6}$ g	2.00	manual
$m_{238Uvial1}$	0.0381126 g	$9.2 \cdot 10^{-6}$ g	2.00	manual

Annex 14 Uncertainty budget for the plutonium gravimetric mixture of IRMM-1027t

Plutonium gravimetric mixture for IRMM-1027t

Author: Jakopic

Author: Rozle Jakopic

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

Input parameters:

a) Mass of plutonium metal and the nitrate solution (E3904) b) Purity of plutonium metal (metal certificate) c) Plutonium isotope amount ratios (IRMM certificate, issued 11 April 2007) d) 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). Purity of MP2 metal on 1 Nov 2017 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 Nov 2017 (reference date for IRMM-1027t certificate)

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-1027t, 1 Nov 2017}

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

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

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

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

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

{Decayed and normalised isotope amount fractions in gravimetric mixture, IRMM-1027t, 1 Nov 2017}

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

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

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

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

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

{Decayed molar mass of plutonium in gravimetric mixtures, IRMM-1027t, 1 Nov 2017}

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

{Decayed and normalised isotope mass fractios in gravimetric mixture, IRMM-1027t, 1 Nov 2017}

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

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

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

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

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

{Decayed amount ratios for purity calculation, 1 Nov 2017}

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

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

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

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

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

{Decayed isotope masses for purity calculation, 1 Nov 2017}

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

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

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

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

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

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

$\eta_{PuMP2Nov2017}=\eta_{PuMP2Jan2007}*\Sigma md_{Pu}/m_{Pu}$;

{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-1027t, 1 Nov 2017}

$w_{Pumixture}=(m_{PuMP2}*\eta_{PuMP2Nov2017})/m_{solution1027t}$;

$w_{Pumixture239}=w_{Pumixture}*wdnorm_{239Pu}$;

$m_{239Puvial1}=w_{Pumixture239}*m_{aliquot1}$;

{Plutonium amount content in gravimetric mixture, IRMM-1027t, 1 Nov 2017}

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

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

List of Quantities:

Quantity	Unit	Definition
$\gamma_{Pumixture}$	g/g	Pu mass fraction in IRMM-1027t
$\gamma_{Pumixture239}$	g/g	^{239}Pu mass fraction in IRMM-1027t
$c_{Pumixture239}$	mol/g	^{239}Pu amount content in IRMM-1027t
$c_{Pumixture}$	mol/g	Pu amount content in IRMM-1027t
$Rd_{238Pu/239Pu}$	mol/mol	decayed ^{238}Pu/^{239}Pu amount ratio in IRMM-1027t, 1 Nov 2017
$Rd_{240Pu/239Pu}$	mol/mol	decayed ^{240}Pu/^{239}Pu amount ratio in IRMM-1027t, 1 Nov 2017
$Rd_{241Pu/239Pu}$	mol/mol	decayed ^{241}Pu/^{239}Pu amount ratio in IRMM-1027t, 1 Nov 2017
$Rd_{242Pu/239Pu}$	mol/mol	decayed ^{242}Pu/^{239}Pu amount ratio in IRMM-1027t, 1 Nov 2017
$R_{238Pu/239Pu}$	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 reference date (1 Nov 2017)
$R_{240Pu/239Pu}$	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
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-1027t, 1 Nov 2017

Quantity	Unit	Definition
$fdnorm_{238Pu}$	mol/mol	Decayed and normalised ^{238}Pu amount fraction in gravimetric mixture, IRMM-1027t, 1 Nov 2017
$fdnorm_{239Pu}$	mol/mol	Decayed and normalised ^{239}Pu amount fraction in gravimetric mixture, IRMM-1027t, 1 Nov 2017
$fdnorm_{240Pu}$	mol/mol	Decayed and normalised ^{240}Pu amount fraction in gravimetric mixture, IRMM-1027t, 1 Nov 2017
$fdnorm_{241Pu}$	mol/mol	Decayed and normalised ^{241}Pu amount fraction in gravimetric mixture, IRMM-1027t, 1 Nov 2017
$fdnorm_{242Pu}$	mol/mol	Decayed and normalised ^{242}Pu amount fraction in gravimetric mixture, IRMM-1027t, 1 Nov 2017
Md_{Pu}	g/mol	Decayed molar mass of Pu in gravimetric mixture, IRMM-1027t, 1 Nov 2017
$wdnorm_{238Pu}$	g/g	Decayed and normalised ^{238}Pu mass fraction in gravimetric mixture, IRMM-1027t, 1 Nov 2017
$wdnorm_{239Pu}$	g/g	Decayed and normalised ^{239}Pu mass fraction in gravimetric mixture, IRMM-1027t, 1 Nov 2017
$wdnorm_{240Pu}$	g/g	Decayed and normalised ^{240}Pu mass fraction in gravimetric mixture, IRMM-1027t, 1 Nov 2017
$wdnorm_{241Pu}$	g/g	Decayed and normalised ^{241}Pu mass fraction in gravimetric mixture, IRMM-1027t, 1 Nov 2017
$wdnorm_{242Pu}$	g/g	Decayed and normalised ^{242}Pu mass fraction in gravimetric mixture, IRMM-1027t, 1 Nov 2017
$\eta_{PuMP2Nov2017}$	g/g	Purity of MP2 metal, 1 Nov 2017
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
$m_{solution1027t}$	g	Mass of gravimetric mixture, IRMM-1027t
m_{Pu}	g	
md_{238Pu}	g	Decayed mass of ^{238}Pu, from 1 Jan 2007 to 1 Nov 2017
md_{239Pu}	g	Decayed mass of ^{239}Pu, from 1 Jan 2007 to 1 Nov 2017
md_{240Pu}	g	Decayed mass of ^{240}Pu, from 1 Jan 2007 to 1 Nov 2017
md_{241Pu}	g	Decayed mass of ^{241}Pu, from 1 Jan 2007 to 1 Nov 2017
md_{242Pu}	g	Decayed mass of ^{242}Pu, from 1 Jan 2007 to 1 Nov 2017
Σmd_{Pu}	g	Sum of decayed Pu masses
$\eta_{PuMP2Jan2007}$	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

Quantity	Unit	Definition
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 Nov 2016
fd_{239Pu}	mol/mol	Decayed ^{239}Pu amount fraction in MP2, from 1 Jan 2007 to 1 Nov 2016
fd_{240Pu}	mol/mol	Decayed ^{240}Pu amount fraction in MP2, from 1 Jan 2007 to 1 Nov 2016
fd_{241Pu}	mol/mol	Decayed ^{241}Pu amount fraction in MP2, from 1 Jan 2007 to 1 Nov 2016
fd_{242Pu}	mol/mol	Decayed ^{242}Pu amount fraction in MP2, from 1 Jan 2007 to 1 Nov 2016
$m_{239Puvial1}$	g	mass of ^{239}Pu in vial 1
$m_{aliquot1}$	g	mass of dispensed mother solution of IRMM-1027t 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: 10.83368 a

01/01/2007, 01/11/2017, delta t= 3957 days / 365.25 = 10.83368 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: 2.7182818284590452536

M_{238Pu}: Type B normal distribution
Value: 238.0495583 g/mol
Expanded Uncertainty: 0.0000012 g/mol
Coverage Factor: 1

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).

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

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).

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

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).

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

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).

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

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).

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

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

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

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

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

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

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

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

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

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

m_{PuMP2}: Type B normal distribution
Value: 2.13568 g
Expanded Uncertainty: 0.00007 g
Coverage Factor: 2

E3904 certificate

$m_{solution1027t}$: Type B normal distribution
Value: 2969.547 g
Expanded Uncertainty: 0.025 g
Coverage Factor: 2

E3904 certificate

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

$\eta_{PuMP2Jan2007}$: Import
Filename: Decay MP2 from 12-03-2001 to 01-01-2007.smu
Symbol: $\eta_{PuMP2Jan2007}$

$m_{aliquot1}$: Type B normal distribution
Value: 2.5490 g
Expanded Uncertainty: 0.0006 g
Coverage Factor: 2

E3908

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}	1.02265858 mol/mol	$2.74 \cdot 10^{-6}$ mol/mol
$\eta_{PuMP2Nov2017}$	0.998319 g/g	$200 \cdot 10^{-6}$ g/g
md_{238Pu}	$27.552 \cdot 10^{-6}$ g	$130 \cdot 10^{-9}$ g
md_{239Pu}	0.97733338 g	$2.90 \cdot 10^{-6}$ g
md_{240Pu}	0.02199747 g	$2.45 \cdot 10^{-6}$ g
md_{241Pu}	$138.789 \cdot 10^{-6}$ g	$906 \cdot 10^{-9}$ g
md_{242Pu}	$74.936 \cdot 10^{-6}$ g	$386 \cdot 10^{-9}$ g
Σmd_{Pu}	0.999572127 g	$642 \cdot 10^{-9}$ 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}	$27.671 \cdot 10^{-6}$ mol/mol	$130 \cdot 10^{-9}$ mol/mol
fd_{239Pu}	0.97742589 mol/mol	$2.88 \cdot 10^{-6}$ mol/mol
fd_{240Pu}	0.02190775 mol/mol	$2.44 \cdot 10^{-6}$ mol/mol
fd_{241Pu}	$137.648 \cdot 10^{-6}$ mol/mol	$899 \cdot 10^{-9}$ 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-1027t

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	$-680 \cdot 10^{-6}$	$-99 \cdot 10^{-12}$ g/g	0.0 %
Δt	10.83368 a					
$R_{240Pu/239Pu}$	0.02243240 mol/mol	$2.55 \cdot 10^{-6}$ mol/mol	normal	$-690 \cdot 10^{-6}$	$-1.8 \cdot 10^{-9}$ g/g	0.0 %
$R_{241Pu/239Pu}$	$237.80 \cdot 10^{-6}$ mol/mol	$1.55 \cdot 10^{-6}$ mol/mol	normal	$-690 \cdot 10^{-6}$	$-1.1 \cdot 10^{-9}$ g/g	0.0 %
$R_{242Pu/239Pu}$	$75.700 \cdot 10^{-6}$ mol/mol	$390 \cdot 10^{-9}$ mol/mol	normal	$-690 \cdot 10^{-6}$	$-270 \cdot 10^{-12}$ g/g	0.0 %
e	2.718281828459					
M_{238Pu}	238.04955830 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$-89 \cdot 10^{-12}$	$-110 \cdot 10^{-18}$ g/g	0.0 %
M_{239Pu}	239.05216170 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$66 \cdot 10^{-9}$	$79 \cdot 10^{-15}$ g/g	0.0 %
M_{240Pu}	240.05381180 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$-64 \cdot 10^{-9}$	$-77 \cdot 10^{-15}$ g/g	0.0 %
M_{241Pu}	241.05684970 g/mol	$1.20 \cdot 10^{-6}$ g/mol	normal	$-680 \cdot 10^{-12}$	$-820 \cdot 10^{-18}$ g/g	0.0 %
M_{242Pu}	242.05874100 g/mol	$1.30 \cdot 10^{-6}$ g/mol	normal	$-220 \cdot 10^{-12}$	$-280 \cdot 10^{-18}$ g/g	0.0 %
τ_{238}	87.7400 a	0.0300 a	normal	0.0	0.0 g/g	0.0 %
τ_{239}	24100.0 a	11.0 a	normal	$9.1 \cdot 10^{-12}$	$100 \cdot 10^{-12}$ g/g	0.0 %
τ_{240}	6561.00 a	7.00 a	normal	not valid!	$-26 \cdot 10^{-24}$ g/g	0.0 %
τ_{241}	14.3250 a	0.0120 a	normal	not valid!	0.0 g/g	0.0 %
τ_{242}	$373.00 \cdot 10^{3}$ a	3000 a	normal	not valid!	$13 \cdot 10^{-24}$ g/g	0.0 %
m_{PuMP2}	2.1356800 g	$35.0 \cdot 10^{-6}$ g	normal	$330 \cdot 10^{-6}$	$12 \cdot 10^{-9}$ g/g	0.7 %
$m_{solution1027t}$	2969.5470 g	0.0125 g	normal	$-240 \cdot 10^{-9}$	$-3.0 \cdot 10^{-9}$ g/g	0.0 %
m_{Pu}	1.0 g	0.0 g	normal	0.0	0.0 g/g	0.0 %
$\eta_{IPuMP2Jan2007}$	0.998746 g/g	$200 \cdot 10^{-6}$ g/g		$700 \cdot 10^{-6}$	$140 \cdot 10^{-9}$ g/g	99.3 %
$\gamma_{Pumixture239}$	$702.011 \cdot 10^{-6}$ g/g	$141 \cdot 10^{-9}$ g/g				

$Rd_{240Pu/239Pu}$: decayed $^{240}Pu/^{239}Pu$ amount ratio in IRMM-1027t, 1 Nov 2017

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
Δt	10.83368 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}	24100.0 a	11.0 a	normal	$-290 \cdot 10^{-12}$	$-3.2 \cdot 10^{-9}$ mol/mol	0.0 %
τ_{240}	6561.00 a	7.00 a	normal	$3.9 \cdot 10^{-9}$	$27 \cdot 10^{-9}$ mol/mol	0.0 %
$Rd_{240Pu/239Pu}$	0.02241372 mol/mol	$2.55 \cdot 10^{-6}$ mol/mol				

$Rd_{241Pu/239Pu}$: decayed $^{241}Pu/^{239}Pu$ amount ratio in IRMM-1027t, 1 Nov 2017

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
Δt	10.83368 a					
$R_{241Pu/239Pu}$	$237.80 \cdot 10^{-6}$ mol/mol	$1.55 \cdot 10^{-6}$ mol/mol	normal	0.59	$920 \cdot 10^{-9}$ mol/mol	99.5 %
e	2.718281828459					
τ_{239}	24100.0 a	11.0 a	normal	$-1.8 \cdot 10^{-12}$	$-20 \cdot 10^{-12}$ mol/mol	0.0 %
τ_{241}	14.3250 a	0.0120 a	normal	$5.2 \cdot 10^{-6}$	$62 \cdot 10^{-9}$ mol/mol	0.5 %
$Rd_{241Pu/239Pu}$	$140.827 \cdot 10^{-6}$ mol/mol	$920 \cdot 10^{-9}$ mol/mol				

$Rd_{242Pu/239Pu}$: decayed $^{242}Pu/^{239}Pu$ amount ratio in IRMM-1027t, 1 Nov 2017

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
Δt	10.83368 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}	24100.0 a	11.0 a	normal	$-980 \cdot 10^{-15}$	$-11 \cdot 10^{-12}$ mol/mol	0.0 %
τ_{242}	$373.00 \cdot 10^{3}$ a	3000 a	normal	$4.1 \cdot 10^{-15}$	$12 \cdot 10^{-12}$ mol/mol	0.0 %
$Rd_{242Pu/239Pu}$	$75.722 \cdot 10^{-6}$ mol/mol	$390 \cdot 10^{-9}$ mol/mol				

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

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$R_{238Pu/239Pu}$	30.830·10^{-6} mol/mol	145·10^{-9} mol/mol	normal	-1.7·10^{-3}	-250·10^{-12} g	0.0 %
Δt	10.83368 a					
$R_{240Pu/239Pu}$	0.02243240 mol/mol	2.55·10^{-6} mol/mol	normal	-1.8·10^{-3}	-4.5·10^{-9} g	0.0 %
$R_{241Pu/239Pu}$	237.80·10^{-6} mol/mol	1.55·10^{-6} mol/mol	normal	-1.8·10^{-3}	-2.7·10^{-9} g	0.0 %
$R_{242Pu/239Pu}$	75.700·10^{-6} mol/mol	390·10^{-9} mol/mol	normal	-1.8·10^{-3}	-690·10^{-12} g	0.0 %
e	2.718281828459					
M_{238Pu}	238.04955830 g/mol	1.20·10^{-6} g/mol	normal	-230·10^{-12}	-270·10^{-18} g	0.0 %
M_{239Pu}	239.05216170 g/mol	1.20·10^{-6} g/mol	normal	170·10^{-9}	200·10^{-15} g	0.0 %
M_{240Pu}	240.05381180 g/mol	1.20·10^{-6} g/mol	normal	-160·10^{-9}	-200·10^{-15} g	0.0 %
M_{241Pu}	241.05684970 g/mol	1.20·10^{-6} g/mol	normal	-1.7·10^{-9}	-2.1·10^{-15} g	0.0 %
M_{242Pu}	242.05874100 g/mol	1.30·10^{-6} g/mol	normal	-550·10^{-12}	-720·10^{-18} g	0.0 %
τ_{238}	87.7400 a	0.0300 a	normal	0.0	0.0 g	0.0 %
τ_{239}	24100.0 a	11.0 a	normal	23·10^{-12}	250·10^{-12} g	0.0 %
τ_{240}	6561.00 a	7.00 a	normal	not valid!	-53·10^{-24} g	0.0 %
τ_{241}	14.3250 a	0.0120 a	normal	not valid!	0.0 g	0.0 %
τ_{242}	373.00·10^{3} a	3000 a	normal	not valid!	53·10^{-24} g	0.0 %
m_{PuMP2}	2.1356800 g	35.0·10^{-6} g	normal	840·10^{-6}	29·10^{-9} g	0.5 %
$m_{solution1027t}$	2969.5470 g	0.0125 g	normal	-600·10^{-9}	-7.5·10^{-9} g	0.0 %
m_{Pu}	1.0 g	0.0 g	normal	0.0	0.0 g	0.0 %
$\eta_{PuMP2Jan2007}$	0.998746 g/g	200·10^{-6} g/g		1.8·10^{-3}	360·10^{-9} g	73.9 %
$m_{aliquot1}$	2.549000 g	300·10^{-6} g	normal	700·10^{-6}	210·10^{-9} g	25.5 %
$m_{239Puvial1}$	1.789425·10^{-3} g	417·10^{-9} g				

Results:

Quantity	Value	Expanded Uncertainty	Coverage factor	Coverage
$\gamma_{Pumixture}$	$717.98 \cdot 10^{-6}$ g/g	$290 \cdot 10^{-9}$ g/g	2.00	manual
$\gamma_{Pumixture239}$	$702.01 \cdot 10^{-6}$ g/g	$280 \cdot 10^{-9}$ g/g	2.00	manual
$c_{Pumixture239}$	$2.9366 \cdot 10^{-6}$ mol/g	$1.2 \cdot 10^{-9}$ mol/g	2.00	manual
$c_{Pumixture}$	$3.0032 \cdot 10^{-6}$ mol/g	$1.2 \cdot 10^{-9}$ mol/g	2.00	manual
$Rd_{238Pu/239Pu}$	$28.31 \cdot 10^{-6}$ mol/mol	$270 \cdot 10^{-9}$ mol/mol	2.00	manual
$Rd_{240Pu/239Pu}$	0.0224137 mol/mol	0.011 % (relative)	1.00	manual
$Rd_{241Pu/239Pu}$	$140.83 \cdot 10^{-6}$ mol/mol	0.65 % (relative)	1.00	manual
$Rd_{242Pu/239Pu}$	$75.72 \cdot 10^{-6}$ mol/mol	0.52 % (relative)	1.00	manual
$fdnorm_{238Pu}$	$27.68 \cdot 10^{-6}$ mol/mol	$260 \cdot 10^{-9}$ mol/mol	2.00	manual
$fdnorm_{239Pu}$	0.9778435 mol/mol	$5.2 \cdot 10^{-6}$ mol/mol	2.00	manual
$fdnorm_{240Pu}$	0.0219171 mol/mol	$4.9 \cdot 10^{-6}$ mol/mol	2.00	manual
$fdnorm_{241Pu}$	$137.7 \cdot 10^{-6}$ mol/mol	$1.8 \cdot 10^{-6}$ mol/mol	2.00	manual
$fdnorm_{242Pu}$	$74.04 \cdot 10^{-6}$ mol/mol	$760 \cdot 10^{-9}$ mol/mol	2.00	manual
Md_{Pu}	239.0745859 g/mol	$6.9 \cdot 10^{-6}$ g/mol	2.00	manual
$wdnorm_{238Pu}$	$27.56 \cdot 10^{-6}$ g/g	$260 \cdot 10^{-9}$ g/g	2.00	manual
$wdnorm_{239Pu}$	0.9777517 g/g	$5.3 \cdot 10^{-6}$ g/g	2.00	manual
$wdnorm_{240Pu}$	0.0220069 g/g	$4.9 \cdot 10^{-6}$ g/g	2.00	manual
$wdnorm_{241Pu}$	$138.8 \cdot 10^{-6}$ g/g	$1.8 \cdot 10^{-6}$ g/g	2.00	manual
$wdnorm_{242Pu}$	$74.97 \cdot 10^{-6}$ g/g	$770 \cdot 10^{-9}$ g/g	2.00	manual
$m_{239Puvial1}$	$1.78943 \cdot 10^{-3}$ g	$420 \cdot 10^{-9}$ g	1.00	manual

Annex 15 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

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

Certificate of weighing

Reg. No. E.3911 **Date of issue**: 28 June 2018 **Page** 1 **of 2**

Applicant: R. Jakopic **Project:** IRMM-1027t
Description: IRMM-1027t vials for homogeneity with IRMM-046c
Request for analysis number: 4207 **ID number**: 29128
Date of request: 30 May 2018 **Weighing dates**: 6, 12 & 13 June 2018

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

Blend	IRMM-046c [g]	IRMM-046c, U95% [g]
1027t-145/046c-45-1	2.51251	0.00010
1027t-365/046c-45-2	2.49881	0.00010
1027t-541/046c-45-3	2.52797	0.00010
1027t-839/046c-45-4	2.48852	0.00010
1027t-1025/046c-69-1	2.58325	0.00010
1027t-21/046c-69-2	2.50364	0.00009
1027t-92/046c-69-3	2.51026	0.00009
1027t-247/046c-69-4	2.28005	0.00008
1027t-306/046c-76-1	2.51247	0.00008
1027t-455/046c-76-2	2.78003	0.00008
1027t-589/046c-76-3	2.39262	0.00008
1027t-660/046c-76-4	2.92142	0.00008
1027t-786/046c-84-1	2.46500	0.00009
1027t-876/046c-84-2	3.01640	0.00009
1027t-965/046c-84-3	2.51861	0.00008

Observations:
Masses were determined by substitution weighing on balance AT 261 with JRC inventory No. 1999 00337 27.

Traceability:
The certified mass values are traceable to the International Kilogram Prototype via regular calibrations of the JRC G2 principal mass standards. The set of working mass standards M 3, with JRC inventory No. 1996 00273, was used as reference in the mass determination.

Retieseweg, B-2440 Geel, Belgium; Tel : +32-(0)14-571 211

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

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

Rožle Jakopič
Nuclear Chemistry Laboratory Responsible

Carmel Hennessy
Analyst

Retieseweg, B-2440 Geel, Belgium; Tel.: +32-(0)14-571 211

Annex 16 The internal test report (4720) for the selected units of IRMM-1027t

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 # 4207

Requested by: Rozle Jakopic

Samples

Sample ID	Applicant sample identification
29128	IDMS for U and Pu for the IRMM-1027t single vials

Date of receipt of samples: May 2018

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-00360for Pu).

Sample ID	Analyte	Result (± expanded uncertainty[1])	Unit	Method[2]
Pu-IDMS, P180717				
Date:	**17/07/2018**			
1027t-21[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.118971313	mol / mol	TIMS/TE
1027t-21[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.118914956	mol / mol	TIMS/TE
1027t-21[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.118999387	mol / mol	TIMS/TE
1027t-21[4]	**$n(^{242}Pu)/n(^{239}Pu)$**	**0.11889(14)**	mol / mol	TIMS/TE
1027t-247[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.108317018	mol / mol	TIMS/TE
1027t-247[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.108317018	mol / mol	TIMS/TE
1027t-247[4]	**$n(^{242}Pu)/n(^{239}Pu)$**	**0.10825(12)**	mol / mol	TIMS/TE
1027t-455[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.132119214	mol / mol	TIMS/TE
1027t-455[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.132180396	mol / mol	TIMS/TE
1027t-455[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.132044136	mol / mol	TIMS/TE
1027t-455[4]	**$n(^{242}Pu)/n(^{239}Pu)$**	**0.13204(17)**	mol / mol	TIMS/TE

1027t-92[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.119215034	mol / mol	TIMS/TE
1027t-92[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.119232153	mol / mol	TIMS/TE
1027t-92[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.119263513	mol / mol	TIMS/TE
1027t-92[4]	**$n(^{242}Pu)/n(^{239}Pu)$**	**0.11917(13)**	mol / mol	TIMS/TE
1027t-306[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.119475334	mol / mol	TIMS/TE
1027t-306[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.119498194	mol / mol	TIMS/TE
1027t-306[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.11941226	mol / mol	TIMS/TE
1027t-306[4]	**$n(^{242}Pu)/n(^{239}Pu)$**	**0.11939(14)**	mol / mol	TIMS/TE
IRMM-290/A3				
Date:	**17/07/2018**			
290-A3[3]	$n(^{242}Pu)/n(^{239}Pu)$	1.001411697	mol / mol	TIMS/TE
290-A3[3]	$n(^{242}Pu)/n(^{239}Pu)$	1.000879857	mol / mol	TIMS/TE
290-A3[3]	$n(^{242}Pu)/n(^{239}Pu)$	1.001291438	mol / mol	TIMS/TE
290-A3[3]	$n(^{242}Pu)/n(^{239}Pu)$	1.000244051	mol / mol	TIMS/TE
290-A3[3]	$n(^{242}Pu)/n(^{239}Pu)$	1.000255477	mol / mol	TIMS/TE
290-A3[4]	$n(^{242}Pu)/n(^{239}Pu)$	1.000398336	mol / mol	TIMS/TE

Sample ID	Analyte	Result (± expanded uncertainty[1])	Unit	Method[2]
Pu-IDMS, P180808				
Date:	**08/08/2018**			
1027t-145[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.119331300	mol / mol	TIMS/TE
1027t-145[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.119348061	mol / mol	TIMS/TE
1027t-145[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.119318377	mol / mol	TIMS/TE
1027t-145[4]	**$n(^{242}Pu)/n(^{239}Pu)$**	**0.11932(12)**	mol / mol	TIMS/TE
1027t-541[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.120134425	mol / mol	TIMS/TE
1027t-541[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.120131541	mol / mol	TIMS/TE
1027t-541[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.120136142	mol / mol	TIMS/TE
1027t-541[4]	**$n(^{242}Pu)/n(^{239}Pu)$**	**0.12012(12)**	mol / mol	TIMS/TE
1027t-1025[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.122893083	mol / mol	TIMS/TE
1027t-1025[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.122732321	mol / mol	TIMS/TE

1027t-1025[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.12272102	mol / mol	TIMS/TE
1027t-1025[4]	**$n(^{242}Pu)/n(^{239}Pu)$**	**0.12277(17)**	mol / mol	TIMS/TE
1027t-365[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.11873078	mol / mol	TIMS/TE
1027t-365[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.11873658	mol / mol	TIMS/TE
1027t-365[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.118770948	mol / mol	TIMS/TE
1027t-365[4]	**$n(^{242}Pu)/n(^{239}Pu)$**	**0.11873(12)**	mol / mol	TIMS/TE
1027t-829[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.118217776	mol / mol	TIMS/TE
1027t-829[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.118229745	mol / mol	TIMS/TE
1027t-829[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.118225322	mol / mol	TIMS/TE
1027t-829[4]	**$n(^{242}Pu)/n(^{239}Pu)$**	**0.11821(12)**	mol / mol	TIMS/TE
IRMM-290/A3				
Date:	**08/08/2018**			
290-A3[3]	$n(^{242}Pu)/n(^{239}Pu)$	1.000281835	mol / mol	TIMS/TE
290-A3[3]	$n(^{242}Pu)/n(^{239}Pu)$	1.000296032	mol / mol	TIMS/TE
290-A3[3]	$n(^{242}Pu)/n(^{239}Pu)$	1.000232110	mol / mol	TIMS/TE
290-A3[3]	$n(^{242}Pu)/n(^{239}Pu)$	1.000361665	mol / mol	TIMS/TE
290-A3[3]	$n(^{242}Pu)/n(^{239}Pu)$	1.000475710	mol / mol	TIMS/TE
290-A3[4]	$n(^{242}Pu)/n(^{239}Pu)$	1.000068128	mol / mol	TIMS/TE

Sample ID	Analyte	Result (± expanded uncertainty[1])	Unit	Method[2]
Pu-IDMS, P180720				
Date:	**20/07/2018**			
1027t-589[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.113777093	mol / mol	TIMS/TE
1027t-589[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.113777093	mol / mol	TIMS/TE
1027t-589[4]	**$n(^{242}Pu)/n(^{239}Pu)$**	**0.11376(12)**	mol / mol	TIMS/TE
1027t-786[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.116984534	mol / mol	TIMS/TE
1027t-786[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.117029968	mol / mol	TIMS/TE
1027t-786[4]	**$n(^{242}Pu)/n(^{239}Pu)$**	**0.11699(13)**	mol / mol	TIMS/TE

1027t-965[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.119454615	mol / mol	TIMS/TE
1027t-965[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.119450627	mol / mol	TIMS/TE
1027t-965[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.11945304	mol / mol	TIMS/TE
1027t-965[4]	**$n(^{242}Pu)/n(^{239}Pu)$**	**0.11944(12)**	mol / mol	TIMS/TE
1027t-660[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.138686476	mol / mol	TIMS/TE
1027t-660[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.138672659	mol / mol	TIMS/TE
1027t-660[4]	**$n(^{242}Pu)/n(^{239}Pu)$**	**0.13866(14)**	mol / mol	TIMS/TE
1027t-876[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.143245343	mol / mol	TIMS/TE
1027t-876[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.143295713	mol / mol	TIMS/TE
1027t-876[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.143258171	mol / mol	TIMS/TE
1027t-876[4]	**$n(^{242}Pu)/n(^{239}Pu)$**	**0.14325(15)**	mol / mol	TIMS/TE
NBL126QC2[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.245151064	mol / mol	TIMS/TE
NBL126QC2[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.245238994	mol / mol	TIMS/TE
NBL126QC2[3]	$n(^{242}Pu)/n(^{239}Pu)$	0.245157849	mol / mol	TIMS/TE
NBL126QC2[4]	**$n(^{242}Pu)/n(^{239}Pu)$**	**0.24515(26)**	mol / mol	TIMS/TE
IRMM-290/A3				
Date:	**20/07/2018**			
290-A3[3]	$n(^{242}Pu)/n(^{239}Pu)$	1.000027033	mol / mol	TIMS/TE
290-A3[3]	$n(^{242}Pu)/n(^{239}Pu)$	1.000312015	mol / mol	TIMS/TE
290-A3[3]	$n(^{242}Pu)/n(^{239}Pu)$	1.000530538	mol / mol	TIMS/TE
290-A3[3]	$n(^{242}Pu)/n(^{239}Pu)$	1.000394837	mol / mol	TIMS/TE
290-A3[3]	$n(^{242}Pu)/n(^{239}Pu)$	1.000288128	mol / mol	TIMS/TE

Sample ID	Analyte	Result (± expanded uncertainty[1])	Unit	Method[3]
U-IDMS, T180627				
Date:	**29/06/2018**			
1027t-589[3]	$n(^{233}U)/n(^{238}U)$	0.066861771	mol / mol	TIMS/TE
1027t-589[3]	$n(^{233}U)/n(^{238}U)$	0.066845075	mol / mol	TIMS/TE

1027t-589[4]	***n*(^{233}U)/*n*(^{238}U)**	**0.066862(43)**	mol / mol	TIMS/TE
1027t-786[3]	*n*(^{233}U)/*n*(^{238}U)	0.06869715	mol / mol	TIMS/TE
1027t-786[3]	*n*(^{233}U)/*n*(^{238}U)	0.068729837	mol / mol	TIMS/TE
1027t-786[4]	***n*(^{233}U)/*n*(^{238}U)**	**0.086722(52)**	mol / mol	TIMS/TE
1027t-965[3]	*n*(^{233}U)/*n*(^{238}U)	0.070197851	mol / mol	TIMS/TE
1027t-965[3]	*n*(^{233}U)/*n*(^{238}U)	0.070191971	mol / mol	TIMS/TE
1027t-965[3]	*n*(^{233}U)/*n*(^{238}U)	0.070168327	mol / mol	TIMS/TE
1027t-965[4]	***n*(^{233}U)/*n*(^{238}U)**	**0.070195(45)**	mol / mol	TIMS/TE
1027t-660[3]	*n*(^{233}U)/*n*(^{238}U)	0.081510025	mol / mol	TIMS/TE
1027t-660[3]	*n*(^{233}U)/*n*(^{238}U)	0.081446256	mol / mol	TIMS/TE
1027t-660[4]	***n*(^{233}U)/*n*(^{238}U)**	**0.081488(60)**	mol / mol	TIMS/TE
1027t-876[3]	*n*(^{233}U)/*n*(^{238}U)	0.084171879	mol / mol	TIMS/TE
1027t-876[3]	*n*(^{233}U)/*n*(^{238}U)	0.084158368	mol / mol	TIMS/TE
1027t-876[3]	*n*(^{233}U)/*n*(^{238}U)	0.084202018	mol / mol	TIMS/TE
1027t-876[4]	***n*(^{233}U)/*n*(^{238}U)**	**0.084188(56)**	mol / mol	TIMS/TE
CRM-116A-QC2[3]	*n*(^{233}U)/*n*(^{238}U)	16.23888073	mol / mol	TIMS/TE
CRM-116A-QC2[3]	*n*(^{233}U)/*n*(^{238}U)	16.24403765	mol / mol	TIMS/TE
CRM-116A-QC2[3]	*n*(^{233}U)/*n*(^{238}U)	16.24659513	mol / mol	TIMS/TE
CRM-116A-QC2[4]	***n*(^{233}U)/*n*(^{238}U)**	**16.245(11)**	mol / mol	TIMS/TE
IRMM-074/10				
Date:	**29/06/2018**			
074/10[3]	*n*(^{235}U)/*n*(^{238}U)	1.000610966	mol / mol	TIMS/TE
074/10[3]	*n*(^{235}U)/*n*(^{238}U)	1.000033828	mol / mol	TIMS/TE
074/10[3]	*n*(^{235}U)/*n*(^{238}U)	0.999910872	mol / mol	TIMS/TE
074/10[3]	*n*(^{235}U)/*n*(^{238}U)	1.000314079	mol / mol	TIMS/TE
074/10[3]	*n*(^{235}U)/*n*(^{238}U)	1.000059095	mol / mol	TIMS/TE

Sample ID	Analyte	Result (± expanded uncertainty[1])	Unit	Method[2]
U-IDMS, T180710				
Date:	**11/07/2018**			
1027t-21[3]	$n(^{233}U)/n(^{238}U)$	0.069893895	mol / mol	TIMS/TE
1027t-21[3]	$n(^{233}U)/n(^{238}U)$	0.069905641	mol / mol	TIMS/TE
1027t-21[3]	$n(^{233}U)/n(^{238}U)$	0.069911369	mol / mol	TIMS/TE
1027t-21[4]	**$n(^{233}U)/n(^{238}U)$**	**0.069885(38)**	mol / mol	TIMS/TE
1027t-247[3]	$n(^{233}U)/n(^{238}U)$	0.063717811	mol / mol	TIMS/TE
1027t-247[3]	$n(^{233}U)/n(^{238}U)$	0.06365978	mol / mol	TIMS/TE
1027t-247[3]	$n(^{233}U)/n(^{238}U)$	0.063619425	mol / mol	TIMS/TE
1027t-247[4]	**$n(^{233}U)/n(^{238}U)$**	**0.063649(66)**	mol / mol	TIMS/TE
1027t-455[3]	$n(^{233}U)/n(^{238}U)$	0.077606069	mol / mol	TIMS/TE
1027t-455[3]	$n(^{233}U)/n(^{238}U)$	0.077610651	mol / mol	TIMS/TE
1027t-455[3]	$n(^{233}U)/n(^{238}U)$	0.077634166	mol / mol	TIMS/TE
1027t-455[4]	**$n(^{233}U)/n(^{238}U)$**	**0.077597(44)**	mol / mol	TIMS/TE
1027t-92[3]	$n(^{233}U)/n(^{238}U)$	0.070071313	mol / mol	TIMS/TE
1027t-92[3]	$n(^{233}U)/n(^{238}U)$	0.07005963[illegible]	mol / mol	TIMS/TE
1027t-92[3]	$n(^{233}U)/n(^{238}U)$	0.07009910[illegible]	mol / mol	TIMS/TE
1027t-92[4]	**$n(^{233}U)/n(^{238}U)$**	**0.070058(44)**	mol / mol	TIMS/TE
1027t-306[3]	$n(^{233}U)/n(^{238}U)$	0.070205071	mol / mol	TIMS/TE
1027t-306[3]	$n(^{233}U)/n(^{238}U)$	0.07017961	mol / mol	TIMS/TE
1027t-306[3]	$n(^{233}U)/n(^{238}U)$	0.070173346	mol / mol	TIMS/TE
1027t-306[4]	**$n(^{233}U)/n(^{238}U)$**	**0.070168(42)**	mol / mol	TIMS/TE
IRMM-074/10				
Date:	**11/07/2018**			
074/10[3]	$n(^{235}U)/n(^{238}U)$	1.000628244	mol / mol	TIMS/TE
074/10[3]	$n(^{235}U)/n(^{238}U)$	1.00050969	mol / mol	TIMS/TE
074/10[3]	$n(^{235}U)/n(^{238}U)$	1.000420379	mol / mol	TIMS/TE

074/10[3]	$n(^{235}U)/n(^{238}U)$	1.000285576	mol / mol	TIMS/TE
074/10[3]	$n(^{235}U)/n(^{238}U)$	1.000015791	mol / mol	TIMS/TE
074/10[3]	$n(^{235}U)/n(^{238}U)$	1.000640684	mol / mol	TIMS/TE

Sample ID	Analyte	Result (± expanded uncertainty[1])	Unit	Method[2]
U-IDMS, T180807				
Date:	**09/08/2018**			
1027t-145[3]	$n(^{233}U)/n(^{238}U)$	0.07012242	mol / mol	TIMS/TE
1027t-145[3]	$n(^{233}U)/n(^{238}U)$	0.070125831	mol / mol	TIMS/TE
1027t-145[3]	$n(^{233}U)/n(^{238}U)$	0.070117036	mol / mol	TIMS/TE
1027t-145[4]	$\mathbf{n(^{233}U)/n(^{238}U)}$	**0.070105(35)**	mol / mol	TIMS/TE
1027t-541[3]	$n(^{233}U)/n(^{238}U)$	0.070585328	mol / mol	TIMS/TE
1027t-541[3]	$n(^{233}U)/n(^{238}U)$	0.070635068	mol / mol	TIMS/TE
1027t-541[3]	$n(^{233}U)/n(^{238}U)$	0.070624881	mol / mol	TIMS/TE
1027t-541[4]	$\mathbf{n(^{233}U)/n(^{238}U)}$	**0.070598(46)**	mol / mol	TIMS/TE
1027t-1025[3]	$n(^{233}U)/n(^{238}U)$	0.072125644	mol / mol	TIMS/TE
1027t-1025[3]	$n(^{233}U)/n(^{238}U)$	0.072188852	mol / mol	TIMS/TE
1027t-1025[3]	$n(^{233}U)/n(^{238}U)$	0.072199373	mol / mol	TIMS/TE
1027t-1025[4]	$\mathbf{n(^{233}U)/n(^{238}U)}$	**0.072154(58)**	mol / mol	TIMS/TE
1027t-365[3]	$n(^{233}U)/n(^{238}U)$	0.069760201	mol / mol	TIMS/TE
1027t-365[3]	$n(^{233}U)/n(^{238}U)$	0.069817555	mol / mol	TIMS/TE
1027t-365[3]	$n(^{233}U)/n(^{238}U)$	0.069792331	mol / mol	TIMS/TE
1027t-365[4]	$\mathbf{n(^{233}U)/n(^{238}U)}$	**0.069773(47)**	mol / mol	TIMS/TE
1027t-839[3]	$n(^{233}U)/n(^{238}U)$	0.069434502	mol / mol	TIMS/TE
1027t-839[3]	$n(^{233}U)/n(^{238}U)$	0.069409325	mol / mol	TIMS/TE
1027t-839[3]	$n(^{233}U)/n(^{238}U)$	0.069488414	mol / mol	TIMS/TE
1027t-839[4]	$\mathbf{n(^{233}U)/n(^{238}U)}$	**0.069427(58)**	mol / mol	TIMS/TE

IRMM-074/10				
Date:	09/08/2018			
074/10[3]	$n(^{235}U)/n(^{238}U)$	1.000591668	mol / mol	TIMS/TE
074/10[3]	$n(^{235}U)/n(^{238}U)$	1.000528552	mol / mol	TIMS/TE
074/10[3]	$n(^{235}U)/n(^{238}U)$	1.00010362	mol / mol	TIMS/TE
074/10[3]	$n(^{235}U)/n(^{238}U)$	1.000406184	mol / mol	TIMS/TE
074/10[3]	$n(^{235}U)/n(^{238}U)$	1.000270523	mol / mol	TIMS/TE
074/10[3]	$n(^{235}U)/n(^{238}U)$	1.000518403	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	Raw data without K-factor correction using standard
	4	Average data of replicates corrected for mass fraction (K-factor using standard)

Files name(s) of raw data

For Pu measurements:
G:\JRC.G.2\Nuclear Safeguards\Nuclear\PUTON DATA - SHARED\IRMM LSD 1027t
Data Files:
P180717 Pu IDMS IRMM-1027t.xls
P180808 1027t Pu IDMS.xls
P180720 Pu IDMS 1027t QC.xls

For U measurements:
G:\JRC.G.2\Nuclear Safeguards\Nuclear\TRITON DATA - SHARED\LSD 1027t
Data Files:
T180807 U 1027t IDMS vials.xls
T180710 U 1027t IDMS.xls
T180627 U 1027t IDMS.xls

13/09/2018 ....

Date | Signature Analyst | Name + Signature Laboratory Responsible Laboratory Name: .....

Annex 17 Short term stability study of blank CAB/DOP coating and blank CMC foam test samples.

The test lasted for 1 week. The photographs were made after immediately preparing the samples (before test) and after storing them at different temperatures for 1 week (after test). The reference temperature was chosen at +18 °C, and +4 °C and +60 °C were chosen as lower and higher temperatures, according to the isochronous study.

Figure 27 Blank CAB/DOP coating before the short term stability test

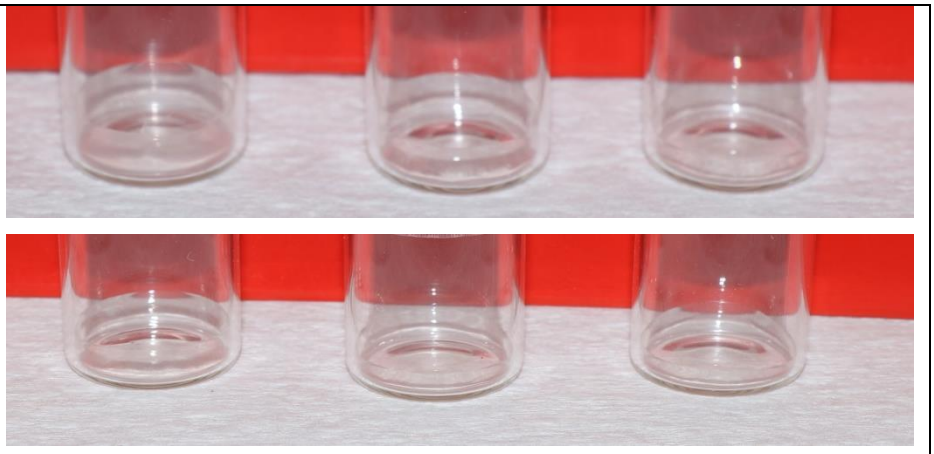
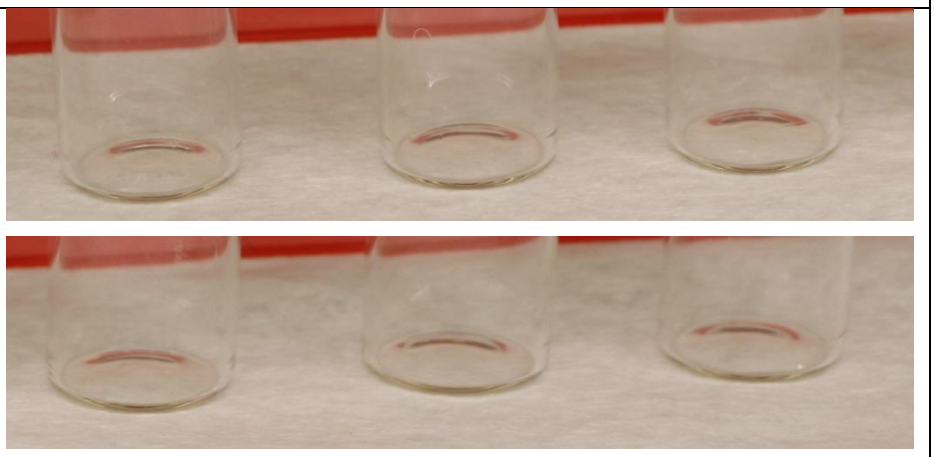
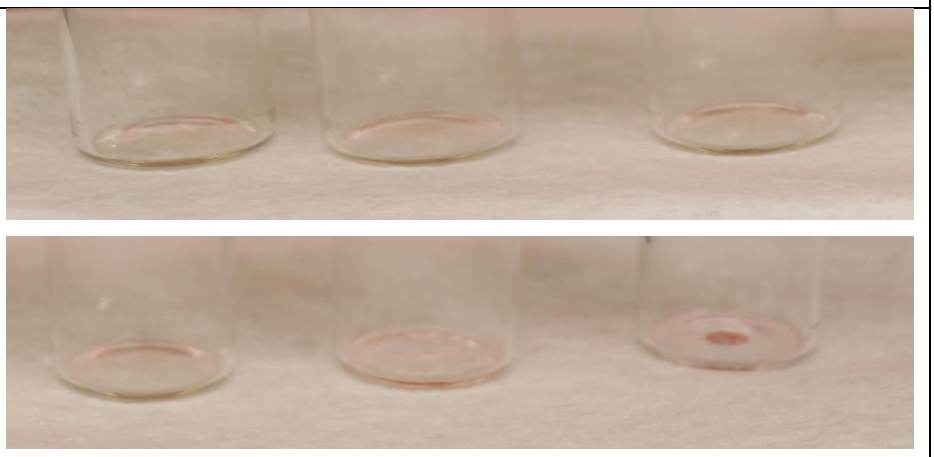
+ 18 °C	
+ 4 °C	
+60 °C	

Figure 28 Blank CAB/DOP coating after the short term stability test

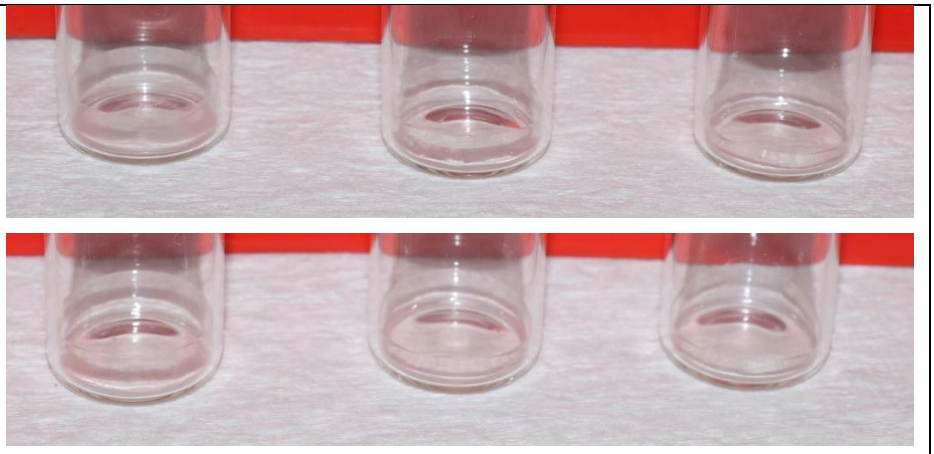
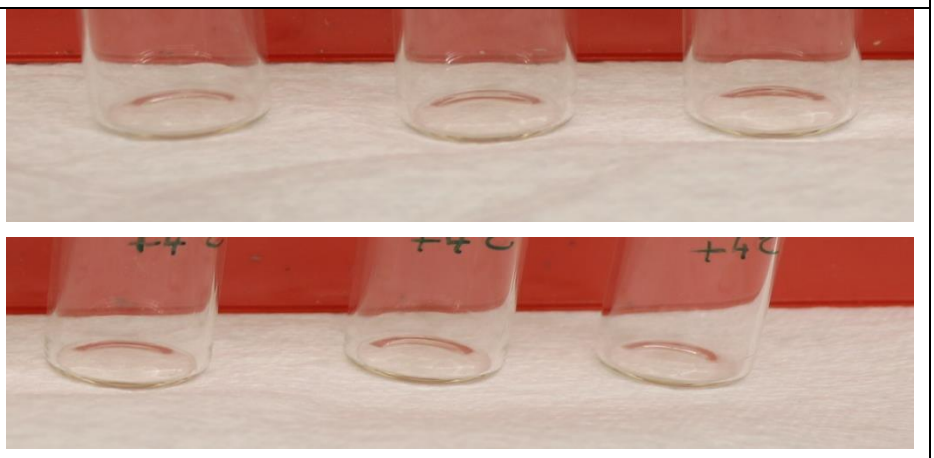
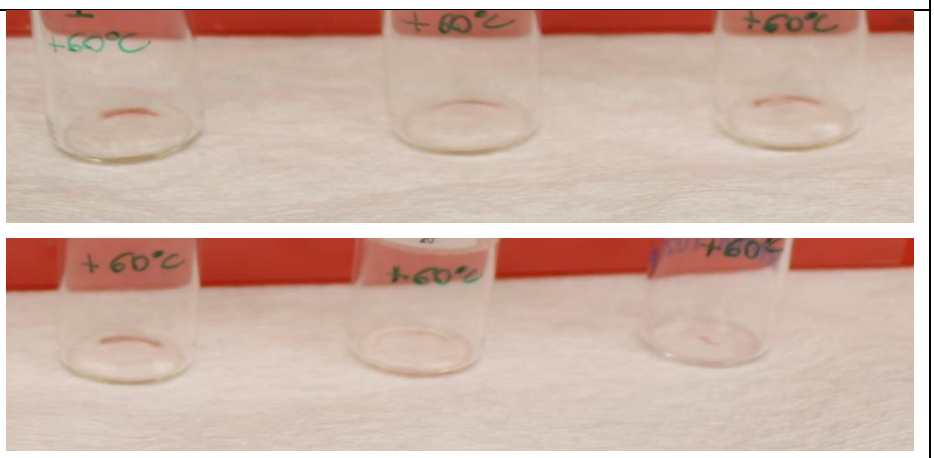
+ 18 °C	
+ 4 °C	
+60 °C	

Figure 29 Blank CMC foam – before the short term stability test

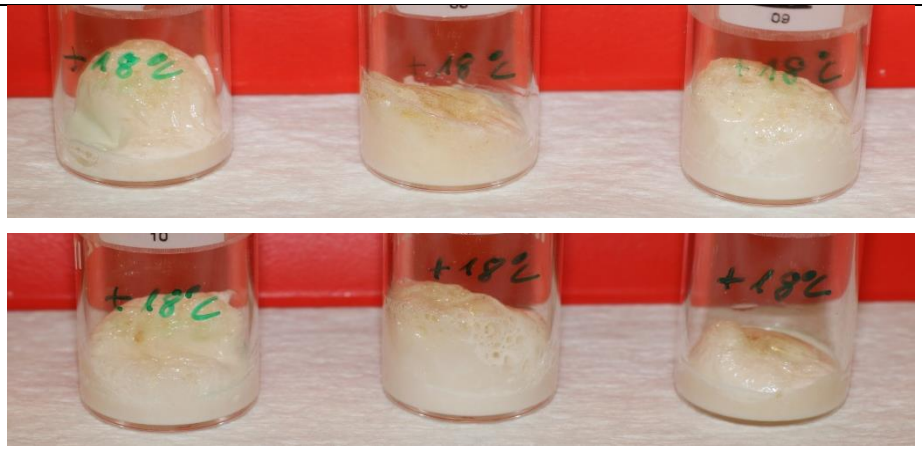
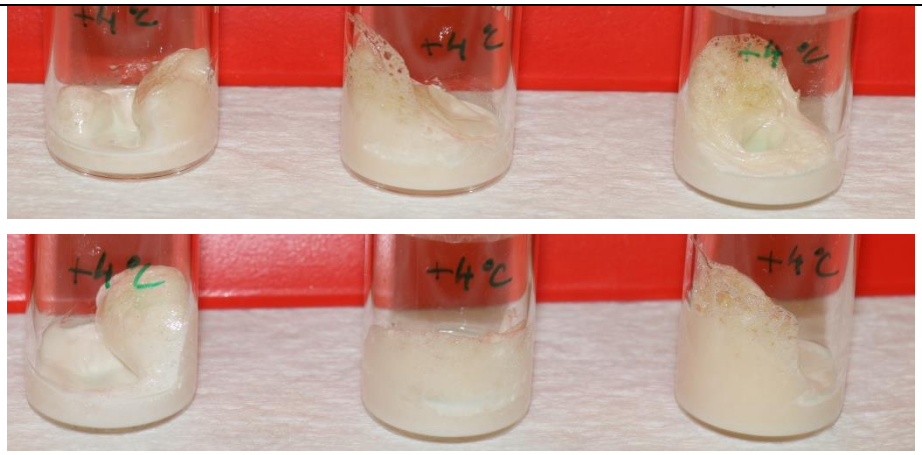
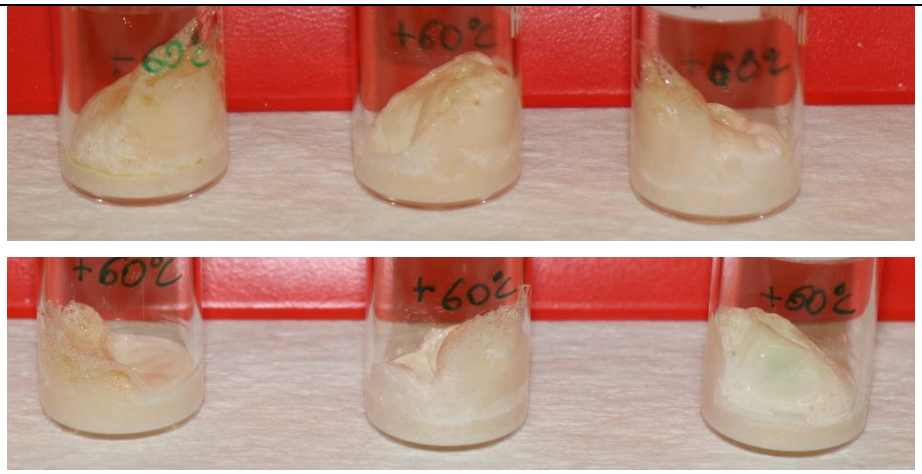
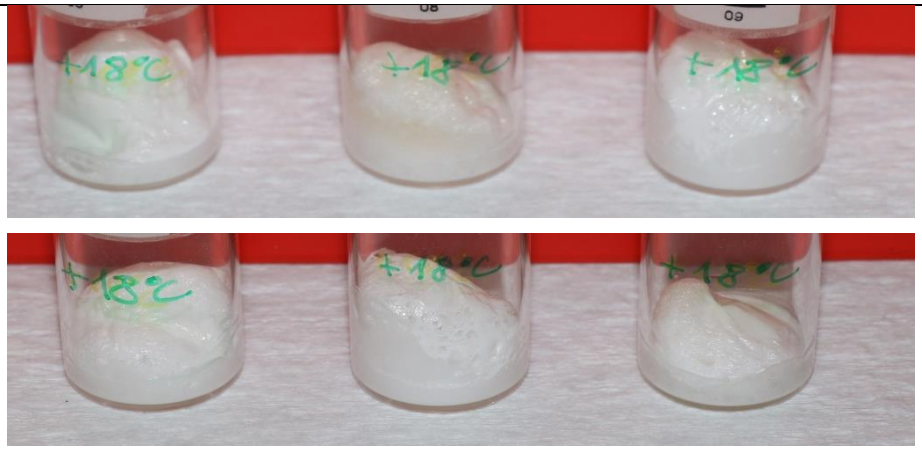
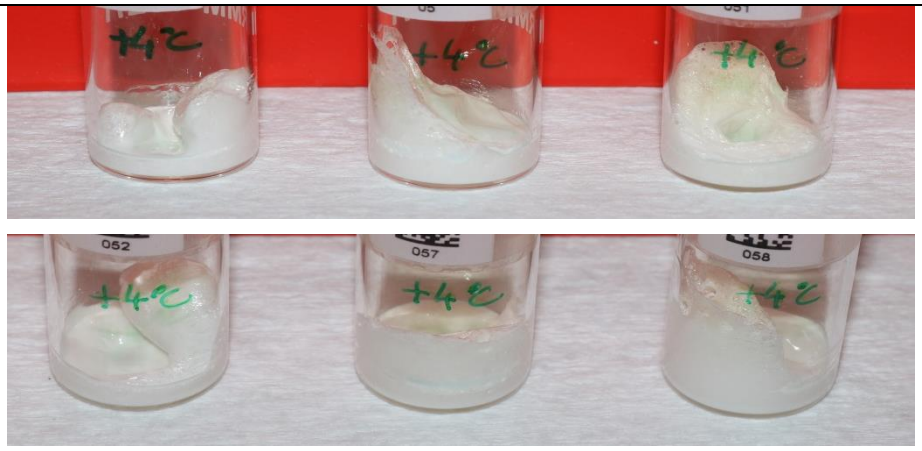
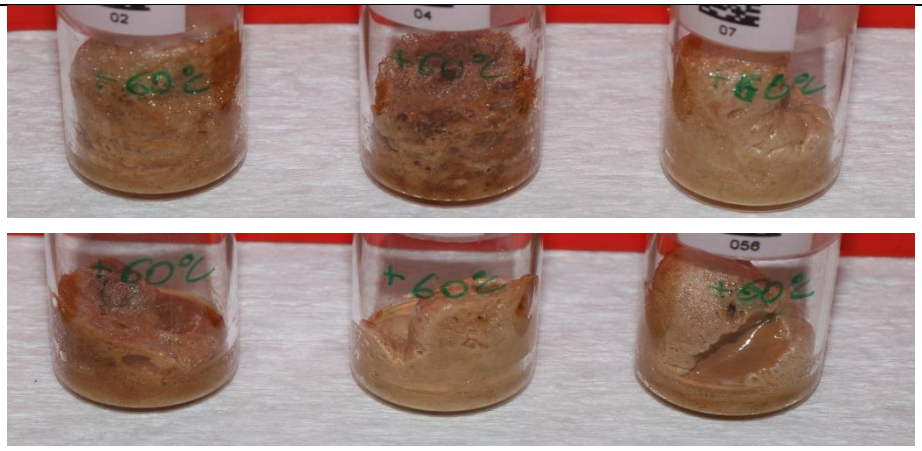
+ 18 °C	
+ 4 °C	
+60 °C	

Figure 30 Blank CMC foam – after the short term stability test

+ 18 °C	
+ 4 °C	
+60 °C	

GETTING IN TOUCH WITH THE EU

In person
All over the European Union there are hundreds of Europe Direct information centres. You can find the address of the centre nearest you at: http://europea.eu/contact

On the phone or by email
Europe Direct is a service that answers your questions about the European Union. You can contact this service:
- by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),
- at the following standard number: +32 22999696, or
- by electronic mail via: http://europa.eu/contact

FINDING INFORMATION ABOUT THE EU

Online
Information about the European Union in all the official languages of the EU is available on the Europa website at: http://europa.eu

EU publications
You can download or order free and priced EU publications from EU Bookshop at: http://bookshop.europa.eu. Multiple copies of free publications may be obtained by contacting Europe Direct or your local information centre (see http://europa.eu/contact).

KJ-NA-29742-EN-N

JRC Mission

As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.

EU Science Hub
ec.europa.eu/jrc

@EU_ScienceHub

EU Science Hub - Joint Research Centre

Joint Research Centre

EU Science Hub

Publications Office

doi:10.2760/639219

ISBN 978-92-76-03326-4