European Commission

JRC REFERENCE MATERIALS REPORT

CERTIFICATION REPORT

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

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

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2021

Joint Research Centre

EUR 30759 EN

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

JRC125500

EUR 30759 EN

PDF ISBN 978-92-76-40041-7 ISSN 1831-9424 doi:10.2760/59260

Luxembourg: Publications Office of the European Union, 2021

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How to cite this report: Toth, K. et al, Preparation and Certification of Large-Sized Dried (LSD) Spike:-IRMM-1027v *Certified reference material for the masses of ^{239}Pu, ^{235}U, ^{238}U and Pu and U isotope amount ratios*, EUR 30759 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-40041-7, doi: 10.2760/59260, JRC125500

Contents

Acknowledgement

The authors would like to thank:

the experts of the Certification Advisory Panel: Sébastien Picart, Commissariat à l'Energie Atomique et aux Energies Alternatives (CEA), France; Thomas Prohaska, Montanuniversität Leoben, Austria; Jochen Vogl, Bundesanstalt für Materialprüfung (BAM), Germany, for reviewing the certification report.

Rüdiger Kessel, Metrodata GmbH, Germany, for discussions on GUM, GUM WB and related topics.

David Vanleeuw, Goedele Sibbens, Viktor Jobbágy, JRC G.2., Belgium, for alpha spectrometry measurements.

Saskia Werelds, JRC G.2., Belgium, for her technical assistance throughout the project, Theo Drooghmans, JRC G.2., Belgium, and Marleen van Bocxstaele, JRC F.1., Belgium, for arrangements in the transport of the CRM material.

Mika Sumi, Urska Repinc from the IAEA-SGAS, Austria and Evelyn Zuleger, Ana Maria Sanchez Hernandez, Karin Casteleyn and the JRC G.II.6. and JRC G.II.8 analytical service from the JRC-Karlsruhe, Germany for carrying out external verification measurements on the selected units of the IRMM-1027v LSD spikes.

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Abstract

Large-Sized Dried (LSD) spikes are used as a fundamental part of the fissile material control of irradiated nuclear fuel and have been provided on a regular basis to safeguards authorities and industry for 30 years [1]. This report describes the preparation and certification of a new batch of LSD spikes. IRMM-1027v is a dried mixture of uranyl- and plutonium nitrate in cellulose acetate butyrate with dioctyl phthalate (CAB/DOP) or carboxymethyl cellulose (CMC). The material is certified for the masses of ^{235}U, ^{238}U and ^{239}Pu 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 [2]. The homogeneity and stability was assessed in accordance with ISO Guide 35:2017 [3] and the uncertainties of the certified values were calculated in accordance with Guide to the Expression of Uncertainty in Measurement (GUM) [4].

The certified reference materials uranium metal EC NRM 101, enriched uranium metal NBL PO CRM 116-A and plutonium metal CETAMA MP2 were used as starting materials to prepare the mother solution. This solution was dispensed into individual vials by means of an automated robot system and subsequently evaporated to dryness. A solution of an organic substance either cellulose acetate butyrate with dioctyl phthalate (CAB/DOP) or carboxymethyl cellulose (CMC) was added to the spike material, evaporated and dried. The organic matrix serves as a stabiliser to retain the dried nuclear material at the bottom of the vial. In total, 905 units were produced.

The heterogeneity of the batch was estimated based on the between-unit standard deviation and stability during dispatch and storage was assessed in accordance with ISO Guide 35:2017 [3].

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 and indicative values with the exception of the ^{233}U values were confirmed by isotope dilution thermal ionisation mass spectrometry (ID-TIMS), thermal ionisation mass spectrometry (TIMS) and the $n(^{238}\mathrm{Pu})/n(^{239}\mathrm{Pu})$ by alpha spectroscopy as independent methods on randomly selected units of IRMM-1027v or the mother solution.

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 54 mg of uranium with a relative mass fraction $m(^{235}\mathrm{U})/m(\mathrm{U})$ of 19.2 % and 1.8 mg of plutonium with a relative mass fraction $m(^{239}\mathrm{Pu})/m(\mathrm{Pu})$ of 97.8 % as dried nitrates in CAB/DOP or CMC.

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

The following values were assigned:

	Isotope amount ratios	
	Certified value 1) [mol/mol]	Uncertainty 2) [mol/mol]
$n(^{234}\mathrm{U})/n(^{238}\mathrm{U})$	0.0027807	0.0000023
$n(^{235}\mathrm{U})/n(^{238}\mathrm{U})$	0.242509	0.000035
$n(^{236}\mathrm{U})/n(^{238}\mathrm{U})$	0.0022322	0.0000018
$n(^{238}\mathrm{Pu})/n(^{239}\mathrm{Pu})$	0.00002787	0.00000026
$n(^{240}\mathrm{Pu})/n(^{239}\mathrm{Pu})$	0.0224103	0.0000051
$n(^{241}\mathrm{Pu})/n(^{239}\mathrm{Pu})$	0.0001279	0.0000017
$n(^{242}\mathrm{Pu})/n(^{239}\mathrm{Pu})$	0.00007573	0.00000078

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

1) The certified values are traceable to the values on the respective metal certificates (EC NRM 101, NBL PO CRM 116-A and CETAMA MP2, Annexes 2-7) and consequently either partly to the SI or to the national metrology data base for the United States. The reference date for the plutonium and uranium isotope amount ratios is November 1, 2019.

2) The reference material was produced in compliance with ISO/IEC 17034:2016 and certified in accordance with ISO Guide 35:2017. The uncertainty of the certified value is the expanded uncertainty with a coverage factor k = 2 with the exception of $n(^{235}\mathrm{U})/n(^{238}\mathrm{U})$ ratio value, which has a coverage factor k = 2.2 based on the t-distribution for the associated effective degrees of freedom (df_{eff} = 13). The expanded uncertainties correspond to a level of confidence of about 95 % estimated in accordance with ISO/IEC Guide 98-3:2008:2008, Guide to the Expression of Uncertainty in Measurement (GUM:2008).

The atomic masses of radionuclides were obtained from M. Wang et al. [5]

The half-lives of radionuclides were obtained from DDEP-BIPM (Table of radionuclides) [6] and R. Wellum et al. [7].

The following values for uranium and plutonium isotopic mass fraction, amount content, mass fraction and isotope amount ratios for the nitrate solution of IRMM-1027v were also assigned as indicative values:

Indicative Values		
	Isotope amount ratio	
	Indicative value [2] [mol/mol]	Uncertainty [3] [mol/mol]
$n(^{233}\mathrm{U})/n(^{238}\mathrm{U})$ [1]	0.0000000909	0.0000000020
	Isotope mass fraction (·100)	
	Indicative value [2] [g/g]	Uncertainty [3] [g/g]
$m(^{233}\mathrm{U})/m(\mathrm{U})$ [1, 4]	0.00000715	0.00000016
$m(^{234}\mathrm{U})/m(\mathrm{U})$ [4]	0.21970	0.00018
$m(^{235}\mathrm{U})/m(\mathrm{U})$ [4]	19.2420	0.0023
$m(^{236}\mathrm{U})/m(\mathrm{U})$ [4]	0.17787	0.00014
$m(^{238}\mathrm{U})/m(\mathrm{U})$ [4]	80.3604	0.0023
$m(^{238}\mathrm{Pu})/m(\mathrm{Pu})$ [4]	0.002713	0.000026
$m(^{239}\mathrm{Pu})/m(\mathrm{Pu})$ [4]	97.77680	0.00052
$m(^{240}\mathrm{Pu})/m(\mathrm{Pu})$ [4]	2.20039	0.00049
$m(^{241}\mathrm{Pu})/m(\mathrm{Pu})$ [4]	0.01261	0.00016
$m(^{242}\mathrm{Pu})/m(\mathrm{Pu})$ [4]	0.007497	0.000077
	Amount content	
	Value [2, 4] [µmol/g solution]	Uncertainty [3] [µmol/g solution]
$^{235}\mathrm{U}$	17.6059	0.0025
$^{238}\mathrm{U}$	72.5990	0.0039
U	90.5688	0.0045
$^{239}\mathrm{Pu}$	2.9680	0.0012
Pu	3.0352	0.0012
	Mass fraction	
	Value [2, 4] [mg/g solution]	Uncertainty [3] [mg/g solution]
$^{235}\mathrm{U}$	4.13817	0.00059
$^{238}\mathrm{U}$	17.28224	0.00092
U	21.5059	0.00011
$^{239}\mathrm{Pu}$	0.70950	0.00029
Pu	0.72564	0.00029

[1] The $n(^{233}\mathrm{U})/n(^{238}\mathrm{U})$ isotope amount ratio and $m(^{233}\mathrm{U})/m(\mathrm{U})$ isotope mass fraction values could not be verified because it is below the detection limit of the ID-TIMS.

[2] Indicative values are values that refer to the nitrate solution and are derived from the certified values with the exception of $n(^{233}\mathrm{U})/n(^{238}\mathrm{U})$ isotope amount ratio. Therefore, they are also traceable to the values on the respective metal certificates (EC NRM 101, NBL PO CRM 116-A and CETAMA MP2) and consequently either partly to the SI or to the national metrology data base for the United States. The reference date for the plutonium and uranium isotopic mass fraction, amount content, mass fractions and isotope amount ratios of the mother solution of IRMM-1027v is November 1, 2019.

[3] The reference material was produced in compliance with ISO/IEC 17034:2016 and certified in accordance with ISO Guide 35:2017. The uncertainty of the indicative value is the expanded uncertainty with a coverage factor k = 2 with the exception of $n(^{233}\mathrm{U})/n(^{238}\mathrm{U})$ and $m(^{233}\mathrm{U})/m(\mathrm{U})$ values, which

has a coverage factor k = 3.1 (df_{eff} = 3), ^{235}U amount content and mass fraction values, which have a coverage factor k = 2.3 (df_{eff} = 9) and the ^{235}U and ^{238}U isotope mass fraction values which have a coverage factor k = 2.2 (df_{eff} = 13) based on the t-distribution for the associated effective degrees of freedom. The expanded uncertainties correspond to a level of confidence of about 95 % estimated in accordance with ISO/IEC Guide 98-3:2008, Guide to the Expression of Uncertainty in Measurement (GUM:2008).

4) Isotope mass fraction is expressed as ($^{xxx}U/U_{tot}$)x100 and ($^{xxx}Pu/Pu_{tot}$)x100.

5) Nitrate solution before dispensing, drying and application of CAB/DOP or CMC.

The atomic masses of radionuclides were obtained from M. Wang et al. [5]

The half-lives of radionuclides were obtained from DDEP-BIPM (Table of radionuclides) [6] and R. Wellum et al. [7].

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 [8]. 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. Currently these international target values are revised by the IAEA jointly with experts from respective stakeholder domains towards the release of the ITVs-2020.

The series of IRMM-1027 Large-Sized Dried (LSD) spikes were prepared by the Joint Research Centre of the European Commission (EC-JRC) to meet the existing requirements for reliable isotope reference materials for the accountancy measurements of uranium and plutonium by isotope dilution mass spectrometry (IDMS) in compliance with the ITVs-2010 in spent nuclear fuel. These spikes contain relatively large amounts of uranium and plutonium (about 55 mg U and 2 mg Pu), isotopically different from the uranium and plutonium in the test sample and are in dried nitrate form. Approximately 1000 units of IRMM-1027 LSD spikes are prepared annually to fulfil the demands for fissile material control from European Safeguards Authorities and industry [9, 10].

1.2 Choice of the material

The IRMM-1027v batch of LSD spikes was prepared from natural uranium (EC NRM 101), enriched uranium (NBL PO CRM 116-A) and plutonium (CETAMA MP2) certified reference metals (Annex 2-Annex 6). Each unit of IRMM-1027v contains about 54 mg of uranium with a relative isotope mass fraction $m(^{235}U)/m(U)$ of 19.2% and 1.8 mg of plutonium with a relative isotope mass fraction $m(^{239}Pu)/m(Pu)$ of 97.8 %. The relative isotope mass fraction $m(^{235}U)/m(U)$ is below 20 %, thus the uranium is classified as "low enriched" for accountability purposes.

Individual units are certified for the mass of ^{239}Pu, ^{235}U and ^{238}U and for the plutonium and uranium isotope amount ratios. The uranium and plutonium amount content and mass in a single IRMM-1027 LSD spike is such that no dilution of a typical sample of dissolved nuclear fuel to be analysed 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 tailor-made headspace vial, in the following referred to as “penicillin vial”, supplied by Euro-Scientific, Belgium.

From the batch IRMM-1027f [11] to the batch IRMM-1027s [12], the cellulose acetate butyrate (CAB) has been used as a stabilising material for the IRMM-1027 LSD spikes for transport, thus for short-term stability purposes. The CAB produces a stable layer at the bottom of the vial and guarantees the integrity of the LSD spikes for about 3 years [13]. Customers, however, require a longer shelf-life of IRMM-1027 LSD spikes, hence JRC-Geel and JRC-Karlsruhe joined their forces to investigate new stabilizing matrices in the framework of the Innovative Nuclear Reference Materials for EURATOM Safeguards and Industry (INS-CRM) exploratory research project [14]. The main objective of the project was to find potential materials that would prolong the shelf-life of LSD spikes from 3 to 5 years or even beyond. The new coatings should fulfil additional requirements such as ready dissolution in nitric acid and a lack of interference with chemical separations or mass spectrometry measurements. Among the tested materials, carboxymethyl cellulose (CMC) has shown very promising results [15, 16]. Hence it was applied from the batch IRMM-1027t onwards [17].

As a result of the successful outcome of the exploratory research project and the real application on the IRMM-1027t and u [18] LSD spikes, the same approach was applied when preparing the IRMM-1027v spikes. Thus, they were coated with either CMC or CAB/dioctyl phthalate (DOP) material.

1.3 Design of the project

The mother solution was prepared gravimetrically by dissolving uranium and plutonium certified reference metals in hydrochloric and nitric acid. Finally, the dried nitrates were treated with CAB/DOP or CMC for preservation during storage and transport. The individual units of IRMM-1027v LSD spikes were prepared by dispensing aliquots (about 2.5 g) of the mother solution into penicillin vials and were evaporated to dryness at around 55°C, under glovebox conditions (~50mmHg under-pressure).

The certified masses of plutonium and uranium isotopes and the certified values of the uranium and plutonium isotope amount ratios are based on the data from the weighing certificates and the certificates of the starting materials (metals). Confirmation measurements and homogeneity assessment were established by IDMS on randomly selected vials. For this project, the confirmation measurements were performed on units that were spiked with IRMM-046c. The homogeneity assessment was performed on the same, single spiked units (IRMM-046c) that were used for the confirmation measurements. A mixed, in-house prepared ^{235}U and ^{239}Pu quality control reference material was measured on the same ID-TIMS turret with each verification set of IRMM-1027v.

2. Participants

Project management and evaluation, processing, homogeneity study, stability study and characterisation were 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 metals of uranium (EC NRM 101, Geel, Belgium and NBL PO CRM 116-A, Lemont, USA) and plutonium (CETAMA MP2, CEA Marcoule, France) were used as starting materials (Figure 1) for the preparation of the IRMM-1027v LSD spikes. The isotopic composition and the purity of the metals are given in Annex 2 - Annex 7.

Figure 1 Starting materials for the preparation of IRMM-1027v LSD spikes: a) one of the electropolished Pu MP2 metal b) etched U NBL PO CRM 116-A metal and c) U EC NRM 101 metal (Source: EC JRC G.2)

3.2 Processing

Dissolution of the Pu metal

The protocol in use at JRC-Geel for the dissolution of Pu MP2 metal consists in applying 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 as the mass of the MP2 ingot is certified (see Annex 5).

For the IRMM-1027v batch, after electro-polishing the 3 selected units of the MP2 metal, the metals were rinsed with deionised water and acetone (*p.a.*, Merck, Darmstadt, Germany) and dried. Then the units were precisely weighed (by substitution method) in a dedicated glove-box on a Mettler Toledo AT 261 DR balance (readability = 0.1/0.01mg) and subsequently transferred to another glove box for dissolution. They were dissolved in about 20-25 mL of hydrochloric acid (c = 6 mol L^{-1}, Suprapur®, Merck). The reaction was vigorous and fast and no visible remaining Pu metal was left. Then, nitric acid solution (c = 8 mol L^{-1}, *p.a.*, Merck) was added to the dissolved Pu solution. 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 2.

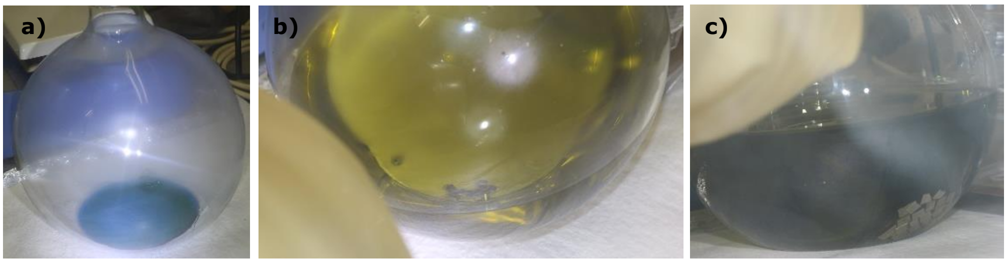
Dissolution of the U metals

The respective units of enriched uranium metal (NBL PO CRM 116-A) and natural uranium metal (EC NRM 101) were weighed (by substitution method) on a Mettler Toledo XPE 205 balance (readability = 0.01mg) and added into the prepared plutonium solution. Prior to weighing, the units of NBL PO CRM 116-A metal were etched with nitric acid (c = 8 mol L^{-1}) to remove surface oxidation products as described in the certificate, and subsequently rinsed with deionised water and acetone (*p.a.*, Merck) and dried, according to the manufacturer's recommendation. The units of the EC NRM 101 uranium metal were weighed as provided without any cleaning (see Figure 1c), as the material was sealed in a glass ampoule under inert atmosphere. The final amounts of concentrated nitric acid and deionised water were added to adjust the concentration of the nitric acid solution (c = 5-6 mol L^{-1}). The solution was left to homogenise for a few days with occasional swirling by hand, and it was weighed to determine the final mass of the mother solution on a Mettler Toledo PR 5002 balance (readability = 0.01g), considering the necessary corrections for air buoyancy effects. The dissolution of the uranium metals is shown in Figure 2.

The conventional mass values of most the weights used for the mass determination of the metals and the mother solution were in accordance with the maximum permissible error of class E2 according to OIML-R 111:2004 [19]. The conventional mass values of some of the larger weights were in accordance with the maximum permissible error of class F1. More detailed information on the weights is available upon request.

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

Figure 2 Dissolution of Pu and U metals: a) MP2 dissolution in HCl, b) flask from 2a after adding HNO_3 and U NBL PO CRM 116-A, c) flask from 2b after adding U EC NRM 101 (Source: EC JRC G.2)



Dispensing, drying and application of CAB/DOP and CMC

Dispensing and weighing of the mother solution into individual penicillin vials were performed by a validated automated system, which was installed at the JRC Geel in collaboration with Nucomat (Lokeren, Belgium) [20]. The major components of the system are a robot, two balances and a dispenser. The robot is software driven and designed to control all movements inside the glove box, such as identifying the vial with a barcode reader, dispensing and weighing of an aliquot of the solution (2.5 g) into the penicillin vials. The weighing component is equipped with an analytical balance (Sartorius TE124S, Göttingen, Germany) and a 5 kg balance (Sartorius TE6101, Göttingen, Germany) to monitor the mass of the mother solution during dispensing. The whole solution (about 2.35 kg) was dispensed into 911 vials over five consecutive working days. 912 units can be found in the certificate of dispensing (Annex 11) however, one vial was excluded from the certification process due to barcode failure and six units due to splashing during dispensing or before drying. Therefore, a total number of 905 units were certified.

The drying of the dispensed solution contained in the vials was carried out on a hot plate. The temperature of the solution was kept below 60 °C for several days (typically 4-5 days continuous heating) to evaporate the solution completely.

For the IRMM-1027v LSD spikes, two organic matrices were used: a) 465 units were prepared with CAB containing a plasticizer dioctyl phthalate (DOP) and b) 440 units were prepared with CMC. The number of units prepared with the two different coating corresponds to the customers' needs.

a) CAB/DOP protocol

After evaporation to dryness, about 0.7 mL of CAB/DOP solution in acetone was added. CAB/DOP solution was prepared by dissolving 10 g CAB (35-39 g/100 g butyryl content, Acros, New Jersey, USA) and 2 g DOP (Sigma-Aldrich, Merck) in 88g acetone. The CAB/DOP solution in the vials was evaporated at room temperature and then heated to about 45 °C to dry completely. Three dedicated glove boxes were used for drying and CAB/DOP application, allowing the preparation of up to 48 units per day in one glove box. The vials were closed with stoppers and aluminium caps, sealed in PVC packages and labelled.

b) CMC protocol

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 70-75 °C under continuous stirring. The mixture was stirred and heated until the dissolution of CMC was complete (usually 2-3 hours) and then allowed to cool to room temperature. A colourless to slightly yellow, transparent solution was obtained. 1.5 mL of this solution was added to the dried nitrates and heated up to about 52-54 °C. The solution in the vials was kept at this temperature to evaporate the nitric acid solution. Once the nitric acid had evaporated completely and the foams were produced, the vials were removed from the hotplate, cooled and closed with butyl rubber caps. This protocol allows the preparation of up to 24 units per day in one glove box.

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

One example each of IRMM-1027v LSD spike prepared with CAB/DOP and CMC spikes are shown in Figure 3. The processing steps are shown in

Figure **4**.

Figure 3 Units of IRMM-1027v LSD spike: a) treated with CAB/DOP and b) treated with CMC (Source: EC JRC G.2)

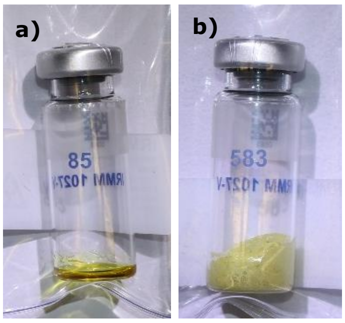
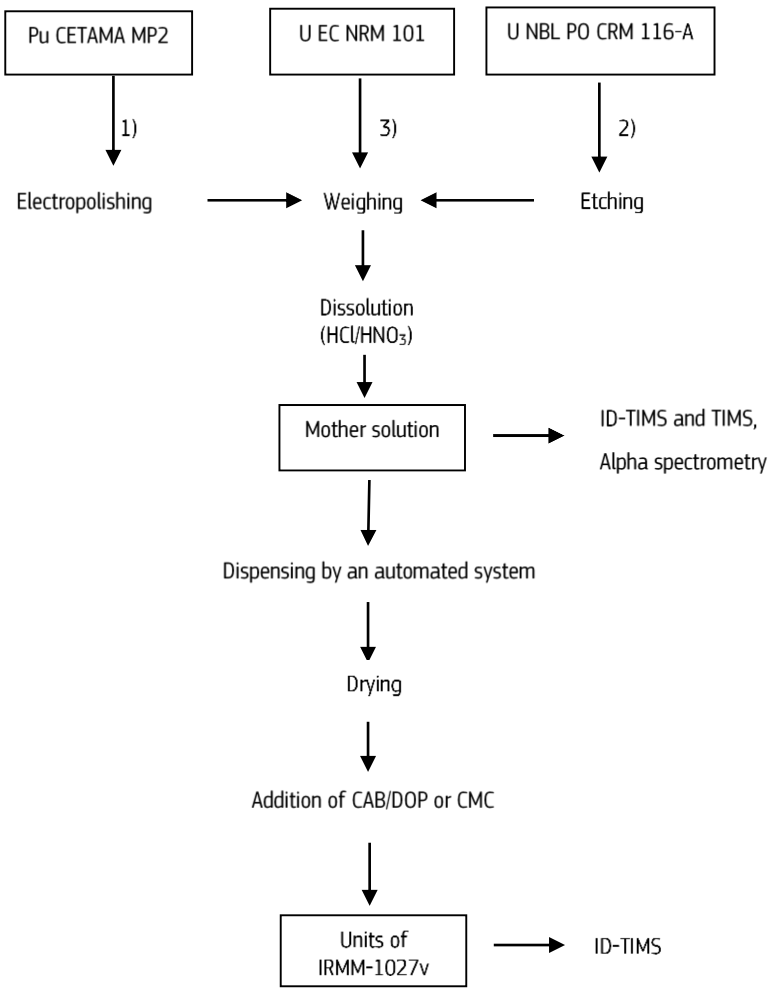


Figure 4 Preparation of IRMM-1027v LSD spikes (Source: EC JRC G.2)



3.3 Process control

This section describes the measurements performed on the mother solution of IRMM-1027v prior to dispensing into vials to verify the amount contents of uranium and plutonium in the solution from gravimetric preparation. Detailed GUM Workbench calculations of the uranium and plutonium amount contents, mass fractions, isotopic compositions and their associated uncertainties from the gravimetric preparation of IRMM-1027v are shown in Annex 13 and Annex 14.

Two aliquots of the mother solution (about 2.5 g each) were individually spiked with a mixed $^{233}U/^{242}Pu$ spike CRM (*ca.* 2 g IRMM-046c) for ID-TIMS analysis. The certificate of IRMM-046c can be found in Annex 8.

The U-Pu separation of the samples was performed using anion-exchange columns (Bio-Rad AG1-X4, 100-200 mesh, Bio-Rad, Hercules, USA) as described in detail in [21].

The ID-TIMS results of the process control measurements for ^{235}U, ^{238}U and ^{239}Pu amount contents in the mother solution of IRMM-1027v were metrologically compatible with the values from the gravimetric preparation, except for one of the two aliquots for ^{238}U amount content (Annex 9, Figure 14). Due to technical reasons and limited access to the JRC-Geel nuclear laboratories in 2020, repeated ID-TIMS measurement for ^{238}U amount content was not possible. However, the deviating aliquot shows a relatively small bias (-0.07%). Furthermore, all ^{238}U amount content confirmation measurements at JRC-Geel on the individual units and the external verification measurements carried out by IAEA-SGAS and JRC-KA verified the gravimetrical value (Figure 9 and Figure 10). It is also important to note that the uncertainty associated with gravimetrical preparation is very small due to the low uncertainties of the starting materials in combination with a primary method of measurement [22]. Moreover, IRMM-1027v is certified for the amount contents of each individual vial and not for the amount content of the mother solution. The latter are only provided as indicative values in the material`s certificate.

The CRM 116-A and the NBL-126 reference materials are used in the JRC G.2 laboratory as quality control (QC) materials for uranium and plutonium IDMS, respectively. These stock solutions were prepared and verified independently from the IRMM-1027v mother solution.[23] An aliquot of CRM 116-A and NBL-126 (ID-QC) material solutions were weighed into a vial and this mixture was spiked with the IRMM-046c ($^{242}Pu/^{233}U$) spike CRM, and measured together with the aliquots of the IRMM-1027v mother solution. One ID-QC was measured on the same sample turret and the result was used for bias correction of the corresponding IRMM-1027v mother solution samples (see Section 6.5 for details).

4. Homogeneity

A key requirement for any reference material is homogeneity. In this respect, it is relevant whether the variation between units is significant compared to the uncertainty of the certified value but most importantly whether the combined uncertainty remains fit for purpose. 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 [2] 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. In case of the IRMM-1027 LSD CRM series, the whole amount of sample per unit is used for analysis. Thus, there is no contribution to the combined uncertainty from the within-unit homogeneity.

4.1 Between-unit homogeneity

The between-unit homogeneity was evaluated to ensure that the certified values of the CRM are valid for all 905 units of the material within the stated uncertainty.

As it was already shown during the certification of the IRMM-1027t and IRMM-1027u [17, 18], there is no difference between the CAB/DOP and CMC covered spikes concerning the certified isotope amount contents. In the course of the certification of IRMM-1027v, twelve single spiked units were selected and eleven of them used (due to one technical outlier) 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 number of selected units for the between-unit homogeneity study is in accordance with ISO Guide 35:2017 [3].

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 dissolved. Randomly selected units of IRMM-1027v were spiked and dissolved with around 2g of a mixed $^{233}U/^{242}Pu$ spike CRM (IRMM-046c) in 5M HNO_3 solution. The solution was evaporated to dryness in the vials. The U-Pu separation was carried out prior to isotope ratio measurements on each unit in the same way as for the process control measurements (see Section 3.3).

Each sample was measured in three replicates. Thus three aliquots were taken from the same spiked and separated unit, loaded on the filaments and measured on the same turret together with isotopic standards (IRMM-074/10 for U and IRMM-290/A3 for Pu) to correct for instrumental mass fractionation. The selected units were measured together with the in-house Isotope Dilution (U/Pu) Quality Control sample. This enabled four IRMM-1027v units plus one QC sample to be measured on the same TIMS turret on the same day. Three turrets were prepared for uranium and three turrets for plutonium measurements. Therefore, the ID-TIMS analysis for all twelve units of IRMM-1027v were performed under intermediate precision conditions.

The respective fractions of the samples were measured in a randomised manner to be able to separate a potential analytical drift from a trend in the filling sequence. 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. A statistically significant downward trend in the ^{239}Pu analytical sequence was found at a confidence level of 95 %. However, a significant day-to-day difference was also observed for the amount content of ^{239}Pu that was strongly (correlation coefficient = 0.94) and significantly correlated with the analytical sequence. Therefore, the data was first normalised (scaled) by the respective day mean and the resulting data did not show any trend at the 95% CL. A statistically significant trend was observed in the filling sequence for the ^{235}U isotope amount content. This trend was included in the calculations. Thus, the uncertainty of homogeneity contains both the random between-unit variation and the trend in the filling sequence. The trend did not inflate significantly the estimation for uncertainty associated with homogeneity as can be seen from Table 1 and the material remained fit for purpose. No trends in the filling sequence or the analytical sequence were visible at a confidence level of 95 % for the ^{238}U isotope amount content. The data were tested for consistency using the Grubbs outlier test at a confidence level of 95 % on the individual results and on the unit means. In the case of ^{235}U amount content, one outlier was detected among the individual results however, no technical reason was found to exclude the data thus it was kept and included in the evaluation of homogeneity.

Quantification of between-unit inhomogeneity of U isotope amount contents was accomplished by analysis of variance (ANOVA), which can separate the between-unit standard deviation (s_{bb}) from the method intermediate precision (s_{ip}). The latter is defined as within-unit standard deviation in cases where the subsamples of the unit are used. Otherwise, it is defined as method repeatability because it is an estimation of the standard deviation of the method (IDMS) under repeatability conditions. In case of the U isotope amount contents we did not observe significant differences between the between-unit standard deviations under repeatability and intermediate precision conditions, whereas the Pu isotope amount content data were normalised by the daily means to compensate for the observed significant day-to-day differences. Therefore, the difference between repeatability and intermediate precision variances was zero or negligible for all the three major isotopes.

The one-way ANOVA uses the *F*-test for comparing multiple group means and checking their equivalence. The test assumes that a) the observations are obtained independently and randomly, b) the residuals are normally distributed c) the variances of the populations (units) are equal (homoscedasticity). Both visual and statistical tests were performed to check these assumptions. The residuals *vs* fitted values and the Levene's test was used to check the homoscedasticity assumptions. The quantiles of the residuals were plotted against the quantiles of the normal distribution on a normal Q-Q plot to visualize and the Shapiro-Wilk test was used to check at the 95% CL the assumption for normality.

The *F*-test results of the ANOVA are unimportant for the determination whether the batch is sufficiently homogeneous. Instead, the between-unit standard deviation was used to assess the homogeneity of the IRMM-1027v batch in accordance with ISO Guide 35 [3]. It is often difficult to prove normality with small data sets (i.e. 3 replicates/unit) therefore the assumption of normality was used even if it could not be proven by statistical tests. 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-1027v (Source: EC JRC G.2)

	Trends 1)		Outliers 2)		Normality 3)	Homoscedasticity 4)
	Analytical sequence	Filling sequence	Individual results	Unit means		
^{235}U amount content	no	yes	yes	none	Not normal (p=6*10^{-4})	Ok (p=0.6)
^{238}U amount content	no	no	none	none	Normal (p=0.2)	Ok (p=0.5)
^{239}Pu amount content	no	no	none	none	Normal (p=0.8)	Ok (p=0.6)

1) Linear regression at CL= 95 %
2) Grubb's test at CL= 95 %
3) Shapiro-Wilk test at CL= 95 %
4) Levene's test at CL= 95 %

It is possible that $s_{ip,rel}$ is too high to calculate $s_{bb,rel}$ by classical ANOVA. In these cases, the mean square between units ($MS_{between}$) can be smaller than the mean squares within groups (MS_{within}), resulting in negative arguments under the square root used for the estimation of the between-unit variation, whereas the true variation cannot be lower than zero. In this case, u^*_{bb}, the maximum inhomogeneity that could be hidden by method repeatability (intermediate precision), was calculated as described by Linsinger et al. [24] and recommended by ISO Guide 35[3]. 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 method intermediate precision ($s_{ip,rel}$), relative between–unit standard deviation ($s_{bb,rel}$) and relative maximum inhomogeneity ($u^*_{bb,rel}$) were calculated as:

$$s_{ip,rel} = \frac{\sqrt{MS_{within}}}{\bar{y}}$$

Equation 1

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

Equation 2

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

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

$\nu_{MSwithin}$ degrees of freedom of MS_{within}

As a consequence of the intermediate precision conditions, day-to-day effects can occur that could mask the between-unit variation. Therefore, the U isotope data were also checked using one way-ANOVA for any significant difference in between-day means. The amount content of U isotopes did not show significant day-to-day differences when they were checked with one way-ANOVA nor the Tukey boxplot representation showed sign of significant differences (Annex 10). However, the power of the F-test of the ANOVA was very low (0.27 and 0.11 for ^{235}U and ^{238}U day-to-day variance check, respectively) that can lead to Type II error: failure to reject the null when it is untrue i.e. the failure to reject that the day-to-day group means are equal in case they are not equal. Therefore, based solely on the ANOVA output no conclusion regarding to the day-to-day equivalence of the U isotope amount content measurements could be drawn. Nevertheless, different approaches (e.g. random effects model with REML or nested ANOVA) for the quantification of between unit variances would provide similar values therefore the ANOVA results were accepted and no day-to-day differences were assumed.

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-1027v (Source: EC JRC G.2)

	$s_{ip,rel}$ [%]	$s_{bb,rel}$ [%]	$u^*_{bb,rel}$ [%]
^{235}U amount content	0.061	**0.021**	0.019
^{238}U amount content	0.075	0.017	**0.024**
^{239}Pu amount content	0.026	**0.020**	0.008

Despite the trend in the ^{235}U filling sequence at a 95 % confidence level and the non-normality of residuals, the ANOVA estimation was accepted because the s_{bb} estimate was very close to the other two isotopes (see Table 2). This is expected when a homogeneous solution is used for the CRM batch preparation. Therefore, the between-unit standard deviation can be used as estimate of u_{hom}. As u^*_{bb} sets the limits of the study to detect inhomogeneity, the larger value of s_{bb} or u^*_{bb} is adopted as uncertainty contribution to account for potential inhomogeneity. In case of the IRMM-1027v, for the ^{235}U and ^{239}Pu isotope amount contents the s_{bb} and for the ^{238}U isotope amount content u^{*}_{bb} could be used to assess the contribution from the homogeneity study. These values remained below 0.05% for all the three dominant isotopes thus; one can conclude that the batch is sufficiently homogeneous and fit for purpose.

The uncertainty associated with homogeneity was assessed via the accredited software SoftCRM® [25] and the ANOVA assumptions were tested using the open-source statistical software R [26].

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-1027v 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-1027v. This has been confirmed in the certification of previous batches of the IRMM-1027 LSD series.

4.3 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 and thus equals the minimum sample intake. Quantification of within-unit inhomogeneity to determine the minimum sample intake for IRMM-1027v 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-1027v is a mixed U/Pu reference material, consisting of U and Pu radionuclides. It should be noted that the term 'stability' in this context does not refer to radioactive decay. Radionuclides are naturally decaying according to their half-lives, a process which is quantitatively predictable using the decay data [6, 7].

5.1 Short-term stability

In the scope of the preparation and certification IRMM-1027t batch, a thorough short-term stability study of the CAB with dioctyl phthalate plasticizer (DOP) and with CMC was carried out [17].

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

No flaking - in case of CAB with DOP – and/or fluid material – in case of CMC – could be observed before and after the test. The CAB with DOP coating did not change at all at any of the three temperature points. In case of the CMC foam, an ongoing reaction accelerated by the temperature (at 60°C) was observed. As the foam still contains unreacted HNO_3 or nitrous gases – being the origin of the brownish colour of the fresh foams – the foam has even further matured and discoloration can be noticed. However, this colour change of the foam does not affect the integrity or the stability of the material as demonstrated during the INS-CRM project [14].

Transport is often referred to as short-term stability. The transport does not affect the stability of the actinide matrix but it can have an influence on the cellulose based stabilizing matrices hence on the shelf-life and usability of the CRMs. For this reason, ten units of IRMM-1027v with each type of stabilizing matrices (CAB/DOP and CMC) were selected to undergo random vibration tests on a L0315M-PA103 Vibration Test System to simulate transport conditions. This electrodynamic shaker has a working frequency range of 5–4500 Hz. It is operated via the Spider MIMO Vibration Control System software.

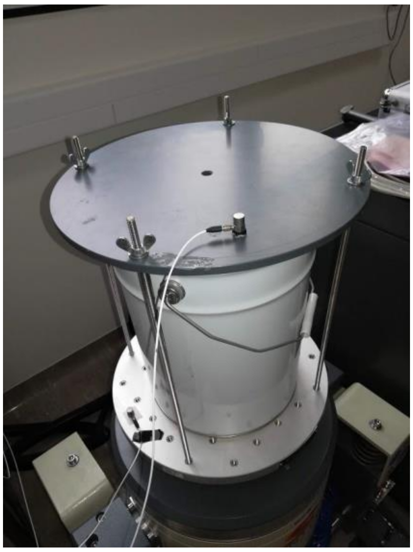


Figure 5 Securing the test sample on the transport simulator (Source: EC JRC G.2)

The test sample was placed on the vibration table as shown in Figure 5 and the random vibration module of the ISTA 2A procedure [27] was set up and performed. The test ran for 180 minutes and an overall G_{rms} level of 1.15 (root mean square acceleration, the square root of the area under the acceleration spectral density curve) was constructed. The details of the set acceleration versus frequency profile is shown in Table 3 and Figure 6. The environmental conditions at the time of the measurement and during the days before the test were the following: 20-22°C, 55-65% relative humidity and atmospheric pressure. The test was done on the same packaging that is used for the transport i.e. the packed units were placed into an EMMA container which was put into a Type A package (TNB 169) and a polystyrene shock absorber was placed between the layers. The Type A container remained in upright standing position throughout the run which is the intended shipping position.

Table 3 The programmed acceleration versus frequency profile

Frequency (Hz)	PSD Level, g^2/Hz
1.0	0.0001
4.0	0.01
100.0	0.01
200.0	0.001

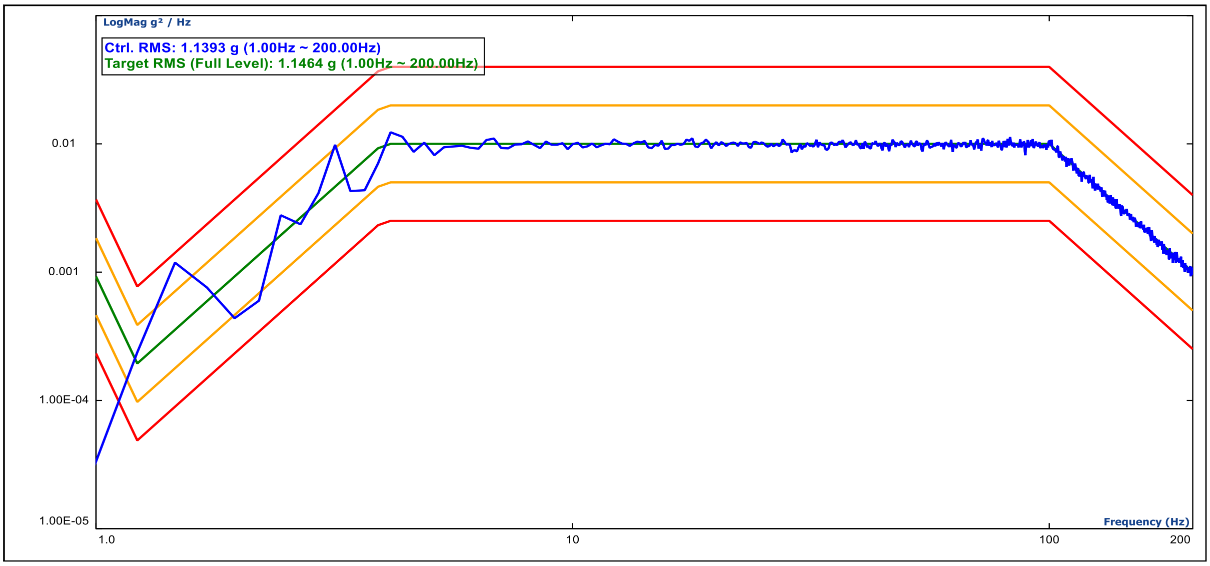


Figure 6 The programmed acceleration versus frequency profile (green line) and the control signal (blue line). Orange lines represent low and high alarm limits. Red lines represent low and high abort limits.

As it can be seen from Figure 6, the vibration simulator could correctly match the desired acceleration versus frequency profile except from slight anomalies in the low frequency region (1-5 Hz) where the signal moved close to the abort limits. These anomalies do not limit the usefulness of the obtained results because this frequency range usually affects very heavy objects (e.g. a building). Therefore we do not expect the low frequency region to have any influence on our test object (<7kg) nor on the packed CRMs that weighs a few grams only.

The simulation was performed around 1-1.5 years after preparation of the CRMs to mimic real life situation (the units are usually shipped to the customers around 1 year after preparation).

The main evaluation criterion was based on the appearance of the spikes before and after performing the transport simulation test. Figure 7 and Figure 8 show that there was no change in the appearance of the spikes, there are no flakes, cracks or loose particles observed after the study neither for the CMC nor for the CAB/DOP matrices. Therefore, we can conclude underpinned by the observed data that the safe transport of 1-1.5 years old IRMM-1027v units can be guaranteed. Transport does not influence the usability and shelf-life of the CRM.

Figure 7 IRMM-1027v CRM units embedded into CMC matrix before (top) and after (bottom) the transport simulation.

Figure 8 IRMM-1027v CRM units embedded into CAB/DOP matrix before (top) and after (bottom) the transport simulation. (Please, note that the order of the units changed.)

IRMM-1027v LSD spikes are packed and shipped to customers following the legal requirements related to radioprotection measures for transport of radioactive materials [28]. IRMM-1027v 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 ($u_{\mathrm{sts,\,rel}}$ = 0) was applied.

5.2 Long-term stability

The change of the reference values with time of the U/Pu CRM IRMM-1027 batches can be perfectly described by radioactive decay equations and therefore have to be compared to the given reference date on the certificate. These decay-corrected certified values are valid as long as the stabilizing organic matrix remains sufficiently intact that allows full sample intake without the risk of loss of the material when opening the vial. Therefore, no additional uncertainty component ($u_{\mathrm{lts,\,rel}}$ = 0) has to be applied to the certified values but the degradation process investigated in prior exploratory research of the stabilizing matrix limits the shelf-life of the IRMM-1027 series of LSD spikes to 5 years.

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 [29] 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 [30, 31, 32]. Furthermore, the JRC-Geel (Belgium), the JRC-Karlsruhe (Germany) and the IAEA at Seibersdorf (Austria) are engaged in mutual verification measurements of mixed uranium-plutonium spike reference materials via EC support task to the IAEA [33]. 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 and CAB/DOP can be demonstrated via the results of the INS-CRM exploratory research project [14, 15, 16]. 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 main findings of the shelf-life of the IRMM-1027 series of LSD spikes was summarized in the previous certification report, IRMM-1027u [18]. A more detailed discussion of the topic will be published soon.

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-1027v series of LSD spikes was prepared by dispensing an aliquot (about 2.5 g) of the mother solution into individual units by an automated system and subsequent drying. The masses of dispensed aliquots per unit before drying are given in Annex 12. The mother solution was prepared by gravimetric mixing of uranium and plutonium metals (see Section 3.2).

Each unit of IRMM-1027v LSD spike is certified for the mass of ^{239}Pu, ^{235}U and ^{238}U and the $n(^{234}\mathrm{U})/n(^{238}\mathrm{U})$, $n(^{235}\mathrm{U})/n(^{238}\mathrm{U})$, $n(^{236}\mathrm{U})/n(^{238}\mathrm{U})$, $n(^{238}\mathrm{Pu})/n(^{239}\mathrm{Pu})$, $n(^{240}\mathrm{Pu})/n(^{239}\mathrm{Pu})$, $n(^{241}\mathrm{Pu})/n(^{239}\mathrm{Pu})$, and $n(^{242}\mathrm{Pu})/n(^{239}\mathrm{Pu})$ amount ratios.

6.1 Purity of the starting materials

The purity of the starting U materials (metals) was taken from the corresponding certificates (Annex 2 Annex 4). The purity of the Pu MP2 metal was calculated for November 1, 2019 (Annex 14) from the original purity of the CETAMA certificate (Annex 5).

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-1027v are calculated from the gravimetric preparation of the mother solution. The following parameters were taken into account: the mass of the metals, their purity and isotopic composition (e.g. isotope amount ratios), the mass of the mother solution and the mass of an aliquot dispensed into each vial. In Table 4, the data supporting the calculation of the masses of ^{235}U, ^{238}U, ^{239}Pu and Pu and U amount ratios of IRMM-1027v are summarised.

Table 4 Gravimetric mixing to prepare the mother solution of IRMM-1027v (Source: EC JRC G.2)

	MP2[5]	EC NRM 101[5]	NBL PO CRM 116-A[5]	Mother solution[5]
Mass [1)] [g]	1.71006(07)	40.46211(08)	10.14037(06)	2352.50(04)
Purity [2)] [g/g]	0.99824(40)	0.99985(05)	0.99945(14)	
Isotope amount ratios [3)] [mol/mol]	$n(^{238}Pu)/n(^{239}Pu)$ 0.00002787(26) $n(^{240}Pu)/n(^{239}Pu)$ 0.0224103(51) $n(^{241}Pu)/n(^{239}Pu)$ 0.0001279(17) $n(^{242}Pu)/n(^{239}Pu)$ 0.00007573(78)	$n(^{234}U)/n(^{238}U)$ 0.00005548(22) $n(^{235}U)/n(^{238}U)$ 0.0072593(36) $n(^{236}U)/n(^{238}U)$ 0.000000151(40)	$n(^{233}U)/n(^{235}U)$ 0.0000003863(86) $n(^{234}U)/n(^{235}U)$ 0.0115836(97) $n(^{236}U)/n(^{235}U)$ 0.0094713(77) $n(^{238}U)/n(^{235}U)$ 0.051277(41)	
U amount content [4)] [µmol/g]	2.7986(25)			
Isotope amount fraction [4)] [mol/mol]	$n(^{235}U)/n(U)$ 0.916107(22)			

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

[2)] The decay-corrected purity of the Pu metal (see Annex 14) and the purity of the U metals. For the original metal certificates, see Annex 2 - Annex 6.

[3)] The decay-corrected Pu isotope amount ratios and the U isotope amount ratios. For the original certificates see Annex 3 - Annex 6.

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

[5)] The numbers in parenthesis are the expanded uncertainties. The coverage factors were established based on the *t*-distribution for the associated effective degrees of freedom.

The uncertainties associated to the characterisation of the certified masses (u_{char}) of ^{235}U, ^{238}U and ^{239}Pu in the individual units are composed of several contributions, which can be derived from the gravimetric mixture of the mother solution (Table 5). The contributors are the following: the uncertainties on the mass determinations ($u_{char,rel1}$ - metals, $u_{char,rel2}$ - mother solution and $u_{char,rel3}$ – dispensed aliquot into the vial), the uncertainty on the purity of the metals ($u_{char,rel4}$), and the uncertainties on the isotope amount ratios ($u_{char,rel5}$). The detailed calculations of the mass fractions, amount fractions and the most important uncertainty budgets are given in Annex 13 and Annex 14. The uncertainty of the mass determination of the aliquot (dispensing) is the major contributor to the combined standard uncertainty associated to the characterisation for the U isotope amount contents. It is also an important contributor to the combined standard uncertainty of characterisation for ^{239}Pu isotope amount content, the second largest after the purity of the MP2 metal.

The uncertainties associated to the characterisation of the certified U and Pu isotope amount ratios are also 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 detailed calculations of the uranium and plutonium isotope amount ratios and their uncertainty budgets are given in Annex 13 and Annex 14.

Table 5 Uncertainty budgets for the masses of ^{235}U, ^{238}U and ^{239}Pu in the gravimetric mixture in the first unit #1 of IRMM-1027v as an example. The main uncertainty contributions associated to the characterisation are highlighted. (Source: EC JRC G.2)

	Relative standard uncertainty contribution					Combined relative uncertainty
	$u_{char,rel1}$ 1) [%]	$u_{char,rel2}$ 2) [%]	$u_{char,rel3}$ 3) [%]	$u_{char,rel4}$ 4) [%]	$u_{char,rel5}$ 5) [%]	$u_{char,rel}$ 7) [%]
^{235}U	0.00029	0.00085	0.012	0.0056	0.0018	0.013
^{238}U	0.00010	0.00085	0.012	0.0025	0.00050 6)	0.012
^{239}Pu	0.0020	0.00085	0.012	0.020	0.00025	0.023

1) Relative standard uncertainty of the mass determination of the metals, see Annex 13 and Annex 14 denoted as $m_{UCRM116A}$ for ^{235}U, m_{UEC101} for ^{238}U and m_{PuMP2} for ^{239}Pu. The respective uncertainties of the mass determinations can be found in Annex 12.

2) Relative standard uncertainty of the mass determination of the mother solution, see Annex 13 and Annex 14 denoted as $m_{solution1027v}$. The respective uncertainty of the mass determination can be found in Annex 12.

3) Relative standard uncertainty of the mass determination of the aliquot in the first vial, see Annex 13 and Annex 14 denoted as $m_{aliquot1}$. The respective uncertainties of the mass determination can be found in Annex 11.

4) Relative standard uncertainty of the purity of the metals, see Annex 13 and Annex 14 denoted as $\eta_{purityEC101}$, $\eta_{purityCRM116A}$ and $\eta_{MP2Nov2019}$. The respective purities can be found in the metal certificates Annex 2 - Annex 5. For the CETAMA MP2 metal, the purity is decayed in a separate GUM file to the 1 January 2007 and from that date ($\eta_{MP2Jan2007}$) is decayed further to the certification date 1 November 2019.

5) Relative standard uncertainty of the major isotope amount ratios, see Annex 13 and Annex 14 denoted as $R_{238U/235Ub}$ for NBL PO CRM-116-A; and $R_{240Pu/239Pu}$ for CETAMA MP2. The respective isotope amount ratios can be found in Annex 3, Annex 5 - Annex 7.

6) For EC NRM 101 the relative standard uncertainty of the two most important isotope amount ratios $R_{235U/238Ua}$ and $R_{238U/235Ub}$ were combined.

7) The final combined relative uncertainty is calculated using $u_{\mathrm{char,rel}} = \sqrt{\sum_{i=1}^{5}(u_{char,rel,i}^{2})}$, assuming no correlation between the different uncertainty contributors.

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. No evaporation loss was assumed. Traceability of the values to the SI is ensured by weighing a calibrated reference weight before and after dispensing a series of 96 units. A correction factor ($K_{nucomat}$) was applied based on the ratio of the last calibration of the reference weight and the mean value obtained during dispensing according to the following equation:

$$\boldsymbol{K_{nucomat}} = \frac{\boldsymbol{m_{ref,cal}}}{\boldsymbol{m_{ref,readout}}} \qquad \text{Equation 4}$$

where $m_{\mathrm{ref,\ readout}}$ is the mean value of the reference mass recorded at ambient conditions during dispensing and $m_{\mathrm{ref,\ cal}}$ is the mass value of the latest calibration of the same reference object after ambient condition correction.
The uncertainty estimate on the dispensed mass (± 0.0006 g, coverage factor k = 2) is composed of several contributions, i.e. the uncertainty on the mass determination by an automated system, the uncertainty on the buoyancy correction, the uncertainty of the correction factor, and the uncertainty associated with the stability of the balance [20].

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 the unknown (U) and a reference weight (S). The so called "SUUS" method was applied [19]. The uncertainty contributions in substitution weighing of the metals are the uncertainties associated with the calibrated reference weights (certificate), air buoyancy correction and the stability of the balance used in "SUUS" method.

6.4 Isotope ratio confirmation measurements

Four unspiked aliquots (about 0.5 g each) of the IRMM-1027v mother solution were analysed to verify the uranium and plutonium isotope amount ratios by TIMS and alpha spectrometry. The U-Pu separation of the samples was performed using anion-exchange columns (Bio-Rad AG1-X4, 100-200 mesh, Bio-Rad, Hercules, USA) as described in detail in [21]. Apart from that, external verification data performed by at IAEA-SGAS and JRC-KA on randomly selected CAB/DOP or CMC coated IRMM-1027v units are also presented.

The results of the uranium and plutonium isotope amount ratio confirmation measurements in the mother solution of IRMM-1027v were compatible with the values from the gravimetric preparation, except for two of the four aliquots for the $n(^{236}U)/n(^{238}U)$ amount ratio. Even in these cases, the compatibility check (see equation 5) results were below 3 and the ratio was verified by external verification on individual units by IAEA-SGAS and JRC-KA. Therefore, this isotope ratio was included in the certificate. As it is apparent from Figure 9 all U isotope ratios show a slight positive bias of the observed values to the gravimetrical value even though they are all within uncertainty with the exception of one measurement of the $n(^{236}U)/n(^{238}U)$ amount ratio. The relative differences are 0.02% for $n(^{235}U)/n(^{238}U)$, 0.04% for $n(^{234}U)/n(^{238}U)$ and 0.08% for $n(^{236}U)/n(^{238}U)$ amount ratios based on the verification data of all three institutes.

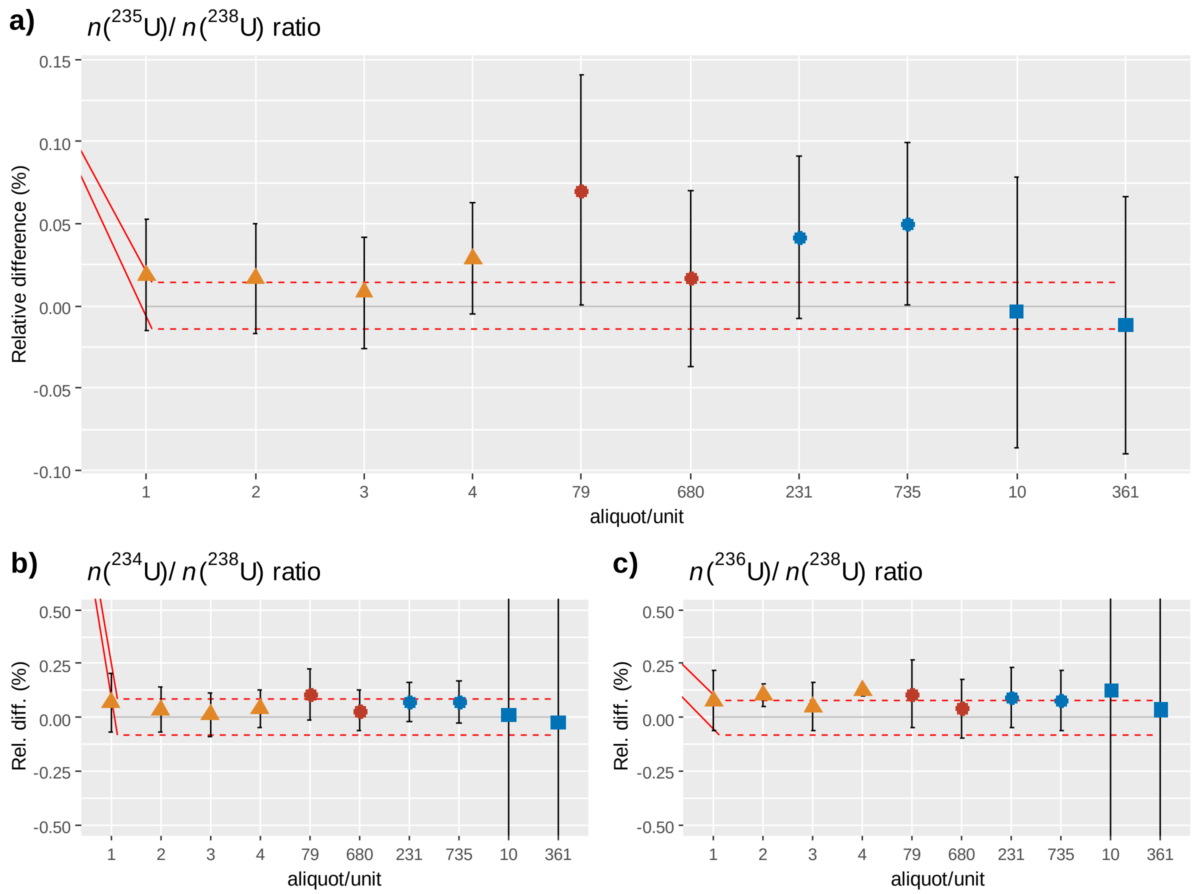


Figure 9 Uranium isotope ratio verification measurements for a) $n(^{235}U)/n(^{238}U)$ b) $n(^{234}U)/n(^{238}U)$ and c) $n(^{236}U)/n(^{238}U)$. Symbol codes: triangle – JRC-GE, circle – IAEA-SGAS, square – JRC-KA. Colour codes: orange – aliquot, red – CAB/DOP, blue – CMC. Error bars show the expanded uncertainties (For JRC-GE results coverage factors are based on the *t*-distribution for the associated effective degrees of freedom that corresponds to a level of confidence of about 95 %). (Source: EC JRC G.2, IAEA-SGAS, EC JRC G.II.6.)

Due to an isobaric interference with ^{238}U coming from the incomplete removal of uranium in the plutonium fraction TIMS would provide a deviating value for the $n(^{238}Pu)/n(^{239}Pu)$ ratio. For this reason, alpha spectroscopy was used as alternative method for the verification of the gravimetrical $n(^{238}Pu)/n(^{239}Pu)$ ratio. Due to the corona pandemic, we could only analyse a single aliquot (with two replicates). The result of this measurement and the external verification by IAEA-SGAS and JRC-KA verified the gravimetrical ratio. Therefore, this isotope ratio was certified, as well. The other Pu isotope ratios were measured by TIMS. These verification measurements are summarized in Figure 10. The relative difference to the gravimetrical value on the $n(^{240}Pu)/n(^{239}Pu)$ isotope ratio is -0.01%, the relative differences on the other ratios vary but all of the expanded uncertainties of the individual measurements overlap with that of the gravimetrical (certified) value. All results pass the compatibility check.

Furthermore, the compatibility check was performed for the results of the confirmation measurements (IDMS) using the compatibility equation (equation 5) [34]. We set the following criteria for the compatibility check: compatibility values that are less than 2 pass, values between 2 and 3 pass with a warning and values larger than 3 fail to pass the check. We have not observed any values larger than 3 during the verification exercise and only few between 2 and 3, which are highlighted in the respective tables.

$$compatibility = \frac{X_{IDMS} - X_{cert}}{\sqrt{u_{IDMS}^2 + u_{cert}^2}} \qquad \text{Equation 5}$$

X_{IDMS}	individual result obtained by IDMS
X_{cert}	gravimetric value established by characterisation
u_{IDMS}	standard uncertainty obtained by IDMS
u_{cert}	standard uncertainty of the certified value

The outcome of the compatibility check is summarized in Table 6.

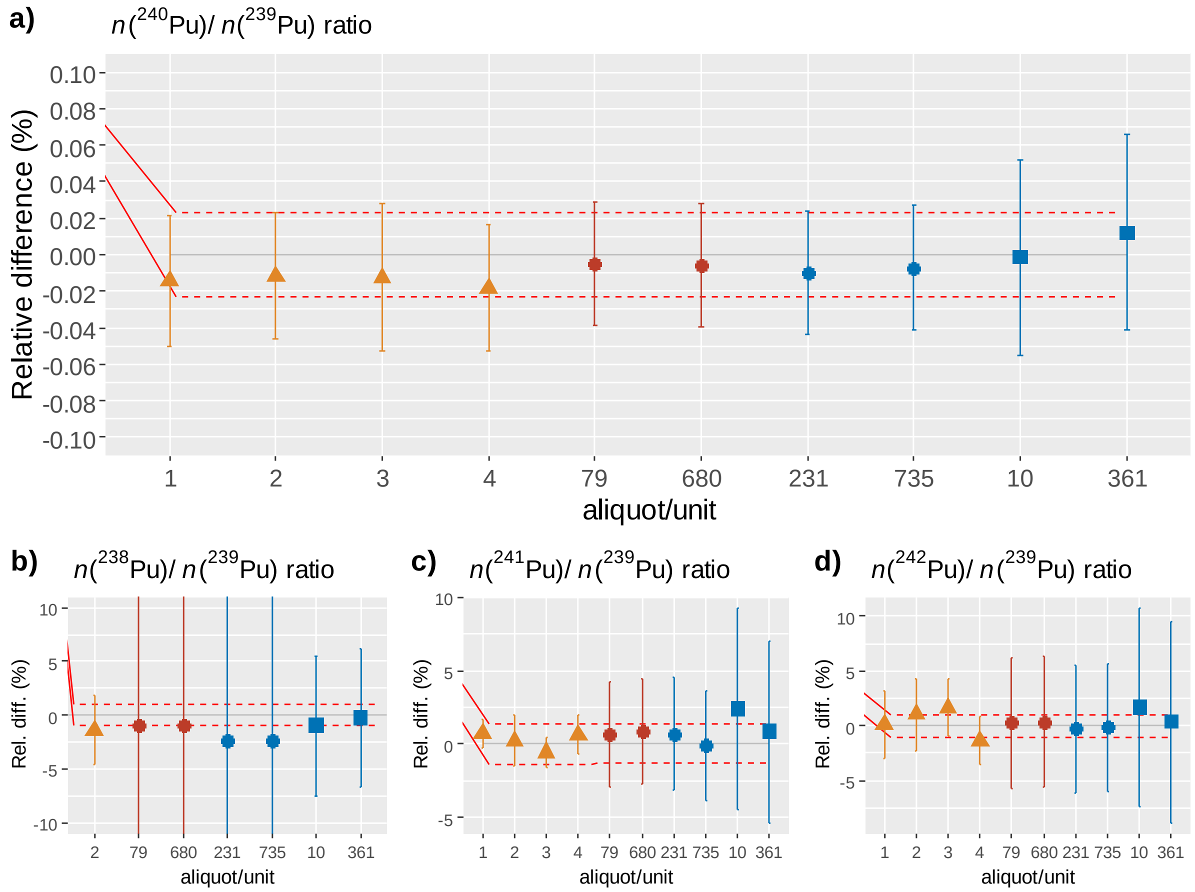


Figure 10 Plutonium isotope ratio verification measurements for a) $n(^{240}Pu)/n(^{239}Pu)$ (TIMS) b) $n(^{238}Pu)/n(^{239}Pu)$ (alpha-spectrometry) and c) $n(^{241}Pu)/n(^{239}Pu)$ (TIMS) and d) $n(^{242}Pu)/n(^{239}Pu)$ (TIMS) ratios. Symbol codes: triangle – JRC-GE, circle – IAEA-SGAS, square – JRC-KA. Colour codes: orange – aliquot, red – CAB/DOP, blue – CMC. Error bars show the expanded uncertainties (For JRC-GE results coverage factors are based on the *t*-distribution for the associated effective degrees of freedom that corresponds to a level of confidence of about 95 %). (Source: EC JRC G.2, IAEA-SGAS, EC JRC G.II.6.)

Table 6 Results of the compatibility evaluation for the isotope ratios (Source: EC JRC G.2, IAEA-SGAS, EC JRC G.II.6)

Aliquot or vial No.	**$n(^{235}U)/n(^{238}U)$ ratio**	$n(^{234}U)/n(^{238}U)$ ratio	$n(^{236}U)/n(^{238}U)$ ratio	**$n(^{240}Pu)/n(^{239}Pu)$ ratio**	$n(^{238}Pu)/n(^{239}Pu)$ ratio	$n(^{241}Pu)/n(^{239}Pu)$ ratio	$n(^{242}Pu)/n(^{239}Pu)$ ratio
1027v-aliquot 1	**1.05**	1.17	1.50	**0.68**	N/A	0.85	0.06
1027v- aliquot 2	**0.93**	0.65	2.32	**0.56**	1.10	0.25	0.68
1027v- aliquot 3	**0.47**	0.20	1.04	**0.55**	N/A	0.66	1.26
1027v- aliquot 4	**1.62**	0.75	2.96	**0.89**	N/A	0.70	1.17

1027v-79	**1.98**	1.44	1.22	**0.24**	0.10	0.33	0.07
1027v-680	**0.61**	0.52	0.50	**0.28**	0.10	0.45	0.12
1027v-231	**1.63**	1.15	1.17	**0.48**	0.25	0.35	0.10
1027v-735	**1.95**	1.13	0.95	**0.35**	0.25	0.04	0.06
1027v-10	**0.09**	0.01	0.14	**0.05**	0.30	0.68	0.36
1027v-361	**0.30**	0.03	0.04	**0.41**	0.08	0.27	0.08

The relative standard uncertainty contribution of the uranium and plutonium isotope amount ratios from the characterisation assessment (gravimetric preparation) are summarised in Table 7. As no uncertainty contribution associated with homogeneity is assigned to these ratios (see Section 4.2), u_{char} represents the combined standard uncertainty.

Table 7 The U and Pu isotope amount ratios and their relative standard uncertainties from the characterisation assessment of IRMM-1027v (Source: EC JRC G.2)

	Value 1) [mol/mol]	u_{char} [mol/mol]	$u_{char, rel}$ [%]
$n(^{234}U)/n(^{238}U)$	0.0027807	0.0000011	0.040
$n(^{235}U)/n(^{238}U)$	0.242509	0.000016	0.0066
$n(^{236}U)/n(^{238}U)$	0.0022322	0.0000009	0.041
$n(^{238}Pu)/n(^{239}Pu)$	0.00002787	0.00000013	0.47
$n(^{240}Pu)/n(^{239}Pu)$	0.0224103	0.0000025	0.011
$n(^{241}Pu)/n(^{239}Pu)$	0.0001279	0.0000008	0.66
$n(^{242}Pu)/n(^{239}Pu)$	0.00007573	0.00000039	0.52

1) The reference date for the isotope amount ratios is November 1, 2019.

The confirmation measurement for the U and Pu isotope amount ratios in the selected vials of IRMM-1027v 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-1027v 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 [12, 17, 35]. Moreover, all the external verification units analysed by IAEA-SGAS and JRC-KA confirmed all the gravimetrical U and Pu isotope amount ratios.

6.5 Amount content confirmation measurements

The confirmation measurements and the homogeneity study were performed on the same set of units (see Section 6) although only the results obtained on single spiked units were used for the uncertainty calculation associated with the homogeneity of the sample. All randomly selected units were used for verification unless they were excluded for technical reason.

Twelve units of IRMM-1027v were randomly selected from the whole batch and analysed by ID-TIMS to verify the uranium and plutonium amount contents from gravimetric preparation. To 12 of these units, about 2.0 g of mixed $^{233}U/^{242}Pu$ spike (IRMM-046c) in 5 M HNO_3 was weighed in and evaporated to dryness. Subsequently, the isotopic equilibrium, chemical separation and isotopic measurements on Triton TIMS were carried out as described in [21]. The weighing certificates and ID-TIMS reports regarding to the single unit verification of the IRMM-1027v batch can be found in Annex 15 and Annex 16.

Independently prepared and certified uranium (CRM-116A) and plutonium quality control (QC) (NBL 126) materials were measured together with each set of sample turrets as QC samples. A correction factor based on the relative biases of the QC measurements was applied to all verification results that were spiked with the same ampoule of IRMM-046c as the respective QC sample. The latter was important because statistically significant ampoule-to-ampoule differences were observed for some of the spike ampoules. The bias correction factor was applied according to Equation 5.

$$c_{IDMS,corr} = c_{IDMS,uncorr} * \frac{1}{1+QC_{bias}}$$ Equation 6

$c_{IDMS,\ corr}$ corrected amount content value of the selected isotope

$c_{IDMS,\ uncorr}$ uncorrected amount content value of the selected isotope

QC_{bias} IDMS QC bias relative to the gravimetrical QC value (expressed as decimal)

In case it was necessary (compatibility value calculated by Equation 5 was larger than 2), an additional uncertainty contribution was assigned to the IDMS values depending on the results of the consistency check. The consistency check was applied under repeatability conditions i.e. on sample subsets that were measured on the same TIMS turret as described by Kessel et al. [36].

At JRC-GE, the IDMS confirmation measurements obtained with the mixed $^{233}U/^{242}Pu$ spike (IRMM-046c) were used for verification. One unit was excluded due to technical issue (weighing) therefore 11 results are reported for all isotopes. IAEA-SGAS reported 10 results each on U and Pu assay, respectively and JRC-KA reported 4 data each as total U and Pu mass per unit, respectively. The results of the confirmation measurements and the randomly selected unit numbers are shown in Figure 11- Figure 13.

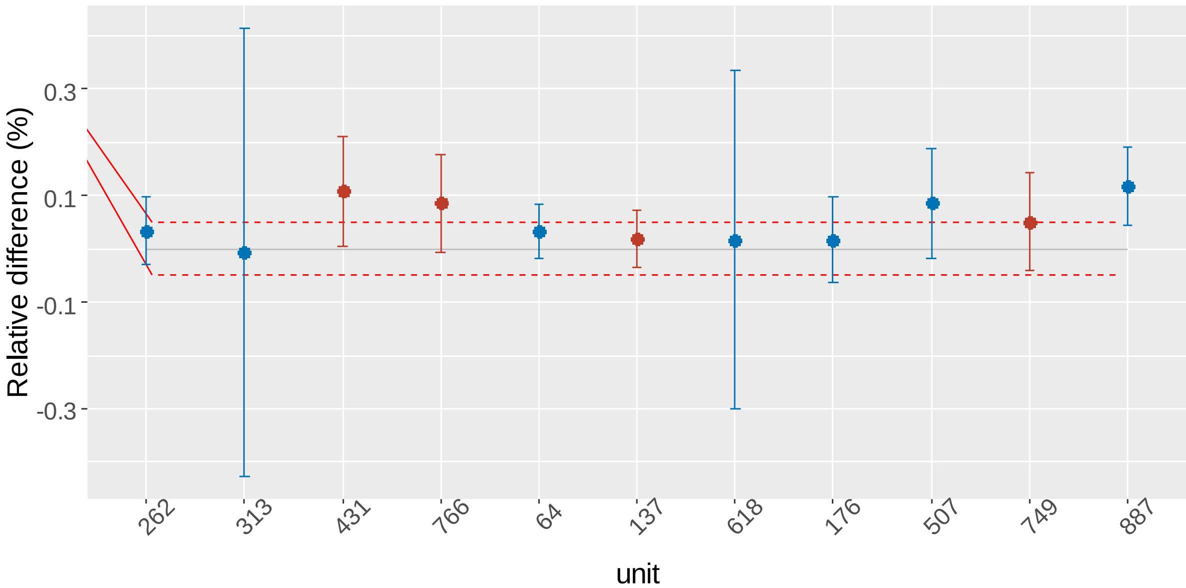


Figure 11 The amount content of ^{235}U in the selected vials of IRMM-1027v measured by ID-TIMS at JRC-GE expressed as the relative difference to the gravimetric value. Colour codes: red – CAB/DOP, blue – CMC. Error bars show the relative expanded uncertainties (coverage factors are based on the *t*-distribution for the associated effective degrees of freedom that corresponds to a level of confidence of about 95 %). Red dotted lines show the combined relative expanded uncertainty %) assigned to the gravimetric value (coverage factor *k* = 2 that corresponds to a level of confidence of about 95 (Source: EC JRC G.2.)

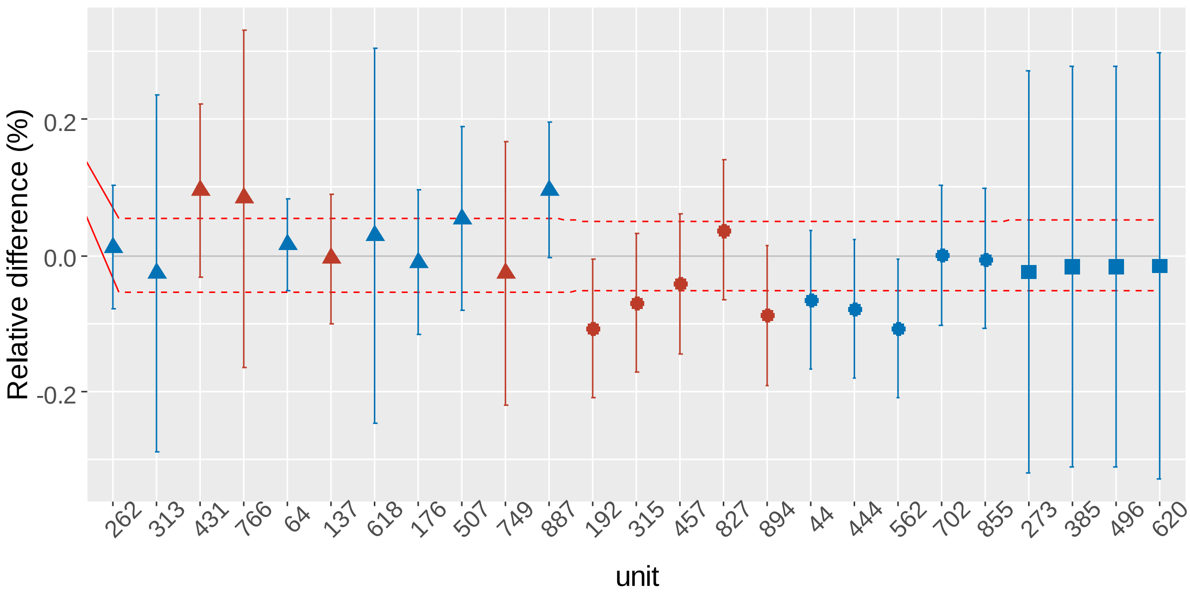


Figure 12 The amount content of ^{238}U, U assay or U mass content for the selected units of IRMM-1027v measured by ID-TIMS. Symbol codes: triangle – JRC-GE (^{238}U amount content), circle – IAEA-SGAS (U assay), square – JRC-KA (U mass per unit). Colour codes: red – CAB/DOP, blue – CMC. Error bars show the relative expanded uncertainties (For JRC-GE results coverage factors are based on the *t*-distribution for the associated effective degrees of freedom that corresponds to a level of confidence of about 95 %). Red dotted lines show the combined relative expanded uncertainty assigned to the gravimetric value (coverage factor k = 2 that corresponds to a level of confidence of about 95 %) (Source: EC JRC G.2, IAEA-SGAS, EC JRC G.II.6.)

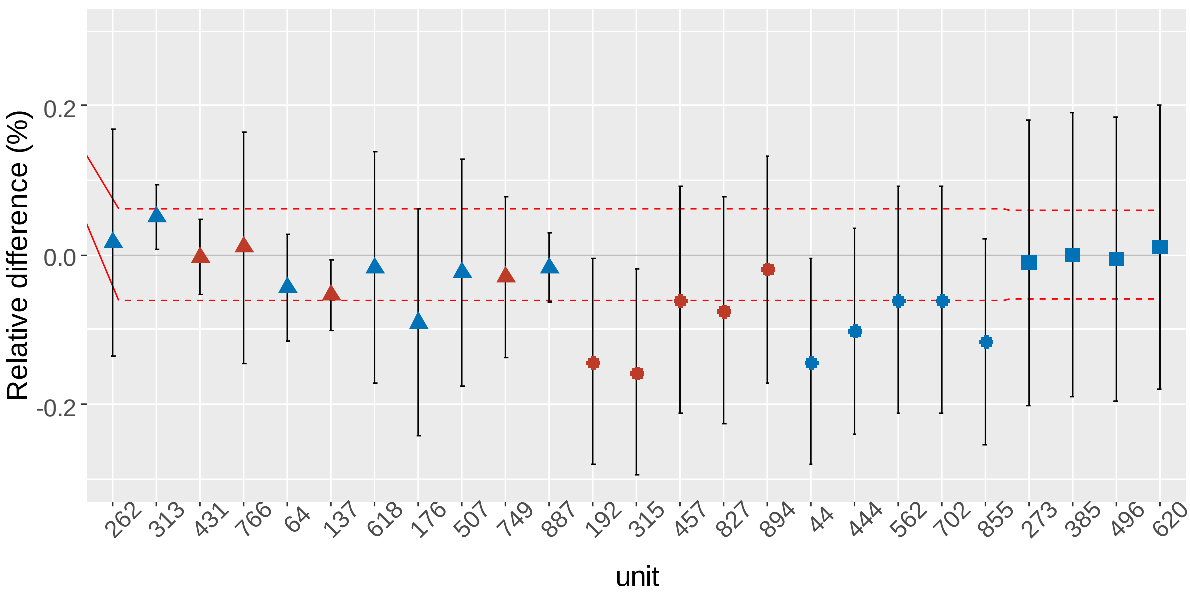


Figure 13 The amount content of ^{239}Pu, Pu assay or Pu mass content in the selected units of IRMM-1027v measured by ID-TIMS expressed as the relative difference from the gravimetric value. Symbol codes: triangle – JRC-GE (^{239}Pu amount content), circle – IAEA-SGAS (Pu assay), square – JRC-KA (Pu mass per unit). Colour codes: red – CAB/DOP, blue – CMC. Error bars show the relative expanded uncertainties (For JRC-GE results coverage factors are based on the *t*-distribution for the associated effective degrees of freedom that corresponds to a level of confidence of about 95 %). Red dotted lines show the combined relative expanded uncertainty assigned to the gravimetric value (coverage factor k = 2 that corresponds to a level of confidence of about 95 %) (Source: EC JRC G.2, IAEA-SGAS, EC JRC G.II.6.)

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

The results of the compatibility evaluations are summarised in Table 8-Table 10.

Table 8 Results of the compatibility evaluation for the ^{235}U, ^{238}U and ^{239}Pu amount content (Source: EC JRC G.2)

Vial No.	^{235}U amount content	^{238}U amount content	^{239}Pu amount content
1027v-262	0.86	0.23	0.16
1027v-313	-0.06	-0.20	1.34
1027v-431	2.27	1.38	-0.09
1027v-766	1.86	0.66	0.08
1027v-64	0.95	0.38	-1.02
1027v-137	0.55	-0.08	-1.40
1027v-618	0.23	0.21	-0.20
1027v-176	0.35	-0.16	-1.11
1027v-507	1.60	0.74	-0.25
1027v-749	1.02	-0.26	-0.62
1027v-887	2.68	1.71	-0.44

Table 9 Results of the compatibility evaluation for the U and Pu assay (Source: IAEA-SGAS)

	U assay	Pu assay
1027v-192	-1.86	-1.90
1027v-315	-1.21	-2.08
1027v-457	-0.72	-0.74
1027v-827	0.66	-0.91
1027v-894	-1.54	-0.24
1027v-044	-1.13	-1.90
1027v-444	-1.37	-1.35
1027v-562	-1.86	-0.74
1027v-702	0.01	-0.74
1027v-855	-0.07	-1.53

Table 10 Results of the compatibility evaluation for the U and Pu mass per unit (Source: EC JRC G.II.6)

	U mass/unit	Pu mass/unit
1027v-273	-0.16	-0.11
1027v-385	-0.11	0.00
1027v-496	-0.11	-0.05
1027v-620	-0.09	0.11

From Table 8 it can be seen that the compatibility is between -2 and +2 at a 95 % CI for all the ^{235}U, ^{238}U and ^{239}Pu amount contents, with the exception of two verification units for ^{235}U. Nevertheless, it can be concluded that the values of the gravimetric preparation are sufficiently verified by results obtained via IDMS and the material is fit for purpose. As for the previous batches, there was no significant difference between the vials treated with CAB/DOP and CMC.

Even after correcting for QC bias, all IDMS results of ^{235}U, ^{238}U and ^{239}Pu amount contents show a slight bias compared to the gravimetric values (+0.05%, +0.03% and -0.02%, respectively (Figure 11 - Figure 13)). A thorough investigation was made concerning the measurements and calculations but we could not find an explanation for the deviations. All results of the ID-TIMS measurements confirmed the gravimetrical values within expanded uncertainties. Therefore, this bias does not affect the certified values and their assigned uncertainties.

The quantity values and uncertainties associated with CRM characterisation and the internal verification data were computed via the commercially available software, GUM Workbench [37].

7. Value Assignment

Certified values are values that fulfil the highest standards of accuracy. Certified values for IRMM-1027v were assigned on the basis of the gravimetric preparation as a primary method of measurement. Full uncertainty budgets in accordance with the ISO GUM '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), between-unit inhomogeneity, u_{hom} (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:

$$\boldsymbol{U_{CRM} = k \cdot \sqrt{u_{char}^2 + u_{hom}^2}} \quad \text{Equation 7}$$

- u_{char} was estimated as described in Section 6
- u_{hom} 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 11. Its relative standard and expanded uncertainties are representative for all the units of the entire IRMM-1027v batch. The certified values of all 905 units are given in Annex 1.

Table 11 Exemplary representation of certified masses and their uncertainties in unit #1 of IRMM-1027v as an example (Source: EC JRC G.2)

Mass	Certified value [mg]	$u_{char, rel}$ [%]	$u_{hom, rel}$ [%]	$U_{CRM, rel}$ 1) [%]	U_{CRM} 1) [mg]
^{235}U mass	10.3301	0.013	0.021	0.049	0.0052
^{238}U mass	43.142	0.012	0.024	0.054	0.023
^{239}Pu mass	1.7711	0.023	0.020	0.062	0.0011

1) Expanded uncertainty, coverage factor k=2

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 of the respective metal certificates (EC NRM 101, CETAMA MP2 and NBL PO CRM 116-A) and consequently either partly to the SI or the national metrology data base for the United States. The values associated to the weighing are traceable to the SI via regular calibrations of the JRC G2's principal mass standards. The mass standards used for the calibration of balances and mass determination of the metals and the mother solution are in accordance with the maximum permissible error of class E1, E2 or F1 according to OIML-R 111:2004. More detailed information about the weight sets is available upon request.

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 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 [38] 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-1027v 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-1027v series 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.

9.2 Storage conditions

The material should be stored at room temperature in an upright position.

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.

9.3 Instructions for use

The spike has to be dissolved in the appropriate amount of acid (e.g. nitric acid with an amount of substance concentration of about c = 5 mol/ L) or sample solution to ensure the isotopic equilibrium between the spike and the sample. Heating on a hotplate (avoid boiling) may be applied to assist the dissolution process.

9.4 Minimum sample intake

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

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 8:

$$C_x = C_y \frac{m_y}{m_x} \frac{R_y - R_b}{R_b - R_x} \frac{\Sigma(R_i)_x}{\Sigma(R_i)_y} \quad , \qquad \text{Equation 8}$$

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-1027 series of LSD spike CRMs was prepared and certified in compliance with international guidelines: IRMM-1027v. 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 unit. 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-based 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 TIMS, ID-TIMS and alpha spectrometry as independent methods of measurement. The uncertainties of the certified values were established in compliance with the Guide to the Expression of Uncertainty in Measurement (GUM). The IRMM-1027v batch is fit for purpose and enables laboratories to meet the International Target Values for Measurement Uncertainties in Safeguarding Nuclear Materials (ITVs) ITV2010. A unit of IRMM-1027v contains about 54 mg of uranium with a relative mass fraction $m(^{235}\text{U})/m(\text{U})$ of 19.2 % and 1.8 mg of plutonium with a relative mass fraction $m(^{239}\text{Pu})/m(\text{Pu})$ of 97.8 % as dried nitrates in CAB/DOP or CMC matrices.

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List of abbreviations and definitions

ANOVA	Analysis of variance
BIPM	Bureau International des Poids et Mesures (International Bureau of Weights and Measures)
c	amount of substance concentration
CAB	Cellulose acetate butyrate
CETAMA	Commission d'Etablissement des Méthodes d'Analyse
CI	Confidence interval
CLSI	Clinical and Laboratory Standards Institute
CMC	Carboxymethyl cellulose
CRM	Certified reference material
DOP	Dioctyl phthalate
EC	European Commission
ESARDA	European Safeguards Research and Development Association
GUM	Guide to the Expression of Uncertainty in Measurement
IAEA	International Atomic Energy Agency
IDMS	Isotope dilution mass spectrometry
ID-TIMS	Isotope dilution thermal ionisation mass spectrometry
ISO	International Organization for Standardization
ITVs	International Target Values
JRC	Joint Research Centre of the European Commission
k	Coverage factor
LSD	Large-Sized dried
m	Mass
M	Molar mass
MS_{between}	Mean of squares between-unit from an ANOVA
MS_{within}	Mean of squares within-unit from an ANOVA
n	amount of substance
NBL	New Brunswick laboratory
NML	Nuclear Material Laboratory
p.a.	pro analysis
R_b	Isotope amount ratio in the blend
R_x	Isotope amount ratio in the un-spiked sample
R_y	Isotope amount ratio in the spike
rel	Index denoting relative figures (uncertainties etc.)
REML	Restricted maximum likelihood
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_{ip}	(Standard deviation associated with) Method intermediate precision
$t_{1/2}$	Half life
TE	Total evaporation
TIMS	Thermal Ionisation Mass Spectrometry
u	Standard uncertainty
U	Expanded uncertainty
u^{*}_{bb}	Standard uncertainty related to a maximum between-unit inhomogeneity that could be hidden by method repeatability; an additional index "rel" is added as appropriate
u_{bb}	Standard uncertainty related to a possible between-unit inhomogeneity; an additional index "rel" is added as appropriate
u_{char}	Standard uncertainty of the material characterisation; an additional index "rel" is added as appropriate
u_{CRM}	Combined standard uncertainty of the certified value; an additional index "rel" is added as appropriate
U_{CRM}	Expanded uncertainty of the certified value; an additional index "rel" is added as appropriate
u_{lts}	Standard uncertainty of the long-term stability; an additional index "rel" is added as appropriate
u_{sts}	Standard uncertainty of the short-term stability; an additional index "rel" is added as appropriate
$\overline{y}$	Arithmetic mean
$\nu_{MSwithin}$	Degrees of freedom of MS_{within}

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Annexes

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

Unit #	Organic substance	^{238}U Mass [1] [mg]	^{238}U Uncertainty [2] [mg]	^{235}U Mass [1] [mg]	^{235}U Uncertainty [2] [mg]	^{239}Pu Mass [1] [mg]	^{239}Pu Uncertainty [2] [mg]
001	CAB/DOP	43.142	0.023	10.3301	0.0052	1.7711	0.0013
002	CAB/DOP	43.736	0.024	10.4725	0.0052	1.7955	0.0013
003	CAB/DOP	43.218	0.023	10.3483	0.0052	1.7742	0.0013
004	CAB/DOP	43.041	0.023	10.3061	0.0051	1.7670	0.0013
005	CAB/DOP	43.060	0.023	10.3107	0.0051	1.7678	0.0013
006	CAB/DOP	43.052	0.023	10.3086	0.0051	1.7674	0.0013
007	CAB/DOP	43.124	0.023	10.3260	0.0052	1.7704	0.0013
008	CAB/DOP	43.698	0.024	10.4634	0.0052	1.7940	0.0013
009	CAB/DOP	44.059	0.024	10.5499	0.0052	1.8088	0.0013
010	CMC	43.857	0.024	10.5014	0.0052	1.8005	0.0013
011	CAB/DOP	43.206	0.023	10.3454	0.0052	1.7738	0.0013
012	CAB/DOP	43.062	0.023	10.3111	0.0051	1.7679	0.0013
013	CAB/DOP	43.873	0.024	10.5052	0.0052	1.8011	0.0013
014	CAB/DOP	43.748	0.024	10.4754	0.0052	1.7960	0.0013
015	CAB/DOP	43.190	0.023	10.3417	0.0052	1.7731	0.0013
016	CAB/DOP	44.071	0.024	10.5527	0.0052	1.8093	0.0013
017	CAB/DOP	43.845	0.024	10.4985	0.0052	1.8000	0.0013
018	CAB/DOP	43.895	0.024	10.5105	0.0052	1.8021	0.0013
019	CAB/DOP	43.897	0.024	10.5110	0.0052	1.8021	0.0013
020	CAB/DOP	43.982	0.024	10.5312	0.0052	1.8056	0.0013
021	CAB/DOP	43.874	0.024	10.5056	0.0052	1.8012	0.0013
022	CAB/DOP	43.788	0.024	10.4849	0.0052	1.7977	0.0013
023	CAB/DOP	43.219	0.023	10.3487	0.0052	1.7743	0.0013
024	CAB/DOP	43.793	0.024	10.4861	0.0052	1.7979	0.0013
025	CAB/DOP	43.098	0.023	10.3198	0.0052	1.7694	0.0013
026	CAB/DOP	43.233	0.023	10.3520	0.0052	1.7749	0.0013
027	CAB/DOP	43.015	0.023	10.2999	0.0051	1.7659	0.0013
028	CAB/DOP	43.710	0.024	10.4663	0.0052	1.7945	0.0013
029	CAB/DOP	43.190	0.023	10.3417	0.0052	1.7731	0.0013
030	CAB/DOP	43.762	0.024	10.4787	0.0052	1.7966	0.0013
031	CAB/DOP	43.259	0.023	10.3583	0.0052	1.7759	0.0013
032	CAB/DOP	43.778	0.024	10.4824	0.0052	1.7972	0.0013
033	CAB/DOP	43.124	0.023	10.3260	0.0052	1.7704	0.0013
034	CAB/DOP	43.829	0.024	10.4948	0.0052	1.7994	0.0013
035	CAB/DOP	43.190	0.023	10.3417	0.0052	1.7731	0.0013
036	CAB/DOP	43.949	0.024	10.5234	0.0052	1.8043	0.0013
037	CAB/DOP	43.918	0.024	10.5159	0.0052	1.8030	0.0013
038	CAB/DOP	43.015	0.023	10.2999	0.0051	1.7659	0.0013
039	CAB/DOP	43.753	0.024	10.4766	0.0052	1.7962	0.0013
040	CAB/DOP	43.271	0.023	10.3612	0.0052	1.7764	0.0013
041	CAB/DOP	43.667	0.024	10.4559	0.0052	1.7927	0.0013
042	CAB/DOP	43.194	0.023	10.3425	0.0052	1.7733	0.0013
043	CAB/DOP	43.155	0.023	10.3334	0.0052	1.7717	0.0013
044	CMC	43.836	0.024	10.4965	0.0052	1.7996	0.0013
045	CAB/DOP	43.131	0.023	10.3276	0.0052	1.7707	0.0013
046	CAB/DOP	42.988	0.023	10.2933	0.0051	1.7648	0.0013
047	CAB/DOP	43.724	0.024	10.4696	0.0052	1.7950	0.0013
048	CAB/DOP	43.188	0.023	10.3413	0.0052	1.7730	0.0013
049	CAB/DOP	43.721	0.024	10.4687	0.0052	1.7949	0.0013

050	CAB/DOP	44.147	0.024	10.5710	0.0052	1.8124	0.0013

		^{238}U		^{235}U		^{239}Pu	
Unit #	Organic substance	Mass 1) [mg]	Uncertainty 2) [mg]	Mass 1) [mg]	Uncertainty 2) [mg]	Mass 1) [mg]	Uncertainty 2) [mg]
051	CAB/DOP	43.733	0.024	10.4716	0.0052	1.7954	0.0013
052	CAB/DOP	43.171	0.023	10.3371	0.0052	1.7723	0.0013
053	CAB/DOP	43.829	0.024	10.4948	0.0052	1.7994	0.0013
054	CAB/DOP	43.871	0.024	10.5047	0.0052	1.8011	0.0013
055	CAB/DOP	43.213	0.023	10.3471	0.0052	1.7740	0.0013
056	CAB/DOP	43.015	0.023	10.2999	0.0051	1.7659	0.0013
057	CAB/DOP	43.050	0.023	10.3082	0.0051	1.7674	0.0013
058	CAB/DOP	43.043	0.023	10.3065	0.0051	1.7671	0.0013
059	CAB/DOP	43.895	0.024	10.5105	0.0052	1.8021	0.0013
060	CAB/DOP	43.033	0.023	10.3040	0.0051	1.7667	0.0013
061	CAB/DOP	43.902	0.024	10.5122	0.0052	1.8023	0.0013
062	CAB/DOP	43.911	0.024	10.5143	0.0052	1.8027	0.0013
063	CAB/DOP	43.838	0.024	10.4969	0.0052	1.7997	0.0013
064	CMC	43.968	0.024	10.5279	0.0052	1.8050	0.0013
065	CAB/DOP	43.045	0.023	10.3069	0.0051	1.7672	0.0013
066	CAB/DOP	43.641	0.023	10.4497	0.0052	1.7916	0.0013
067	CAB/DOP	43.237	0.023	10.3529	0.0052	1.7750	0.0013
068	CAB/DOP	43.069	0.023	10.3127	0.0051	1.7681	0.0013
069	CAB/DOP	43.805	0.024	10.4890	0.0052	1.7984	0.0013
070	CAB/DOP	42.995	0.023	10.2949	0.0051	1.7651	0.0013
071	CAB/DOP	43.009	0.023	10.2982	0.0051	1.7657	0.0013
072	CAB/DOP	43.923	0.024	10.5172	0.0052	1.8032	0.0013
073	CAB/DOP	43.937	0.024	10.5205	0.0052	1.8038	0.0013
074	CAB/DOP	43.655	0.023	10.4530	0.0052	1.7922	0.0013
075	CAB/DOP	43.266	0.023	10.3599	0.0052	1.7762	0.0013
076	CAB/DOP	42.976	0.023	10.2904	0.0051	1.7643	0.0013
077	CAB/DOP	43.816	0.024	10.4915	0.0052	1.7988	0.0013
078	CAB/DOP	43.816	0.024	10.4915	0.0052	1.7988	0.0013
079	CAB/DOP	43.938	0.024	10.5209	0.0052	1.8038	0.0013
080	CAB/DOP	43.035	0.023	10.3045	0.0051	1.7667	0.0013
081	CAB/DOP	43.695	0.024	10.4625	0.0052	1.7938	0.0013
082	CAB/DOP	43.975	0.024	10.5296	0.0052	1.8053	0.0013
083	CAB/DOP	43.798	0.024	10.4874	0.0052	1.7981	0.0013
084	CAB/DOP	43.684	0.024	10.4601	0.0052	1.7934	0.0013
085	CAB/DOP	44.042	0.024	10.5457	0.0052	1.8081	0.0013
086	CAB/DOP	43.658	0.023	10.4538	0.0052	1.7923	0.0013
087	CMC	43.940	0.024	10.5213	0.0052	1.8039	0.0013
088	CAB/DOP	43.098	0.023	10.3198	0.0052	1.7694	0.0013
089	CAB/DOP	43.788	0.024	10.4849	0.0052	1.7977	0.0013
090	CAB/DOP	43.626	0.023	10.4460	0.0052	1.7910	0.0013
091	CAB/DOP	43.874	0.024	10.5056	0.0052	1.8012	0.0013
092	CAB/DOP	43.200	0.023	10.3442	0.0052	1.7735	0.0013
093	CAB/DOP	43.565	0.023	10.4315	0.0052	1.7885	0.0013
094	CAB/DOP	43.204	0.023	10.3450	0.0052	1.7737	0.0013
095	CAB/DOP	43.510	0.023	10.4183	0.0052	1.7862	0.0013
096	CAB/DOP	43.256	0.023	10.3574	0.0052	1.7758	0.0013
097	CMC	43.653	0.023	10.4526	0.0052	1.7921	0.0013
098	CMC	43.702	0.024	10.4642	0.0052	1.7941	0.0013
099	CMC	43.206	0.023	10.3454	0.0052	1.7738	0.0013
100	CMC	43.731	0.024	10.4712	0.0052	1.7953	0.0013

Unit #	Organic substance	^{238}U Mass [1] [mg]	^{238}U Uncertainty [2] [mg]	^{235}U Mass [1] [mg]	^{235}U Uncertainty [2] [mg]	^{239}Pu Mass [1] [mg]	^{239}Pu Uncertainty [2] [mg]
101	CMC	43.641	0.023	10.4497	0.0052	1.7916	0.0013
102	CMC	43.733	0.024	10.4716	0.0052	1.7954	0.0013
103	CMC	43.252	0.023	10.3566	0.0052	1.7757	0.0013
104	CMC	43.717	0.024	10.4679	0.0052	1.7948	0.0013
105	CMC	43.764	0.024	10.4791	0.0052	1.7967	0.0013
106	CMC	43.940	0.024	10.5213	0.0052	1.8039	0.0013
107	CMC	43.676	0.024	10.4580	0.0052	1.7930	0.0013
108	CMC	43.961	0.024	10.5263	0.0052	1.8048	0.0013
109	CMC	43.726	0.024	10.4700	0.0052	1.7951	0.0013
110	CMC	43.733	0.024	10.4716	0.0052	1.7954	0.0013
111	CMC	43.781	0.024	10.4832	0.0052	1.7974	0.0013
112	CMC	43.007	0.023	10.2978	0.0051	1.7656	0.0013
113	CMC	43.581	0.023	10.4352	0.0052	1.7891	0.0013
114	CMC	43.095	0.023	10.3189	0.0052	1.7692	0.0013
115	CMC	43.755	0.024	10.4770	0.0052	1.7963	0.0013
116	CMC	43.829	0.024	10.4948	0.0052	1.7994	0.0013
117	CMC	43.691	0.024	10.4617	0.0052	1.7937	0.0013
118	CMC	43.793	0.024	10.4861	0.0052	1.7979	0.0013
119	CMC	43.748	0.024	10.4754	0.0052	1.7960	0.0013
120	CMC	43.840	0.024	10.4973	0.0052	1.7998	0.0013
121	CMC	43.887	0.024	10.5085	0.0052	1.8017	0.0013
122	CMC	43.624	0.023	10.4456	0.0052	1.7909	0.0013
123	CMC	43.790	0.024	10.4853	0.0052	1.7977	0.0013
124	CMC	43.620	0.023	10.4447	0.0052	1.7908	0.0013
125	CMC	43.983	0.024	10.5316	0.0052	1.8057	0.0013
126	CMC	43.776	0.024	10.4820	0.0052	1.7972	0.0013
127	CMC	43.705	0.024	10.4650	0.0052	1.7943	0.0013
128	CMC	43.743	0.024	10.4741	0.0052	1.7958	0.0013
129	CAB/DOP	43.762	0.024	10.4787	0.0052	1.7966	0.0013
130	CMC	43.698	0.024	10.4634	0.0052	1.7940	0.0013
131	CMC	43.802	0.024	10.4882	0.0052	1.7982	0.0013
132	CMC	43.778	0.024	10.4824	0.0052	1.7972	0.0013
133	CMC	43.632	0.023	10.4476	0.0052	1.7913	0.0013
134	CMC	43.712	0.024	10.4667	0.0052	1.7945	0.0013
135	CMC	43.178	0.023	10.3388	0.0052	1.7726	0.0013
136	CMC	43.791	0.024	10.4857	0.0052	1.7978	0.0013
137	CAB/DOP	43.639	0.023	10.4493	0.0052	1.7916	0.0013
138	CMC	43.734	0.024	10.4721	0.0052	1.7955	0.0013
139	CMC	43.800	0.024	10.4878	0.0052	1.7982	0.0013
140	CMC	43.517	0.023	10.4199	0.0052	1.7865	0.0013
141	CMC	43.190	0.023	10.3417	0.0052	1.7731	0.0013
142	CMC	43.717	0.024	10.4679	0.0052	1.7948	0.0013
143	CMC	43.705	0.024	10.4650	0.0052	1.7943	0.0013
144	CMC	43.722	0.024	10.4692	0.0052	1.7950	0.0013
145	CAB/DOP	43.769	0.024	10.4803	0.0052	1.7969	0.0013
146	CAB/DOP	43.579	0.023	10.4348	0.0052	1.7891	0.0013
147	CAB/DOP	43.117	0.023	10.3243	0.0052	1.7701	0.0013
148	CAB/DOP	43.600	0.023	10.4398	0.0052	1.7899	0.0013
149	CAB/DOP	43.000	0.023	10.2962	0.0051	1.7653	0.0013
150	CAB/DOP	43.470	0.023	10.4087	0.0052	1.7846	0.0013

Unit #	Organic substance	^{238}U Mass [1] [mg]	^{238}U Uncertainty [2] [mg]	^{235}U Mass [1] [mg]	^{235}U Uncertainty [2] [mg]	^{239}Pu Mass [1] [mg]	^{239}Pu Uncertainty [2] [mg]
151	CAB/DOP	43.169	0.023	10.3367	0.0052	1.7723	0.0013
152	CAB/DOP	43.691	0.024	10.4617	0.0052	1.7937	0.0013
153	CAB/DOP	43.745	0.024	10.4745	0.0052	1.7959	0.0013
154	CAB/DOP	43.698	0.024	10.4634	0.0052	1.7940	0.0013
155	CAB/DOP	43.783	0.024	10.4836	0.0052	1.7974	0.0013
156	CAB/DOP	43.589	0.023	10.4373	0.0052	1.7895	0.0013
157	CAB/DOP	43.931	0.024	10.5192	0.0052	1.8035	0.0013
158	CAB/DOP	43.745	0.024	10.4745	0.0052	1.7959	0.0013
159	CAB/DOP	43.710	0.024	10.4663	0.0052	1.7945	0.0013
160	CAB/DOP	43.700	0.024	10.4638	0.0052	1.7940	0.0013
161	CAB/DOP	43.728	0.024	10.4704	0.0052	1.7952	0.0013
162	CAB/DOP	43.760	0.024	10.4783	0.0052	1.7965	0.0013
163	CAB/DOP	43.501	0.023	10.4162	0.0052	1.7859	0.0013
164	CAB/DOP	43.926	0.024	10.5180	0.0052	1.8033	0.0013
165	CAB/DOP	43.722	0.024	10.4692	0.0052	1.7950	0.0013
166	CAB/DOP	43.864	0.024	10.5031	0.0052	1.8008	0.0013
167	CAB/DOP	43.627	0.023	10.4464	0.0052	1.7911	0.0013
168	CAB/DOP	43.681	0.024	10.4592	0.0052	1.7933	0.0013
169	CAB/DOP	43.835	0.024	10.4961	0.0052	1.7996	0.0013
170	CAB/DOP	43.634	0.023	10.4481	0.0052	1.7913	0.0013
171	CAB/DOP	43.778	0.024	10.4824	0.0052	1.7972	0.0013
172	CAB/DOP	43.702	0.024	10.4642	0.0052	1.7941	0.0013
173	CAB/DOP	43.632	0.023	10.4476	0.0052	1.7913	0.0013
174	CAB/DOP	43.821	0.024	10.4927	0.0052	1.7990	0.0013
175	CAB/DOP	43.712	0.024	10.4667	0.0052	1.7945	0.0013
176	CMC	43.747	0.024	10.4749	0.0052	1.7960	0.0013
177	CMC	43.636	0.023	10.4485	0.0052	1.7914	0.0013
178	CAB/DOP	43.674	0.024	10.4576	0.0052	1.7930	0.0013
179	CAB/DOP	43.650	0.023	10.4518	0.0052	1.7920	0.0013
180	CAB/DOP	43.135	0.023	10.3285	0.0052	1.7708	0.0013
181	CAB/DOP	43.515	0.023	10.4195	0.0052	1.7865	0.0013
182	CAB/DOP	43.828	0.024	10.4944	0.0052	1.7993	0.0013
183	CAB/DOP	43.781	0.024	10.4832	0.0052	1.7974	0.0013
184	CAB/DOP	43.690	0.024	10.4613	0.0052	1.7936	0.0013
185	CAB/DOP	43.702	0.024	10.4642	0.0052	1.7941	0.0013
186	CAB/DOP	43.591	0.023	10.4377	0.0052	1.7896	0.0013
187	CAB/DOP	43.731	0.024	10.4712	0.0052	1.7953	0.0013
188	CAB/DOP	43.902	0.024	10.5122	0.0052	1.8023	0.0013
189	CAB/DOP	43.584	0.023	10.4361	0.0052	1.7893	0.0013
190	CMC	43.895	0.024	10.5105	0.0052	1.8021	0.0013
191	CAB/DOP	43.498	0.023	10.4154	0.0052	1.7857	0.0013
192	CAB/DOP	43.883	0.024	10.5076	0.0052	1.8016	0.0013
193	CAB/DOP	43.731	0.024	10.4712	0.0052	1.7953	0.0013
194	CAB/DOP	43.598	0.023	10.4394	0.0052	1.7899	0.0013
195	CAB/DOP	43.850	0.024	10.4998	0.0052	1.8002	0.0013
196	CAB/DOP	43.809	0.024	10.4898	0.0052	1.7985	0.0013
197	CAB/DOP	43.695	0.024	10.4625	0.0052	1.7938	0.0013
198	CAB/DOP	43.752	0.024	10.4762	0.0052	1.7962	0.0013
199	CAB/DOP	43.672	0.024	10.4572	0.0052	1.7929	0.0013
200	CAB/DOP	43.850	0.024	10.4998	0.0052	1.8002	0.0013

Unit #	Organic substance	^{238}U		^{235}U		^{239}Pu	
		Mass 1) [mg]	Uncertainty 2) [mg]	Mass 1) [mg]	Uncertainty 2) [mg]	Mass 1) [mg]	Uncertainty 2) [mg]
201	CMC	43.613	0.023	10.4431	0.0052	1.7905	0.0013
202	CAB/DOP	43.712	0.024	10.4667	0.0052	1.7945	0.0013
203	CAB/DOP	43.683	0.024	10.4596	0.0052	1.7933	0.0013
204	CAB/DOP	43.745	0.024	10.4745	0.0052	1.7959	0.0013
205	CAB/DOP	43.726	0.024	10.4700	0.0052	1.7951	0.0013
206	CAB/DOP	43.703	0.024	10.4646	0.0052	1.7942	0.0013
207	CMC	43.506	0.023	10.4174	0.0052	1.7861	0.0013
208	CMC	43.928	0.024	10.5184	0.0052	1.8034	0.0013
209	CAB/DOP	43.567	0.023	10.4319	0.0052	1.7886	0.0013
210	CMC	43.798	0.024	10.4874	0.0052	1.7981	0.0013
211	CMC	42.995	0.023	10.2949	0.0051	1.7651	0.0013
212	CAB/DOP	43.646	0.023	10.4509	0.0052	1.7918	0.0013
213	CMC	43.774	0.024	10.4816	0.0052	1.7971	0.0013
214	CAB/DOP	43.667	0.024	10.4559	0.0052	1.7927	0.0013
215	CAB/DOP	43.613	0.023	10.4431	0.0052	1.7905	0.0013
216	CAB/DOP	43.567	0.023	10.4319	0.0052	1.7886	0.0013
217	CAB/DOP	43.135	0.023	10.3285	0.0052	1.7708	0.0013
218	CAB/DOP	43.511	0.023	10.4187	0.0052	1.7863	0.0013
219	CAB/DOP	43.781	0.024	10.4832	0.0052	1.7974	0.0013
220	CAB/DOP	43.660	0.023	10.4543	0.0052	1.7924	0.0013
221	CAB/DOP	43.741	0.024	10.4737	0.0052	1.7957	0.0013
222	CAB/DOP	43.864	0.024	10.5031	0.0052	1.8008	0.0013
223	CAB/DOP	43.593	0.023	10.4381	0.0052	1.7896	0.0013
224	CAB/DOP	43.529	0.023	10.4228	0.0052	1.7870	0.0013
225	CAB/DOP	43.698	0.024	10.4634	0.0052	1.7940	0.0013
226	CAB/DOP	43.899	0.024	10.5114	0.0052	1.8022	0.0013
227	CAB/DOP	43.717	0.024	10.4679	0.0052	1.7948	0.0013
228	CAB/DOP	43.703	0.024	10.4646	0.0052	1.7942	0.0013
229	CAB/DOP	43.717	0.024	10.4679	0.0052	1.7948	0.0013
230	CAB/DOP	43.650	0.023	10.4518	0.0052	1.7920	0.0013
231	CMC	43.575	0.023	10.4340	0.0052	1.7889	0.0013
232	CAB/DOP	43.076	0.023	10.3144	0.0051	1.7684	0.0013
233	CAB/DOP	43.651	0.023	10.4522	0.0052	1.7921	0.0013
234	CAB/DOP	43.729	0.024	10.4708	0.0052	1.7952	0.0013
235	CAB/DOP	43.696	0.024	10.4629	0.0052	1.7939	0.0013
236	CAB/DOP	43.690	0.024	10.4613	0.0052	1.7936	0.0013
237	CAB/DOP	43.657	0.023	10.4534	0.0052	1.7923	0.0013
238	CAB/DOP	43.828	0.024	10.4944	0.0052	1.7993	0.0013
239	CAB/DOP	43.626	0.023	10.4460	0.0052	1.7910	0.0013
240	CAB/DOP	43.589	0.023	10.4373	0.0052	1.7895	0.0013
241	CAB/DOP	43.847	0.024	10.4990	0.0052	1.8001	0.0013
242	CAB/DOP	43.762	0.024	10.4787	0.0052	1.7966	0.0013
243	CAB/DOP	43.634	0.023	10.4481	0.0052	1.7913	0.0013
244	CAB/DOP	43.605	0.023	10.4410	0.0052	1.7901	0.0013
245	CAB/DOP	43.771	0.024	10.4807	0.0052	1.7970	0.0013
246	CAB/DOP	43.577	0.023	10.4344	0.0052	1.7890	0.0013
247	CAB/DOP	43.743	0.024	10.4741	0.0052	1.7958	0.0013
248	CAB/DOP	43.757	0.024	10.4774	0.0052	1.7964	0.0013
249	CAB/DOP	43.610	0.023	10.4423	0.0052	1.7904	0.0013
250	CAB/DOP	43.150	0.023	10.3322	0.0052	1.7715	0.0013

Unit #	Organic substance	^{238}U Mass 1) [mg]	^{238}U Uncertainty 2) [mg]	^{235}U Mass 1) [mg]	^{235}U Uncertainty 2) [mg]	^{239}Pu Mass 1) [mg]	^{239}Pu Uncertainty 2) [mg]
251	CAB/DOP	43.579	0.023	10.4348	0.0052	1.7891	0.0013
252	CAB/DOP	43.551	0.023	10.4282	0.0052	1.7879	0.0013
253	CMC	43.074	0.023	10.3140	0.0051	1.7684	0.0013
254	CAB/DOP	43.627	0.023	10.4464	0.0052	1.7911	0.0013
255	CAB/DOP	43.683	0.024	10.4596	0.0052	1.7933	0.0013
256	CAB/DOP	43.662	0.023	10.4547	0.0052	1.7925	0.0013
257	CAB/DOP	43.038	0.023	10.3053	0.0051	1.7669	0.0013
258	CAB/DOP	43.562	0.023	10.4307	0.0052	1.7884	0.0013
259	CAB/DOP	43.646	0.023	10.4509	0.0052	1.7918	0.0013
260	CAB/DOP	43.660	0.023	10.4543	0.0052	1.7924	0.0013
261	CAB/DOP	43.631	0.023	10.4472	0.0052	1.7912	0.0013
262	CMC	43.743	0.024	10.4741	0.0052	1.7958	0.0013
263	CAB/DOP	43.639	0.023	10.4493	0.0052	1.7916	0.0013
264	CAB/DOP	43.169	0.023	10.3367	0.0052	1.7723	0.0013
265	CAB/DOP	43.553	0.023	10.4286	0.0052	1.7880	0.0013
266	CAB/DOP	43.686	0.024	10.4605	0.0052	1.7935	0.0013
267	CAB/DOP	43.731	0.024	10.4712	0.0052	1.7953	0.0013
268	CAB/DOP	43.717	0.024	10.4679	0.0052	1.7948	0.0013
269	CAB/DOP	43.669	0.024	10.4563	0.0052	1.7928	0.0013
270	CAB/DOP	43.641	0.023	10.4497	0.0052	1.7916	0.0013
271	CAB/DOP	43.024	0.023	10.3020	0.0051	1.7663	0.0013
272	CAB/DOP	43.598	0.023	10.4394	0.0052	1.7899	0.0013
273	CMC	43.662	0.023	10.4547	0.0052	1.7925	0.0013
274	CAB/DOP	43.807	0.024	10.4894	0.0052	1.7984	0.0013
275	CAB/DOP	43.664	0.023	10.4551	0.0052	1.7926	0.0013
276	CAB/DOP	43.634	0.023	10.4481	0.0052	1.7913	0.0013
277	CAB/DOP	43.638	0.023	10.4489	0.0052	1.7915	0.0013
278	CAB/DOP	43.776	0.024	10.4820	0.0052	1.7972	0.0013
279	CAB/DOP	43.683	0.024	10.4596	0.0052	1.7933	0.0013
280	CAB/DOP	43.684	0.024	10.4601	0.0052	1.7934	0.0013
281	CAB/DOP	43.565	0.023	10.4315	0.0052	1.7885	0.0013
282	CAB/DOP	43.876	0.024	10.5060	0.0052	1.8013	0.0013
283	CAB/DOP	43.683	0.024	10.4596	0.0052	1.7933	0.0013
284	CAB/DOP	43.582	0.023	10.4356	0.0052	1.7892	0.0013
285	CAB/DOP	43.752	0.024	10.4762	0.0052	1.7962	0.0013
286	CAB/DOP	43.752	0.024	10.4762	0.0052	1.7962	0.0013
287	CAB/DOP	43.807	0.024	10.4894	0.0052	1.7984	0.0013
288	CAB/DOP	43.641	0.023	10.4497	0.0052	1.7916	0.0013
289	CMC	43.717	0.024	10.4679	0.0052	1.7948	0.0013
290	CMC	43.482	0.023	10.4116	0.0052	1.7851	0.0013
291	CMC	43.107	0.023	10.3218	0.0052	1.7697	0.0013
292	CMC	43.710	0.024	10.4663	0.0052	1.7945	0.0013
293	CMC	43.702	0.024	10.4642	0.0052	1.7941	0.0013
294	CAB/DOP	43.539	0.023	10.4253	0.0052	1.7874	0.0013
295	CMC	43.738	0.024	10.4729	0.0052	1.7956	0.0013
296	CMC	43.556	0.023	10.4294	0.0052	1.7882	0.0013
297	CMC	43.086	0.023	10.3169	0.0052	1.7689	0.0013
298	CMC	43.586	0.023	10.4365	0.0052	1.7894	0.0013
299	CMC	43.544	0.023	10.4265	0.0052	1.7877	0.0013
300	CMC	43.857	0.024	10.5014	0.0052	1.8005	0.0013

Unit #	Organic substance	^{238}U		^{235}U		^{239}Pu	
		Mass [1)] [mg]	Uncertainty [2)] [mg]	Mass [1)] [mg]	Uncertainty [2)] [mg]	Mass [1)] [mg]	Uncertainty [2)] [mg]
301	CMC	43.584	0.023	10.4361	0.0052	1.7893	0.0013
302	CMC	43.100	0.023	10.3202	0.0052	1.7694	0.0013
303	CMC	43.544	0.023	10.4265	0.0052	1.7877	0.0013
304	CMC	43.638	0.023	10.4489	0.0052	1.7915	0.0013
305	CMC	43.657	0.023	10.4534	0.0052	1.7923	0.0013
306	CMC	43.076	0.023	10.3144	0.0051	1.7684	0.0013
307	CMC	43.626	0.023	10.4460	0.0052	1.7910	0.0013
308	CMC	43.726	0.024	10.4700	0.0052	1.7951	0.0013
309	CMC	43.546	0.023	10.4269	0.0052	1.7877	0.0013
310	CMC	43.766	0.024	10.4795	0.0052	1.7967	0.0013
311	CMC	43.840	0.024	10.4973	0.0052	1.7998	0.0013
312	CMC	43.613	0.023	10.4431	0.0052	1.7905	0.0013
313	CMC	43.741	0.024	10.4737	0.0052	1.7957	0.0013
314	CMC	43.558	0.023	10.4298	0.0052	1.7882	0.0013
315	CAB/DOP	43.769	0.024	10.4803	0.0052	1.7969	0.0013
316	CMC	43.709	0.024	10.4658	0.0052	1.7944	0.0013
317	CMC	43.791	0.024	10.4857	0.0052	1.7978	0.0013
318	CMC	43.653	0.023	10.4526	0.0052	1.7921	0.0013
319	CMC	43.076	0.023	10.3144	0.0051	1.7684	0.0013
320	CMC	43.600	0.023	10.4398	0.0052	1.7899	0.0013
321	CMC	43.487	0.023	10.4129	0.0052	1.7853	0.0013
322	CMC	43.874	0.024	10.5056	0.0052	1.8012	0.0013
323	CMC	43.579	0.023	10.4348	0.0052	1.7891	0.0013
324	CMC	43.880	0.024	10.5068	0.0052	1.8014	0.0013
325	CMC	43.536	0.023	10.4245	0.0052	1.7873	0.0013
326	CMC	43.138	0.023	10.3293	0.0052	1.7710	0.0013
327	CMC	43.541	0.023	10.4257	0.0052	1.7875	0.0013
328	CMC	43.619	0.023	10.4443	0.0052	1.7907	0.0013
329	CMC	43.686	0.024	10.4605	0.0052	1.7935	0.0013
330	CMC	43.733	0.024	10.4716	0.0052	1.7954	0.0013
331	CMC	43.081	0.023	10.3156	0.0052	1.7686	0.0013
332	CMC	43.617	0.023	10.4439	0.0052	1.7906	0.0013
333	CMC	43.729	0.024	10.4708	0.0052	1.7952	0.0013
334	CMC	43.674	0.024	10.4576	0.0052	1.7930	0.0013
335	CMC	43.715	0.024	10.4675	0.0052	1.7947	0.0013
336	CMC	43.710	0.024	10.4663	0.0052	1.7945	0.0013
337	CAB/DOP	43.774	0.024	10.4816	0.0052	1.7971	0.0013
338	CAB/DOP	43.690	0.024	10.4613	0.0052	1.7936	0.0013
339	CAB/DOP	43.598	0.023	10.4394	0.0052	1.7899	0.0013
340	CAB/DOP	43.747	0.024	10.4749	0.0052	1.7960	0.0013
341	CMC	43.797	0.024	10.4870	0.0052	1.7980	0.0013
342[5)]	CAB/DOP	43.734	0.024	10.4721	0.0052	1.7955	0.0013
343[5)]	CAB/DOP	43.658	0.023	10.4538	0.0052	1.7923	0.0013
344	CAB/DOP	43.728	0.024	10.4704	0.0052	1.7952	0.0013
345[5)]	CAB/DOP	43.601	0.023	10.4402	0.0052	1.7900	0.0013
346	CAB/DOP	43.838	0.024	10.4969	0.0052	1.7997	0.0013
347	CAB/DOP	43.722	0.024	10.4692	0.0052	1.7950	0.0013
348	CAB/DOP	43.660	0.023	10.4543	0.0052	1.7924	0.0013
349	CAB/DOP	43.641	0.023	10.4497	0.0052	1.7916	0.0013
350	CAB/DOP	43.100	0.023	10.3202	0.0052	1.7694	0.0013

Unit #	Organic substance	^{238}U Mass [1] [mg]	^{238}U Uncertainty [2] [mg]	^{235}U Mass [1] [mg]	^{235}U Uncertainty [2] [mg]	^{239}Pu Mass [1] [mg]	^{239}Pu Uncertainty [2] [mg]
351	CAB/DOP	43.613	0.023	10.4431	0.0052	1.7905	0.0013
352	CAB/DOP	43.681	0.024	10.4592	0.0052	1.7933	0.0013
353	CAB/DOP	43.750	0.024	10.4758	0.0052	1.7961	0.0013
354	CAB/DOP	43.767	0.024	10.4799	0.0052	1.7968	0.0013
355	CAB/DOP	43.665	0.023	10.4555	0.0052	1.7926	0.0013
356	CAB/DOP	42.990	0.023	10.2937	0.0051	1.7649	0.0013
357	CAB/DOP	43.610	0.023	10.4423	0.0052	1.7904	0.0013
358	CAB/DOP	43.823	0.024	10.4932	0.0052	1.7991	0.0013
359	CAB/DOP	43.600	0.023	10.4398	0.0052	1.7899	0.0013
360	CAB/DOP	43.691	0.024	10.4617	0.0052	1.7937	0.0013
361	CMC	43.752	0.024	10.4762	0.0052	1.7962	0.0013
362	CAB/DOP	43.745	0.024	10.4745	0.0052	1.7959	0.0013
363	CAB/DOP	43.650	0.023	10.4518	0.0052	1.7920	0.0013
364	CAB/DOP	43.695	0.024	10.4625	0.0052	1.7938	0.0013
365[5]	CAB/DOP	43.622	0.023	10.4452	0.0052	1.7908	0.0013
366	CAB/DOP	43.895	0.024	10.5105	0.0052	1.8021	0.0013
367	CAB/DOP	43.703	0.024	10.4646	0.0052	1.7942	0.0013
368	CAB/DOP	43.696	0.024	10.4629	0.0052	1.7939	0.0013
369	CAB/DOP	42.990	0.023	10.2937	0.0051	1.7649	0.0013
370	CAB/DOP	43.513	0.023	10.4191	0.0052	1.7864	0.0013
371[5]	CAB/DOP	43.710	0.024	10.4663	0.0052	1.7945	0.0013
372	CAB/DOP	43.098	0.023	10.3198	0.0052	1.7694	0.0013
373	CAB/DOP	43.596	0.023	10.4389	0.0052	1.7898	0.0013
374[5]	CAB/DOP	43.607	0.023	10.4414	0.0052	1.7902	0.0013
375[5]	CAB/DOP	43.911	0.024	10.5143	0.0052	1.8027	0.0013
376	CAB/DOP	43.662	0.023	10.4547	0.0052	1.7925	0.0013
377	CAB/DOP	43.755	0.024	10.4770	0.0052	1.7963	0.0013
378	CAB/DOP	43.740	0.024	10.4733	0.0052	1.7957	0.0013
379	CAB/DOP	43.670	0.024	10.4567	0.0052	1.7928	0.0013
380	CAB/DOP	43.717	0.024	10.4679	0.0052	1.7948	0.0013
381[5]	CAB/DOP	43.620	0.023	10.4447	0.0052	1.7908	0.0013
382	CAB/DOP	43.690	0.024	10.4613	0.0052	1.7936	0.0013
383[5]	CAB/DOP	43.660	0.023	10.4543	0.0052	1.7924	0.0013
384	CAB/DOP	43.805	0.024	10.4890	0.0052	1.7984	0.0013
385	CMC	43.788	0.024	10.4849	0.0052	1.7977	0.0013
386	CMC	43.672	0.024	10.4572	0.0052	1.7929	0.0013
387	CMC	43.745	0.024	10.4745	0.0052	1.7959	0.0013
388	CMC	43.581	0.023	10.4352	0.0052	1.7891	0.0013
389	CMC	43.797	0.024	10.4870	0.0052	1.7980	0.0013
390	CMC	43.748	0.024	10.4754	0.0052	1.7960	0.0013
391	CMC	43.676	0.024	10.4580	0.0052	1.7930	0.0013
392	CMC	43.589	0.023	10.4373	0.0052	1.7895	0.0013
393	CMC	43.050	0.023	10.3082	0.0051	1.7674	0.0013
394	CMC	43.710	0.024	10.4663	0.0052	1.7945	0.0013
395	CMC	43.610	0.023	10.4423	0.0052	1.7904	0.0013
396	CMC	43.888	0.024	10.5089	0.0052	1.8018	0.0013
397	CMC	43.529	0.023	10.4228	0.0052	1.7870	0.0013
398	CMC	43.677	0.024	10.4584	0.0052	1.7931	0.0013
399	CMC	43.740	0.024	10.4733	0.0052	1.7957	0.0013
400	CMC	43.035	0.023	10.3045	0.0051	1.7667	0.0013

Unit #	Organic substance	^{238}U Mass [1] [mg]	^{238}U Uncertainty [2] [mg]	^{235}U Mass [1] [mg]	^{235}U Uncertainty [2] [mg]	^{239}Pu Mass [1] [mg]	^{239}Pu Uncertainty [2] [mg]
401	CMC	43.653	0.023	10.4526	0.0052	1.7921	0.0013
402	CMC	43.755	0.024	10.4770	0.0052	1.7963	0.0013
403	CMC	43.728	0.024	10.4704	0.0052	1.7952	0.0013
404	CMC	43.660	0.023	10.4543	0.0052	1.7924	0.0013
405	CMC	43.624	0.023	10.4456	0.0052	1.7909	0.0013
406	CMC	43.107	0.023	10.3218	0.0052	1.7697	0.0013
407	CMC	43.669	0.024	10.4563	0.0052	1.7928	0.0013
408	CMC	43.643	0.023	10.4501	0.0052	1.7917	0.0013
409	CMC	43.677	0.024	10.4584	0.0052	1.7931	0.0013
410	CMC	43.686	0.024	10.4605	0.0052	1.7935	0.0013
411	CMC	44.011	0.024	10.5383	0.0052	1.8068	0.0013
412	CMC	43.413	0.023	10.3951	0.0052	1.7823	0.0013
413	CMC	43.937	0.024	10.5205	0.0052	1.8038	0.0013
414	CMC	43.646	0.023	10.4509	0.0052	1.7918	0.0013
415	CMC	43.817	0.024	10.4919	0.0052	1.7989	0.0013
416	CMC	43.738	0.024	10.4729	0.0052	1.7956	0.0013
417	CMC	43.643	0.023	10.4501	0.0052	1.7917	0.0013
418	CMC	43.594	0.023	10.4385	0.0052	1.7897	0.0013
419	CMC	43.123	0.023	10.3256	0.0052	1.7703	0.0013
420	CMC	43.470	0.023	10.4087	0.0052	1.7846	0.0013
421	CMC	43.033	0.023	10.3040	0.0051	1.7667	0.0013
422	CMC	43.695	0.024	10.4625	0.0052	1.7938	0.0013
423	CMC	43.588	0.023	10.4369	0.0052	1.7894	0.0013
424	CMC	43.783	0.024	10.4836	0.0052	1.7974	0.0013
425	CMC	43.097	0.023	10.3194	0.0052	1.7693	0.0013
426	CMC	43.636	0.023	10.4485	0.0052	1.7914	0.0013
427	CMC	43.534	0.023	10.4241	0.0052	1.7872	0.0013
428	CMC	43.840	0.024	10.4973	0.0052	1.7998	0.0013
429	CAB/DOP	43.769	0.024	10.4803	0.0052	1.7969	0.0013
430	CMC	43.859	0.024	10.5018	0.0052	1.8006	0.0013
431	CAB/DOP	43.619	0.023	10.4443	0.0052	1.7907	0.0013
432	CMC	43.772	0.024	10.4812	0.0052	1.7970	0.0013
433	CAB/DOP	43.672	0.024	10.4572	0.0052	1.7929	0.0013
434	CAB/DOP	43.764	0.024	10.4791	0.0052	1.7967	0.0013
435	CAB/DOP	43.688	0.024	10.4609	0.0052	1.7935	0.0013
436	CAB/DOP	43.691	0.024	10.4617	0.0052	1.7937	0.0013
437	CAB/DOP	43.781	0.024	10.4832	0.0052	1.7974	0.0013
438	CAB/DOP	43.717	0.024	10.4679	0.0052	1.7948	0.0013
439	CAB/DOP	43.736	0.024	10.4725	0.0052	1.7955	0.0013
440	CAB/DOP	43.670	0.024	10.4567	0.0052	1.7928	0.0013
441	CAB/DOP	43.766	0.024	10.4795	0.0052	1.7967	0.0013
442	CAB/DOP	43.700	0.024	10.4638	0.0052	1.7940	0.0013
443	CAB/DOP	43.669	0.024	10.4563	0.0052	1.7928	0.0013
444	CMC	43.710	0.024	10.4663	0.0052	1.7945	0.0013
445	CAB/DOP	43.790	0.024	10.4853	0.0052	1.7977	0.0013
446	CAB/DOP	43.506	0.023	10.4174	0.0052	1.7861	0.0013
447	CAB/DOP	43.892	0.024	10.5097	0.0052	1.8019	0.0013
448	CAB/DOP	43.690	0.024	10.4613	0.0052	1.7936	0.0013
449	CAB/DOP	43.593	0.023	10.4381	0.0052	1.7896	0.0013
450	CAB/DOP	43.976	0.024	10.5300	0.0052	1.8054	0.0013

Unit #	Organic substance	^{238}U Mass [1] [mg]	^{238}U Uncertainty [2] [mg]	^{235}U Mass [1] [mg]	^{235}U Uncertainty [2] [mg]	^{239}Pu Mass [1] [mg]	^{239}Pu Uncertainty [2] [mg]
451	CAB/DOP	43.629	0.023	10.4468	0.0052	1.7911	0.0013
452	CAB/DOP	43.714	0.024	10.4671	0.0052	1.7946	0.0013
453	CAB/DOP	43.738	0.024	10.4729	0.0052	1.7956	0.0013
454	CAB/DOP	43.710	0.024	10.4663	0.0052	1.7945	0.0013
455	CAB/DOP	43.722	0.024	10.4692	0.0052	1.7950	0.0013
456	CAB/DOP	43.748	0.024	10.4754	0.0052	1.7960	0.0013
457	CAB/DOP	43.715	0.024	10.4675	0.0052	1.7947	0.0013
458	CAB/DOP	43.605	0.023	10.4410	0.0052	1.7901	0.0013
459	CAB/DOP	43.036	0.023	10.3049	0.0051	1.7668	0.0013
460	CAB/DOP	43.709	0.024	10.4658	0.0052	1.7944	0.0013
461	CAB/DOP	43.674	0.024	10.4576	0.0052	1.7930	0.0013
462	CAB/DOP	43.581	0.023	10.4352	0.0052	1.7891	0.0013
463	CAB/DOP	43.752	0.024	10.4762	0.0052	1.7962	0.0013
464	CAB/DOP	43.824	0.024	10.4936	0.0052	1.7992	0.0013
465	CAB/DOP	43.686	0.024	10.4605	0.0052	1.7935	0.0013
466	CAB/DOP	43.786	0.024	10.4845	0.0052	1.7976	0.0013
467	CAB/DOP	43.565	0.023	10.4315	0.0052	1.7885	0.0013
468	CAB/DOP	43.738	0.024	10.4729	0.0052	1.7956	0.0013
469	CAB/DOP	43.076	0.023	10.3144	0.0051	1.7684	0.0013
470	CAB/DOP	43.544	0.023	10.4265	0.0052	1.7877	0.0013
471	CAB/DOP	43.705	0.024	10.4650	0.0052	1.7943	0.0013
472	CAB/DOP	43.833	0.024	10.4956	0.0052	1.7995	0.0013
473	CAB/DOP	43.076	0.023	10.3144	0.0051	1.7684	0.0013
474	CAB/DOP	43.607	0.023	10.4414	0.0052	1.7902	0.0013
475	CAB/DOP	43.724	0.024	10.4696	0.0052	1.7950	0.0013
476	CAB/DOP	43.570	0.023	10.4327	0.0052	1.7887	0.0013
477	CAB/DOP	43.805	0.024	10.4890	0.0052	1.7984	0.0013
478	CAB/DOP	43.669	0.024	10.4563	0.0052	1.7928	0.0013
479	CAB/DOP	43.791	0.024	10.4857	0.0052	1.7978	0.0013
480	CAB/DOP	43.066	0.023	10.3119	0.0051	1.7680	0.0013
481	CAB/DOP	43.672	0.024	10.4572	0.0052	1.7929	0.0013
482	CAB/DOP	43.703	0.024	10.4646	0.0052	1.7942	0.0013
483	CAB/DOP	43.636	0.023	10.4485	0.0052	1.7914	0.0013
484	CAB/DOP	43.869	0.024	10.5043	0.0052	1.8010	0.0013
485	CAB/DOP	43.660	0.023	10.4543	0.0052	1.7924	0.0013
486	CAB/DOP	43.696	0.024	10.4629	0.0052	1.7939	0.0013
487	CAB/DOP	43.745	0.024	10.4745	0.0052	1.7959	0.0013
488	CAB/DOP	43.804	0.024	10.4886	0.0052	1.7983	0.0013
489	CAB/DOP	43.655	0.023	10.4530	0.0052	1.7922	0.0013
490	CAB/DOP	43.734	0.024	10.4721	0.0052	1.7955	0.0013
491	CAB/DOP	43.059	0.023	10.3103	0.0051	1.7677	0.0013
492	CAB/DOP	43.831	0.024	10.4952	0.0052	1.7994	0.0013
493	CAB/DOP	43.499	0.023	10.4158	0.0052	1.7858	0.0013
494	CAB/DOP	43.696	0.024	10.4629	0.0052	1.7939	0.0013
495	CAB/DOP	43.880	0.024	10.5068	0.0052	1.8014	0.0013
496	CMC	43.691	0.024	10.4617	0.0052	1.7937	0.0013
497	CAB/DOP	43.833	0.024	10.4956	0.0052	1.7995	0.0013
498	CAB/DOP	43.710	0.024	10.4663	0.0052	1.7945	0.0013
499	CAB/DOP	43.679	0.024	10.4588	0.0052	1.7932	0.0013
500	CAB/DOP	43.804	0.024	10.4886	0.0052	1.7983	0.0013

Unit #	Organic substance	^{238}U Mass 1) [mg]	^{238}U Uncertainty 2) [mg]	^{235}U Mass 1) [mg]	^{235}U Uncertainty 2) [mg]	^{239}Pu Mass 1) [mg]	^{239}Pu Uncertainty 2) [mg]
501	CAB/DOP	43.772	0.024	10.4812	0.0052	1.7970	0.0013
502	CAB/DOP	43.582	0.023	10.4356	0.0052	1.7892	0.0013
503	CAB/DOP	43.095	0.023	10.3189	0.0052	1.7692	0.0013
504	CAB/DOP	43.515	0.023	10.4195	0.0052	1.7865	0.0013
505	CAB/DOP	43.157	0.023	10.3338	0.0052	1.7718	0.0013
506	CAB/DOP	43.515	0.023	10.4195	0.0052	1.7865	0.0013
507	CAB/DOP	43.829	0.024	10.4948	0.0052	1.7994	0.0013
508	CAB/DOP	43.036	0.023	10.3049	0.0051	1.7668	0.0013
509	CAB/DOP	43.658	0.023	10.4538	0.0052	1.7923	0.0013
510	CMC	43.715	0.024	10.4675	0.0052	1.7947	0.0013
511	CAB/DOP	43.695	0.024	10.4625	0.0052	1.7938	0.0013
512	CAB/DOP	43.043	0.023	10.3065	0.0051	1.7671	0.0013
513	CAB/DOP	43.631	0.023	10.4472	0.0052	1.7912	0.0013
514	CAB/DOP	43.620	0.023	10.4447	0.0052	1.7908	0.0013
515	CAB/DOP	43.057	0.023	10.3098	0.0051	1.7676	0.0013
516	CAB/DOP	43.722	0.024	10.4692	0.0052	1.7950	0.0013
517	CAB/DOP	43.674	0.024	10.4576	0.0052	1.7930	0.0013
518	CAB/DOP	43.759	0.024	10.4778	0.0052	1.7965	0.0013
519	CAB/DOP	43.702	0.024	10.4642	0.0052	1.7941	0.0013
520	CAB/DOP	43.012	0.023	10.2991	0.0051	1.7658	0.0013
521	CAB/DOP	43.605	0.023	10.4410	0.0052	1.7901	0.0013
522	CAB/DOP	43.807	0.024	10.4894	0.0052	1.7984	0.0013
523	CAB/DOP	43.779	0.024	10.4828	0.0052	1.7973	0.0013
524	CAB/DOP	43.658	0.023	10.4538	0.0052	1.7923	0.0013
525	CAB/DOP	43.800	0.024	10.4878	0.0052	1.7982	0.0013
526	CAB/DOP	43.707	0.024	10.4654	0.0052	1.7943	0.0013
527	CAB/DOP	43.710	0.024	10.4663	0.0052	1.7945	0.0013
528	CAB/DOP	42.983	0.023	10.2920	0.0051	1.7646	0.0013
529	CAB/DOP	43.693	0.024	10.4621	0.0052	1.7938	0.0013
530	CAB/DOP	43.636	0.023	10.4485	0.0052	1.7914	0.0013
531	CAB/DOP	43.817	0.024	10.4919	0.0052	1.7989	0.0013
532	CAB/DOP	43.800	0.024	10.4878	0.0052	1.7982	0.0013
533	CAB/DOP	43.722	0.024	10.4692	0.0052	1.7950	0.0013
534	CAB/DOP	43.745	0.024	10.4745	0.0052	1.7959	0.0013
535	CAB/DOP	43.605	0.023	10.4410	0.0052	1.7901	0.0013
536	CAB/DOP	43.871	0.024	10.5047	0.0052	1.8011	0.0013
537	CAB/DOP	43.707	0.024	10.4654	0.0052	1.7943	0.0013
538	CAB/DOP	43.724	0.024	10.4696	0.0052	1.7950	0.0013
539	CAB/DOP	43.636	0.023	10.4485	0.0052	1.7914	0.0013
540	CAB/DOP	43.764	0.024	10.4791	0.0052	1.7967	0.0013
541	CAB/DOP	43.710	0.024	10.4663	0.0052	1.7945	0.0013
542	CAB/DOP	43.914	0.024	10.5151	0.0052	1.8028	0.0013
543	CAB/DOP	43.816	0.024	10.4915	0.0052	1.7988	0.0013
544	CAB/DOP	43.641	0.023	10.4497	0.0052	1.7916	0.0013
545	CAB/DOP	43.690	0.024	10.4613	0.0052	1.7936	0.0013
546	CAB/DOP	43.741	0.024	10.4737	0.0052	1.7957	0.0013
547	CAB/DOP	43.074	0.023	10.3140	0.0051	1.7684	0.0013
548	CAB/DOP	43.536	0.023	10.4245	0.0052	1.7873	0.0013
549	CAB/DOP	43.703	0.024	10.4646	0.0052	1.7942	0.0013
550	CAB/DOP	43.873	0.024	10.5052	0.0052	1.8011	0.0013

Unit #	Organic substance	^{238}U Mass [1] [mg]	^{238}U Uncertainty [2] [mg]	^{235}U Mass [1] [mg]	^{235}U Uncertainty [2] [mg]	^{239}Pu Mass [1] [mg]	^{239}Pu Uncertainty [2] [mg]
551	CAB/DOP	43.686	0.024	10.4605	0.0052	1.7935	0.0013
552	CAB/DOP	43.823	0.024	10.4932	0.0052	1.7991	0.0013
553	CAB/DOP	43.793	0.024	10.4861	0.0052	1.7979	0.0013
554	CAB/DOP	43.724	0.024	10.4696	0.0052	1.7950	0.0013
555	CAB/DOP	43.772	0.024	10.4812	0.0052	1.7970	0.0013
556	CAB/DOP	43.641	0.023	10.4497	0.0052	1.7916	0.0013
557	CAB/DOP	43.767	0.024	10.4799	0.0052	1.7968	0.0013
558	CAB/DOP	43.829	0.024	10.4948	0.0052	1.7994	0.0013
559	CAB/DOP	43.729	0.024	10.4708	0.0052	1.7952	0.0013
560	CAB/DOP	43.740	0.024	10.4733	0.0052	1.7957	0.0013
561	CAB/DOP	43.024	0.023	10.3020	0.0051	1.7663	0.0013
562	CMC	43.589	0.023	10.4373	0.0052	1.7895	0.0013
563	CAB/DOP	43.771	0.024	10.4807	0.0052	1.7970	0.0013
564	CAB/DOP	43.691	0.024	10.4617	0.0052	1.7937	0.0013
565	CAB/DOP	43.736	0.024	10.4725	0.0052	1.7955	0.0013
566	CAB/DOP	43.771	0.024	10.4807	0.0052	1.7970	0.0013
567	CAB/DOP	42.996	0.023	10.2954	0.0051	1.7652	0.0013
568	CAB/DOP	43.757	0.024	10.4774	0.0052	1.7964	0.0013
569	CAB/DOP	43.757	0.024	10.4774	0.0052	1.7964	0.0013
570	CAB/DOP	43.662	0.023	10.4547	0.0052	1.7925	0.0013
571	CAB/DOP	43.793	0.024	10.4861	0.0052	1.7979	0.0013
572	CAB/DOP	43.683	0.024	10.4596	0.0052	1.7933	0.0013
573	CAB/DOP	43.111	0.023	10.3227	0.0052	1.7698	0.0013
574	CMC	43.610	0.023	10.4423	0.0052	1.7904	0.0013
575	CAB/DOP	43.788	0.024	10.4849	0.0052	1.7977	0.0013
576	CAB/DOP	43.636	0.023	10.4485	0.0052	1.7914	0.0013
577	CMC	43.800	0.024	10.4878	0.0052	1.7982	0.0013
578	CMC	43.721	0.024	10.4687	0.0052	1.7949	0.0013
579	CMC	43.791	0.024	10.4857	0.0052	1.7978	0.0013
580	CMC	43.769	0.024	10.4803	0.0052	1.7969	0.0013
581	CMC	43.759	0.024	10.4778	0.0052	1.7965	0.0013
582	CMC	43.762	0.024	10.4787	0.0052	1.7966	0.0013
583	CMC	43.560	0.023	10.4303	0.0052	1.7883	0.0013
584	CMC	43.036	0.023	10.3049	0.0051	1.7668	0.0013
585	CMC	43.753	0.024	10.4766	0.0052	1.7962	0.0013
586	CMC	43.677	0.024	10.4584	0.0052	1.7931	0.0013
587	CMC	43.076	0.023	10.3144	0.0051	1.7684	0.0013
588	CMC	43.693	0.024	10.4621	0.0052	1.7938	0.0013
589	CMC	43.745	0.024	10.4745	0.0052	1.7959	0.0013
590	CMC	43.807	0.024	10.4894	0.0052	1.7984	0.0013
591	CMC	43.731	0.024	10.4712	0.0052	1.7953	0.0013
592	CMC	43.724	0.024	10.4696	0.0052	1.7950	0.0013
593	CMC	43.817	0.024	10.4919	0.0052	1.7989	0.0013
594	CMC	43.717	0.024	10.4679	0.0052	1.7948	0.0013
595	CMC	43.601	0.023	10.4402	0.0052	1.7900	0.0013
596	CMC	43.866	0.024	10.5035	0.0052	1.8009	0.0013
597	CMC	43.696	0.024	10.4629	0.0052	1.7939	0.0013
598	CMC	43.798	0.024	10.4874	0.0052	1.7981	0.0013
599	CMC	43.797	0.024	10.4870	0.0052	1.7980	0.0013
600	CMC	43.776	0.024	10.4820	0.0052	1.7972	0.0013

Unit #	Organic substance	^{238}U Mass 1) [mg]	^{238}U Uncertainty 2) [mg]	^{235}U Mass 1) [mg]	^{235}U Uncertainty 2) [mg]	^{239}Pu Mass 1) [mg]	^{239}Pu Uncertainty 2) [mg]
601	CMC	43.764	0.024	10.4791	0.0052	1.7967	0.0013
602	CMC	43.679	0.024	10.4588	0.0052	1.7932	0.0013
603	CMC	43.852	0.024	10.5002	0.0052	1.8003	0.0013
604	CMC	43.712	0.024	10.4667	0.0052	1.7945	0.0013
605	CMC	43.631	0.023	10.4472	0.0052	1.7912	0.0013
606	CMC	43.888	0.024	10.5089	0.0052	1.8018	0.0013
607	CMC	43.883	0.024	10.5076	0.0052	1.8016	0.0013
608	CMC	43.612	0.023	10.4427	0.0052	1.7904	0.0013
609	CMC	43.762	0.024	10.4787	0.0052	1.7966	0.0013
610	CMC	43.655	0.023	10.4530	0.0052	1.7922	0.0013
611	CMC	43.900	0.024	10.5118	0.0052	1.8023	0.0013
612	CMC	43.709	0.024	10.4658	0.0052	1.7944	0.0013
613	CMC	43.795	0.024	10.4865	0.0052	1.7979	0.0013
614	CMC	43.679	0.024	10.4588	0.0052	1.7932	0.0013
615	CMC	43.795	0.024	10.4865	0.0052	1.7979	0.0013
616	CMC	43.804	0.024	10.4886	0.0052	1.7983	0.0013
617	CMC	43.634	0.023	10.4481	0.0052	1.7913	0.0013
618	CMC	43.676	0.024	10.4580	0.0052	1.7930	0.0013
619	CMC	43.128	0.023	10.3268	0.0052	1.7706	0.0013
620	CMC	43.707	0.024	10.4654	0.0052	1.7943	0.0013
621	CMC	43.781	0.024	10.4832	0.0052	1.7974	0.0013
622	CMC	43.698	0.024	10.4634	0.0052	1.7940	0.0013
623	CMC	43.786	0.024	10.4845	0.0052	1.7976	0.0013
624	CAB/DOP	43.683	0.024	10.4596	0.0052	1.7933	0.0013
625	CMC	43.776	0.024	10.4820	0.0052	1.7972	0.0013
626	CMC	43.643	0.023	10.4501	0.0052	1.7917	0.0013
627	CMC	43.914	0.024	10.5151	0.0052	1.8028	0.0013
628	CMC	43.686	0.024	10.4605	0.0052	1.7935	0.0013
629	CMC	43.855	0.024	10.5010	0.0052	1.8004	0.0013
630	CMC	43.686	0.024	10.4605	0.0052	1.7935	0.0013
631	CMC	43.776	0.024	10.4820	0.0052	1.7972	0.0013
632	CMC	43.778	0.024	10.4824	0.0052	1.7972	0.0013
633 4)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
634	CMC	43.774	0.024	10.4816	0.0052	1.7971	0.0013
635	CMC	43.731	0.024	10.4712	0.0052	1.7953	0.0013
636	CMC	42.977	0.023	10.2908	0.0051	1.7644	0.0013
637	CMC	43.650	0.023	10.4518	0.0052	1.7920	0.0013
638	CMC	43.798	0.024	10.4874	0.0052	1.7981	0.0013
639	CMC	43.802	0.024	10.4882	0.0052	1.7982	0.0013
640	CMC	43.755	0.024	10.4770	0.0052	1.7963	0.0013
641	CMC	43.753	0.024	10.4766	0.0052	1.7962	0.0013
642	CMC	43.726	0.024	10.4700	0.0052	1.7951	0.0013
643	CMC	43.728	0.024	10.4704	0.0052	1.7952	0.0013
644	CMC	43.814	0.024	10.4911	0.0052	1.7987	0.0013
645	CMC	43.755	0.024	10.4770	0.0052	1.7963	0.0013
646	CMC	43.748	0.024	10.4754	0.0052	1.7960	0.0013
647	CMC	42.998	0.023	10.2958	0.0051	1.7652	0.0013
648	CMC	43.629	0.023	10.4468	0.0052	1.7911	0.0013
649	CMC	43.757	0.024	10.4774	0.0052	1.7964	0.0013
650	CMC	43.717	0.024	10.4679	0.0052	1.7948	0.0013

Unit #	Organic substance	^{238}U Mass [1] [mg]	^{238}U Uncertainty [2] [mg]	^{235}U Mass [1] [mg]	^{235}U Uncertainty [2] [mg]	^{239}Pu Mass [1] [mg]	^{239}Pu Uncertainty [2] [mg]
651	CMC	43.864	0.024	10.5031	0.0052	1.8008	0.0013
652	CMC	43.672	0.024	10.4572	0.0052	1.7929	0.0013
653	CMC	43.821	0.024	10.4927	0.0052	1.7990	0.0013
654	CMC	43.691	0.024	10.4617	0.0052	1.7937	0.0013
655	CMC	43.681	0.024	10.4592	0.0052	1.7933	0.0013
656	CMC	43.743	0.024	10.4741	0.0052	1.7958	0.0013
657	CMC	43.092	0.023	10.3181	0.0052	1.7691	0.0013
658	CMC	43.695	0.024	10.4625	0.0052	1.7938	0.0013
659	CMC	43.748	0.024	10.4754	0.0052	1.7960	0.0013
660	CMC	43.798	0.024	10.4874	0.0052	1.7981	0.0013
661	CMC	43.753	0.024	10.4766	0.0052	1.7962	0.0013
662	CMC	43.826	0.024	10.4940	0.0052	1.7992	0.0013
663	CMC	43.726	0.024	10.4700	0.0052	1.7951	0.0013
664	CMC	43.752	0.024	10.4762	0.0052	1.7962	0.0013
665	CMC	43.767	0.024	10.4799	0.0052	1.7968	0.0013
666	CMC	43.607	0.023	10.4414	0.0052	1.7902	0.0013
667	CMC	43.074	0.023	10.3140	0.0051	1.7684	0.0013
668	CMC	43.696	0.024	10.4629	0.0052	1.7939	0.0013
669	CMC	43.760	0.024	10.4783	0.0052	1.7965	0.0013
670	CMC	43.766	0.024	10.4795	0.0052	1.7967	0.0013
671	CMC	43.705	0.024	10.4650	0.0052	1.7943	0.0013
672	CMC	43.791	0.024	10.4857	0.0052	1.7978	0.0013
673	CMC	43.741	0.024	10.4737	0.0052	1.7957	0.0013
674	CMC	43.769	0.024	10.4803	0.0052	1.7969	0.0013
675	CMC	43.753	0.024	10.4766	0.0052	1.7962	0.0013
676	CMC	43.760	0.024	10.4783	0.0052	1.7965	0.0013
677	CMC	43.738	0.024	10.4729	0.0052	1.7956	0.0013
678	CMC	43.664	0.023	10.4551	0.0052	1.7926	0.0013
679	CMC	43.710	0.024	10.4663	0.0052	1.7945	0.0013
680	CAB/DOP	43.835	0.024	10.4961	0.0052	1.7996	0.0013
681	CMC	43.078	0.023	10.3148	0.0052	1.7685	0.0013
682	CMC	43.620	0.023	10.4447	0.0052	1.7908	0.0013
683	CMC	43.724	0.024	10.4696	0.0052	1.7950	0.0013
684	CMC	43.677	0.024	10.4584	0.0052	1.7931	0.0013
685	CMC	43.140	0.023	10.3297	0.0052	1.7711	0.0013
686	CMC	43.591	0.023	10.4377	0.0052	1.7896	0.0013
687	CMC	43.653	0.023	10.4526	0.0052	1.7921	0.0013
688	CMC	43.816	0.024	10.4915	0.0052	1.7988	0.0013
689	CMC	43.057	0.023	10.3098	0.0051	1.7676	0.0013
690	CMC	43.667	0.024	10.4559	0.0052	1.7927	0.0013
691	CMC	43.721	0.024	10.4687	0.0052	1.7949	0.0013
692	CMC	43.653	0.023	10.4526	0.0052	1.7921	0.0013
693	CMC	43.038	0.023	10.3053	0.0051	1.7669	0.0013
694	CMC	43.710	0.024	10.4663	0.0052	1.7945	0.0013
695	CMC	43.012	0.023	10.2991	0.0051	1.7658	0.0013
696	CMC	43.579	0.023	10.4348	0.0052	1.7891	0.0013
697	CMC	43.762	0.024	10.4787	0.0052	1.7966	0.0013
698	CMC	43.809	0.024	10.4898	0.0052	1.7985	0.0013
699	CMC	43.741	0.024	10.4737	0.0052	1.7957	0.0013
700	CMC	43.650	0.023	10.4518	0.0052	1.7920	0.0013

Unit #	Organic substance	^{238}U Mass [1] [mg]	^{238}U Uncertainty [2] [mg]	^{235}U Mass [1] [mg]	^{235}U Uncertainty [2] [mg]	^{239}Pu Mass [1] [mg]	^{239}Pu Uncertainty [2] [mg]
701	CMC	43.098	0.023	10.3198	0.0052	1.7694	0.0013
702	CMC	43.648	0.023	10.4514	0.0052	1.7919	0.0013
703	CMC	43.802	0.024	10.4882	0.0052	1.7982	0.0013
704	CMC	43.707	0.024	10.4654	0.0052	1.7943	0.0013
705	CMC	43.753	0.024	10.4766	0.0052	1.7962	0.0013
706	CMC	43.731	0.024	10.4712	0.0052	1.7953	0.0013
707	CAB/DOP	43.809	0.024	10.4898	0.0052	1.7985	0.0013
708	CMC	43.709	0.024	10.4658	0.0052	1.7944	0.0013
709	CMC	43.743	0.024	10.4741	0.0052	1.7958	0.0013
710	CMC	43.786	0.024	10.4845	0.0052	1.7976	0.0013
711	CMC	43.774	0.024	10.4816	0.0052	1.7971	0.0013
712	CMC	43.690	0.024	10.4613	0.0052	1.7936	0.0013
713	CMC	43.778	0.024	10.4824	0.0052	1.7972	0.0013
714	CMC	43.757	0.024	10.4774	0.0052	1.7964	0.0013
715	CMC	43.696	0.024	10.4629	0.0052	1.7939	0.0013
716	CMC	43.785	0.024	10.4841	0.0052	1.7975	0.0013
717	CMC	43.610	0.023	10.4423	0.0052	1.7904	0.0013
718	CMC	43.086	0.023	10.3169	0.0052	1.7689	0.0013
719	CMC	43.627	0.023	10.4464	0.0052	1.7911	0.0013
720	CMC	43.823	0.024	10.4932	0.0052	1.7991	0.0013
721	CMC	43.798	0.024	10.4874	0.0052	1.7981	0.0013
722	CMC	43.677	0.024	10.4584	0.0052	1.7931	0.0013
723	CMC	43.755	0.024	10.4770	0.0052	1.7963	0.0013
724	CMC	43.747	0.024	10.4749	0.0052	1.7960	0.0013
725	CMC	43.743	0.024	10.4741	0.0052	1.7958	0.0013
726	CMC	43.798	0.024	10.4874	0.0052	1.7981	0.0013
727	CMC	43.703	0.024	10.4646	0.0052	1.7942	0.0013
728	CMC	43.778	0.024	10.4824	0.0052	1.7972	0.0013
729	CMC	43.641	0.023	10.4497	0.0052	1.7916	0.0013
730	CMC	43.085	0.023	10.3165	0.0052	1.7688	0.0013
731	CMC	43.653	0.023	10.4526	0.0052	1.7921	0.0013
732	CAB/DOP	43.679	0.024	10.4588	0.0052	1.7932	0.0013
733	CMC	43.850	0.024	10.4998	0.0052	1.8002	0.0013
734	CMC	43.705	0.024	10.4650	0.0052	1.7943	0.0013
735	CMC	43.772	0.024	10.4812	0.0052	1.7970	0.0013
736	CMC	43.736	0.024	10.4725	0.0052	1.7955	0.0013
737	CMC	43.007	0.023	10.2978	0.0051	1.7656	0.0013
738	CMC	43.641	0.023	10.4497	0.0052	1.7916	0.0013
739	CMC	43.762	0.024	10.4787	0.0052	1.7966	0.0013
740	CMC	43.745	0.024	10.4745	0.0052	1.7959	0.0013
741	CMC	43.731	0.024	10.4712	0.0052	1.7953	0.0013
742	CMC	43.052	0.023	10.3086	0.0051	1.7674	0.0013
743	CMC	43.636	0.023	10.4485	0.0052	1.7914	0.0013
744	CMC	43.767	0.024	10.4799	0.0052	1.7968	0.0013
745	CMC	43.750	0.024	10.4758	0.0052	1.7961	0.0013
746	CMC	43.728	0.024	10.4704	0.0052	1.7952	0.0013
747	CMC	43.693	0.024	10.4621	0.0052	1.7938	0.0013
748	CMC	43.074	0.023	10.3140	0.0051	1.7684	0.0013
749	CAB/DOP	43.612	0.023	10.4427	0.0052	1.7904	0.0013
750	CMC	43.643	0.023	10.4501	0.0052	1.7917	0.0013

Unit #	Organic substance	^{238}U		^{235}U		^{239}Pu	
		Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
751	CMC	43.055	0.023	10.3094	0.0051	1.7676	0.0013
752	CMC	43.620	0.023	10.4447	0.0052	1.7908	0.0013
753	CMC	43.831	0.024	10.4952	0.0052	1.7994	0.0013
754	CMC	43.788	0.024	10.4849	0.0052	1.7977	0.0013
755	CMC	43.714	0.024	10.4671	0.0052	1.7946	0.0013
756	CMC	43.740	0.024	10.4733	0.0052	1.7957	0.0013
757	CMC	43.766	0.024	10.4795	0.0052	1.7967	0.0013
758	CMC	43.731	0.024	10.4712	0.0052	1.7953	0.0013
759	CMC	43.762	0.024	10.4787	0.0052	1.7966	0.0013
760	CMC	43.709	0.024	10.4658	0.0052	1.7944	0.0013
761	CMC	43.804	0.024	10.4886	0.0052	1.7983	0.0013
762	CMC	43.759	0.024	10.4778	0.0052	1.7965	0.0013
763	CMC	43.753	0.024	10.4766	0.0052	1.7962	0.0013
764	CMC	43.785	0.024	10.4841	0.0052	1.7975	0.0013
765	CMC	43.586	0.023	10.4365	0.0052	1.7894	0.0013
766	CAB/DOP	43.817	0.024	10.4919	0.0052	1.7989	0.0013
767	CMC	43.767	0.024	10.4799	0.0052	1.7968	0.0013
768	CMC	43.721	0.024	10.4687	0.0052	1.7949	0.0013
769	CAB/DOP	43.819	0.024	10.4923	0.0052	1.7989	0.0013
770[4]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
771	CAB/DOP	43.639	0.023	10.4493	0.0052	1.7916	0.0013
772[4]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
773	CAB/DOP	43.677	0.024	10.4584	0.0052	1.7931	0.0013
774[4]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
775[4]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
776[4]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
777	CAB/DOP	43.698	0.024	10.4634	0.0052	1.7940	0.0013
778	CAB/DOP	43.871	0.024	10.5047	0.0052	1.8011	0.0013
779	CAB/DOP	43.752	0.024	10.4762	0.0052	1.7962	0.0013
780	CAB/DOP	43.757	0.024	10.4774	0.0052	1.7964	0.0013
781	CAB/DOP	43.715	0.024	10.4675	0.0052	1.7947	0.0013
782	CAB/DOP	43.762	0.024	10.4787	0.0052	1.7966	0.0013
783	CAB/DOP	43.880	0.024	10.5068	0.0052	1.8014	0.0013
784	CAB/DOP	43.617	0.023	10.4439	0.0052	1.7906	0.0013
785	CMC	43.009	0.023	10.2982	0.0051	1.7657	0.0013
786	CAB/DOP	43.816	0.024	10.4915	0.0052	1.7988	0.0013
787	CAB/DOP	43.586	0.023	10.4365	0.0052	1.7894	0.0013
788	CAB/DOP	43.665	0.023	10.4555	0.0052	1.7926	0.0013
789	CAB/DOP	43.864	0.024	10.5031	0.0052	1.8008	0.0013
790	CAB/DOP	43.710	0.024	10.4663	0.0052	1.7945	0.0013
791	CAB/DOP	43.738	0.024	10.4729	0.0052	1.7956	0.0013
792	CAB/DOP	43.828	0.024	10.4944	0.0052	1.7993	0.0013
793	CAB/DOP	43.650	0.023	10.4518	0.0052	1.7920	0.0013
794	CAB/DOP	43.764	0.024	10.4791	0.0052	1.7967	0.0013
795	CAB/DOP	43.100	0.023	10.3202	0.0052	1.7694	0.0013
796	CAB/DOP	43.581	0.023	10.4352	0.0052	1.7891	0.0013
797	CAB/DOP	43.805	0.024	10.4890	0.0052	1.7984	0.0013
798	CAB/DOP	43.005	0.023	10.2974	0.0051	1.7655	0.0013
799	CAB/DOP	43.615	0.023	10.4435	0.0052	1.7906	0.0013
800	CAB/DOP	43.664	0.023	10.4551	0.0052	1.7926	0.0013

Unit #	Organic substance	^{238}U Mass [1] [mg]	^{238}U Uncertainty [2] [mg]	^{235}U Mass [1] [mg]	^{235}U Uncertainty [2] [mg]	^{239}Pu Mass [1] [mg]	^{239}Pu Uncertainty [2] [mg]
801	CAB/DOP	43.873	0.024	10.5052	0.0052	1.8011	0.0013
802	CAB/DOP	43.783	0.024	10.4836	0.0052	1.7974	0.0013
803	CAB/DOP	43.714	0.024	10.4671	0.0052	1.7946	0.0013
804	CAB/DOP	43.772	0.024	10.4812	0.0052	1.7970	0.0013
805	CAB/DOP	43.850	0.024	10.4998	0.0052	1.8002	0.0013
806	CAB/DOP	43.728	0.024	10.4704	0.0052	1.7952	0.0013
807	CAB/DOP	43.702	0.024	10.4642	0.0052	1.7941	0.0013
808	CAB/DOP	42.977	0.023	10.2908	0.0051	1.7644	0.0013
809	CAB/DOP	43.651	0.023	10.4522	0.0052	1.7921	0.0013
810	CAB/DOP	43.774	0.024	10.4816	0.0052	1.7971	0.0013
811	CAB/DOP	43.764	0.024	10.4791	0.0052	1.7967	0.0013
812	CAB/DOP	43.728	0.024	10.4704	0.0052	1.7952	0.0013
813	CAB/DOP	43.669	0.024	10.4563	0.0052	1.7928	0.0013
814	CAB/DOP	43.102	0.023	10.3206	0.0052	1.7695	0.0013
815	CAB/DOP	43.546	0.023	10.4269	0.0052	1.7877	0.0013
816	CAB/DOP	43.079	0.023	10.3152	0.0052	1.7686	0.0013
817	CMC	43.620	0.023	10.4447	0.0052	1.7908	0.0013
818[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
819	CMC	43.035	0.023	10.3045	0.0051	1.7667	0.0013
820	CMC	43.664	0.023	10.4551	0.0052	1.7926	0.0013
821	CMC	43.781	0.024	10.4832	0.0052	1.7974	0.0013
822	CMC	43.776	0.024	10.4820	0.0052	1.7972	0.0013
823	CMC	43.612	0.023	10.4427	0.0052	1.7904	0.0013
824	CMC	43.793	0.024	10.4861	0.0052	1.7979	0.0013
825	CMC	43.040	0.023	10.3057	0.0051	1.7669	0.0013
826	CMC	43.662	0.023	10.4547	0.0052	1.7925	0.0013
827	CAB/DOP	43.696	0.024	10.4629	0.0052	1.7939	0.0013
828	CMC	43.079	0.023	10.3152	0.0052	1.7686	0.0013
829	CMC	43.539	0.023	10.4253	0.0052	1.7874	0.0013
830	CMC	43.816	0.024	10.4915	0.0052	1.7988	0.0013
831	CMC	42.993	0.023	10.2945	0.0051	1.7650	0.0013
832	CMC	43.596	0.023	10.4389	0.0052	1.7898	0.0013
833	CMC	43.064	0.023	10.3115	0.0051	1.7679	0.0013
834	CMC	43.584	0.023	10.4361	0.0052	1.7893	0.0013
835	CMC	43.035	0.023	10.3045	0.0051	1.7667	0.0013
836	CMC	43.715	0.024	10.4675	0.0052	1.7947	0.0013
837	CMC	43.722	0.024	10.4692	0.0052	1.7950	0.0013
838	CMC	43.781	0.024	10.4832	0.0052	1.7974	0.0013
839	CMC	43.709	0.024	10.4658	0.0052	1.7944	0.0013
840	CMC	43.810	0.024	10.4903	0.0052	1.7986	0.0013
841	CMC	43.840	0.024	10.4973	0.0052	1.7998	0.0013
842	CMC	43.698	0.024	10.4634	0.0052	1.7940	0.0013
843	CMC	43.693	0.024	10.4621	0.0052	1.7938	0.0013
844	CMC	43.935	0.024	10.5201	0.0052	1.8037	0.0013
845	CMC	43.741	0.024	10.4737	0.0052	1.7957	0.0013
846	CMC	43.778	0.024	10.4824	0.0052	1.7972	0.0013
847	CMC	43.662	0.023	10.4547	0.0052	1.7925	0.0013
848	CMC	43.054	0.023	10.3090	0.0051	1.7675	0.0013
849	CMC	43.714	0.024	10.4671	0.0052	1.7946	0.0013
850	CMC	43.798	0.024	10.4874	0.0052	1.7981	0.0013

Unit #	Organic substance	^{238}U Mass 1) [mg]	^{238}U Uncertainty 2) [mg]	^{235}U Mass 1) [mg]	^{235}U Uncertainty 2) [mg]	^{239}Pu Mass 1) [mg]	^{239}Pu Uncertainty 2) [mg]
851	CMC	43.733	0.024	10.4716	0.0052	1.7954	0.0013
852	CMC	43.774	0.024	10.4816	0.0052	1.7971	0.0013
853	CMC	43.766	0.024	10.4795	0.0052	1.7967	0.0013
854	CMC	43.800	0.024	10.4878	0.0052	1.7982	0.0013
855	CMC	43.791	0.024	10.4857	0.0052	1.7978	0.0013
856	CMC	43.631	0.023	10.4472	0.0052	1.7912	0.0013
857	CMC	43.861	0.024	10.5023	0.0052	1.8006	0.0013
858	CMC	42.996	0.023	10.2954	0.0051	1.7652	0.0013
859	CMC	43.615	0.023	10.4435	0.0052	1.7906	0.0013
860	CMC	43.892	0.024	10.5097	0.0052	1.8019	0.0013
861	CMC	43.679	0.024	10.4588	0.0052	1.7932	0.0013
862	CMC	43.714	0.024	10.4671	0.0052	1.7946	0.0013
863	CMC	43.911	0.024	10.5143	0.0052	1.8027	0.0013
864	CMC	42.986	0.023	10.2929	0.0051	1.7647	0.0013
865	CMC	43.736	0.024	10.4725	0.0052	1.7955	0.0013
866	CMC	43.786	0.024	10.4845	0.0052	1.7976	0.0013
867	CMC	43.731	0.024	10.4712	0.0052	1.7953	0.0013
868	CMC	43.722	0.024	10.4692	0.0052	1.7950	0.0013
869	CAB/DOP	43.005	0.023	10.2974	0.0051	1.7655	0.0013
870	CMC	43.676	0.024	10.4580	0.0052	1.7930	0.0013
871	CMC	43.709	0.024	10.4658	0.0052	1.7944	0.0013
872	CMC	43.066	0.023	10.3119	0.0051	1.7680	0.0013
873	CMC	43.603	0.023	10.4406	0.0052	1.7901	0.0013
874	CMC	43.019	0.023	10.3007	0.0051	1.7661	0.0013
875	CMC	43.684	0.024	10.4601	0.0052	1.7934	0.0013
876	CMC	43.821	0.024	10.4927	0.0052	1.7990	0.0013
877	CMC	43.845	0.024	10.4985	0.0052	1.8000	0.0013
878	CMC	43.729	0.024	10.4708	0.0052	1.7952	0.0013
879	CMC	43.683	0.024	10.4596	0.0052	1.7933	0.0013
880	CMC	43.054	0.023	10.3090	0.0051	1.7675	0.0013
881	CMC	43.657	0.023	10.4534	0.0052	1.7923	0.0013
882	CMC	43.840	0.024	10.4973	0.0052	1.7998	0.0013
883	CMC	43.729	0.024	10.4708	0.0052	1.7952	0.0013
884	CMC	43.805	0.024	10.4890	0.0052	1.7984	0.0013
885	CMC	43.667	0.024	10.4559	0.0052	1.7927	0.0013
886	CMC	43.866	0.024	10.5035	0.0052	1.8009	0.0013
887	CMC	43.612	0.023	10.4427	0.0052	1.7904	0.0013
888	CMC	43.862	0.024	10.5027	0.0052	1.8007	0.0013
889	CMC	43.805	0.024	10.4890	0.0052	1.7984	0.0013
890	CMC	43.809	0.024	10.4898	0.0052	1.7985	0.0013
891	CMC	43.824	0.024	10.4936	0.0052	1.7992	0.0013
892	CMC	43.641	0.023	10.4497	0.0052	1.7916	0.0013
893	CMC	43.791	0.024	10.4857	0.0052	1.7978	0.0013
894	CAB/DOP	43.755	0.024	10.4770	0.0052	1.7963	0.0013
895	CMC	43.055	0.023	10.3094	0.0051	1.7676	0.0013
896	CMC	43.634	0.023	10.4481	0.0052	1.7913	0.0013
897	CMC	43.057	0.023	10.3098	0.0051	1.7676	0.0013
898	CMC	43.636	0.023	10.4485	0.0052	1.7914	0.0013
899	CMC	43.123	0.023	10.3256	0.0052	1.7703	0.0013
900	CMC	43.619	0.023	10.4443	0.0052	1.7907	0.0013

Unit #	Organic substance	^{238}U Mass [1] [mg]	^{238}U Uncertainty [2] [mg]	^{235}U Mass [1] [mg]	^{235}U Uncertainty [2] [mg]	^{239}Pu Mass [1] [mg]	^{239}Pu Uncertainty [2] [mg]
901	CMC	43.866	0.024	10.5035	0.0052	1.8009	0.0013
902	CMC	43.641	0.023	10.4497	0.0052	1.7916	0.0013
903	CMC	43.848	0.024	10.4994	0.0052	1.8001	0.0013
904	CMC	43.667	0.024	10.4559	0.0052	1.7927	0.0013
905	CMC	43.057	0.023	10.3098	0.0051	1.7676	0.0013
906	CMC	43.681	0.024	10.4592	0.0052	1.7933	0.0013
907	CMC	43.060	0.023	10.3107	0.0051	1.7678	0.0013
908	CMC	43.690	0.024	10.4613	0.0052	1.7936	0.0013
909	CMC	43.842	0.024	10.4977	0.0052	1.7999	0.0013
910	CMC	43.667	0.024	10.4559	0.0052	1.7927	0.0013
911	CMC	43.759	0.024	10.4778	0.0052	1.7965	0.0013
912	CMC	43.154	0.023	10.3330	0.0052	1.7716	0.0013

1) The certified values are traceable to the values on the respective metal certificates (EC NRM 101, NBL PO CRM 116-A and CETAMA MP2). The reference date for the mass of ^{238}U, ^{235}U and ^{239}Pu per unit is November 1, 2019.

2) The reference material was produced in compliance with ISO/IEC 17034:2016 and certified in accordance with ISO Guide 35:2017. The uncertainty of the certified value 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 98-3:2008, Guide to the Expression of Uncertainty in Measurement (GUM:1995).

3) One unit excluded from the certification process based on barcode failure.

4) 6 units excluded from the certification process due to splashing before drying.

5) 9 units reserved for experimental purposes.

The atomic masses of radionuclides were obtained from Wang et al. (The AME 2016 atomic mass evaluation (II). Tables, Graphs and References, Chinese Physics C, Vol. 41, No. 3, 2017). The half-lives of radionuclides were obtained from DDEP-BIPM (Table of radionuclides) and R. Wellum et al. (A new evaluation of the half-life of ^{241}Pu, J. Anal. At. Spectrom., 24, 801-807, 2009).

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) $g \cdot kg^{-1}$

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

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

Annex 3 The certificate of isotopic composition of EC NRM 101

European Commission
JOINT
RESEARCH
CENTRE

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

CERTIFICATE OF ISOTOPIC COMPOSITION
****

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

2. Sample identification : EC 101

3. Results :

	Amount Ratio(s)	Mass Ratio(s)	Uncertainty (computed on a 2s basis for each element)
n(234U)/n(238U)	0.00005548		+/- 0.00000022
n(235U)/n(238U)	0.0072593		+/- 0.0000036
n(236U)/n(238U)	0.000000151		+/- 0.000000040

4. Reference number : SMS 7315

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

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

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

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

c. P.De Bievre / A.Alonso

W.DE BOLLE
Stable Isotope Measurements

Annex 4 The certificate of NBL PO CRM 116-A uranium metal

New Brunswick Laboratory
U.S. Department of Energy

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

Certified Property Values

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

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

Notes:

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

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

October 31, 2013
Steven Bakhtiar
Laboratory Director

Page 1 of 3

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

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

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

Suggested Preparation Procedure for Achieving Accurate Mass and Amount Content Values

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

Description:

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

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

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

Measurement Uncertainty:

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

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

References:

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

Annex 5 The certificate of CETAMA MP2 plutonium metal

CETAMA

COMMISSARIAT A L'ENERGIE ATOMIQUE

COMMISSION D'ETABLISSEMENT DES METHODES D'ANALYSE

cea

REFERENCE MATERIAL CERTIFICATE

PLUTONIUM METAL
"MP2"

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

(For X and x values see list page 4)

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

99.90 ± 0.04 %

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

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

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

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

CETAMA CRM manager

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 1828

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.

IRMM

Institute for Reference Materials and Measurements

CERTIFICATE OF ISOTOPIC COMPOSITION

Geel, 30 May 2001

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

2. Sample Identification: MP2 (Pu metal)

3. Isotopic composition:

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

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

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

4. Reference number: IMN 10031

5. Remarks:

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

A Verbruggen
Isotope Measurements Unit

Copy: R Wellum
F Kehoe

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

European Commission - JRC

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

Rodier

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

Annex 6 The certificate of plutonium isotope abundances of CETAMA MP2

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

CERTIFICATE of a reference measurement

IM/MeaC/07/116

11 April 2007

SUBJECT : Recertification of CEA CETAMA MP2

1. Applicant: A. Verbruggen
2. Sample Identification:
   - CEA/CETAMA/MP2
   - Chemical form: Pu metal provided by CEA/CETAMA
3. Measurands:
   - Isotopic composition

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

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

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

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

EUROPEAN COMMISSION
DIRECTORATE GENERAL JRC

JOINT RESEARCH CENTRE
IRMM
Institute for Reference Materials and Measurements

CERTIFICATE of a reference measurement

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

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

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

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

- Isotopic composition

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

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

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

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

5. Uncertainty:
All uncertainties indicated are expanded uncertainties $U = k \cdot u_c$ where u_c is the combined standard uncertainty calculated according to the ISO/BIPM guide. They are given in parentheses and include a coverage factor k=2. They apply to the last two digits of the value. The values certified are traceable to the SI.
The primary certified values are the isotope amount content and ratios; other values are derived from them. Reproducing the derived values may result in differences due to rounding errors.
The detailed uncertainty budget for the uranium amount content is enclosed (see Attachment).

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

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

André Verbruggen
Task leader

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

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

Uncertainty budget for isotope amount content

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

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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	0.35491	0.00015
^{233}U	4.4627	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, IRMM-074/10 and IRMM-290b/A3. 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.

There is no minimum sample intake to be taken into account.

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, October 2020

Last revision

Signed: 23-10-2020

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

Derived Values		
	Isotopic mass fraction	
	Value [1] [%]	Uncertainty [2] [%]
$m(^{233}U)/m(U)\times 100$	99.75836	0.00051
$m(^{234}U)/m(U)\times 100$	0.01942	0.00012
$m(^{235}U)/m(U)\times 100$	0.00740	0.00023
$m(^{236}U)/m(U)\times 100$	0.00038	0.00019
$m(^{238}U)/m(U)\times 100$	0.21443	0.00040
$m(^{238}Pu)/m(Pu)\times 100$	0.49672	0.00044
$m(^{239}Pu)/m(Pu)\times 100$	0.21220	0.00012
$m(^{240}Pu)/m(Pu)\times 100$	4.3261	0.0033
$m(^{241}Pu)/m(Pu)\times 100$	0.28208	0.00030
$m(^{242}Pu)/m(Pu)\times 100$	94.6583	0.0038
$m(^{244}Pu)/m(Pu)\times 100$	0.024364	0.000046
	Amount content	
	Value [1] [µmol/g]	Uncertainty [2] [µmol/g]
Pu	0.37512	0.00015
U	4.4733	0.0010
	Mass fraction	
	Value [1] [mg/g]	Uncertainty [2] [mg/g]
Pu	0.090757	0.000037
^{242}Pu	0.085909	0.000035
U	1.04251	0.00024
^{233}U	1.04000	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.
The atomic masses used in the calculation were taken from Wang et al., The AME 2016 atomic mass evaluation (II). Tables, Graphs and References, Chinese Physics C. Vol 41, No. 3, 2017.
Half-lives of plutonium isotopes were taken from Laboratorie National Henry Becquerel, http://www.nucleide.org/DDEPWG/DDEPdata.htm and R. Wellum et al, J .Anal. At. Spectrom., 24, 801-807, 2009.

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·L^{-1}.

ANALYTICAL METHODS USED FOR CERTIFICATION

The certified values were established by isotope dilution mass spectrometry (IDMS) on randomly selected units of IRMM-046c using IRMM-1027m as spike. The isotope ratio measurements were performed on a Triton TIMS (Thermo Fisher Scientific) using total evaporation method. Pu standard IRMM-290b/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

The material is ready for use after ampoule opening. Users are cautioned that once the ampoule is opened, the amount contents of plutonium and uranium may be affected by evaporation losses.
IRMM-046c is for use as a spike Isotopic Reference Material (IRM) to determine the plutonium and uranium amount contents by isotope dilution mass spectrometry (IDMS) in a wide range of nuclear samples.

STORAGE

The users are reminded to close the vial(s) immediately after taking the sample.
The vials should be stored at + 18 °C ± 5 °C.
However, the European Commission cannot be held responsible for changes that happen during storage of the material at the customer's premises, especially of opened samples.

LEGAL NOTICE

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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.

Annex 9 IRMM-1027v mother solution verification

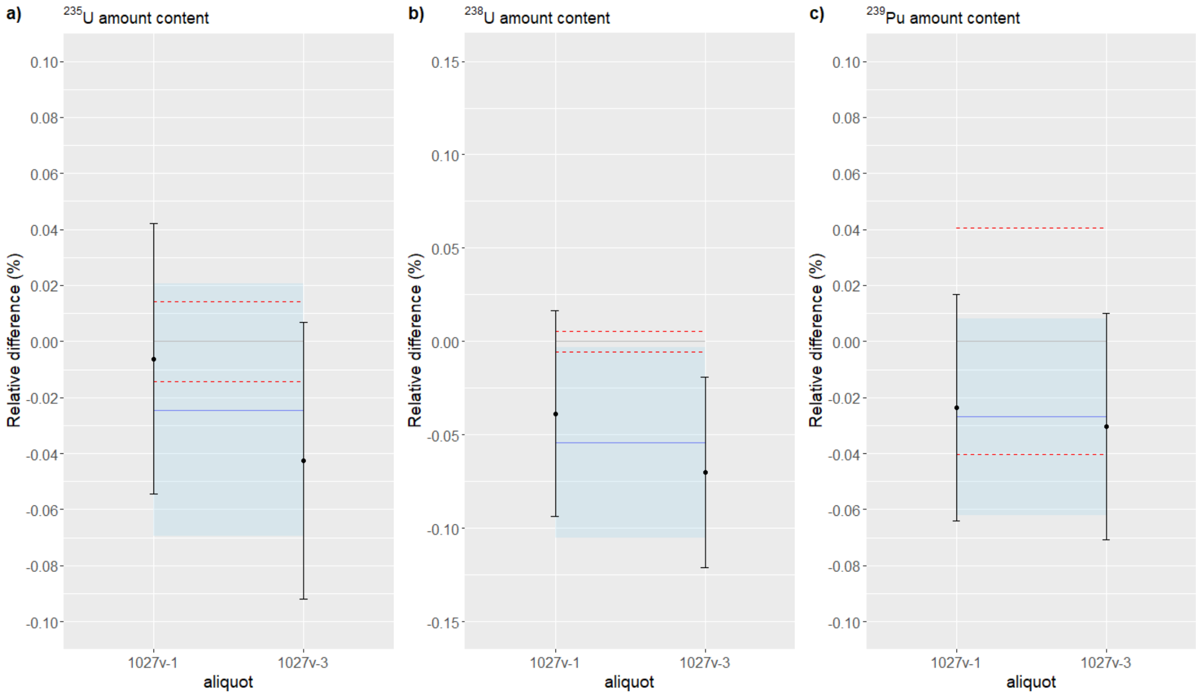

Figure 14 Verification results of the IRMM-1027v mother solution by IDMS on the a) ^{235}U, b) ^{238}U and c) ^{239}Pu amount contents. Red dashed lines show the relative expanded uncertainty of the gravimetric value with a coverage factor k = 2 with the exception of ^{235}U amount content and mass fraction values, which have a coverage factor k = 2.3 (df_{eff} = 9). Blue lines show the mean ID-TIMS values and the blue shaded area represents their expanded uncertainties with a coverage factor k = 2.

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

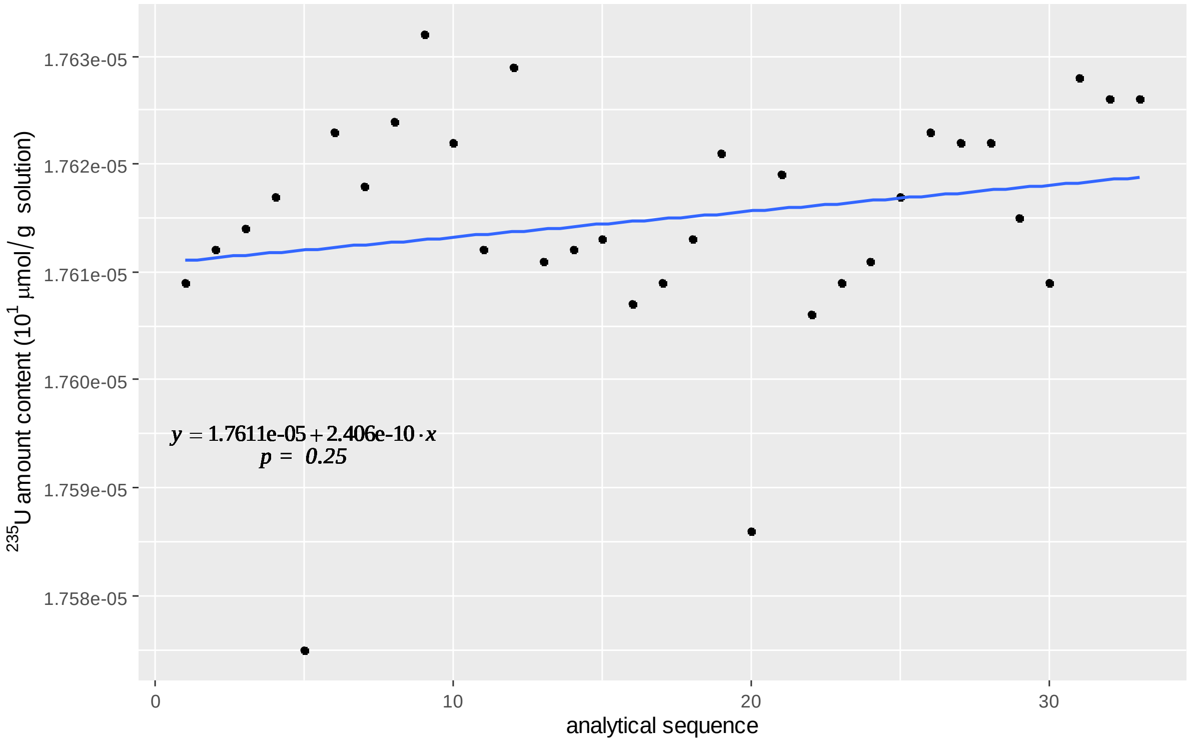

Figure 15 The amount content of ^{235}U from homogeneity study for the 33 replicate measurements (18 selected units, 3 replicates each) are shown as a function of the analytical sequence. No significant trend at the 95% CI was observed.

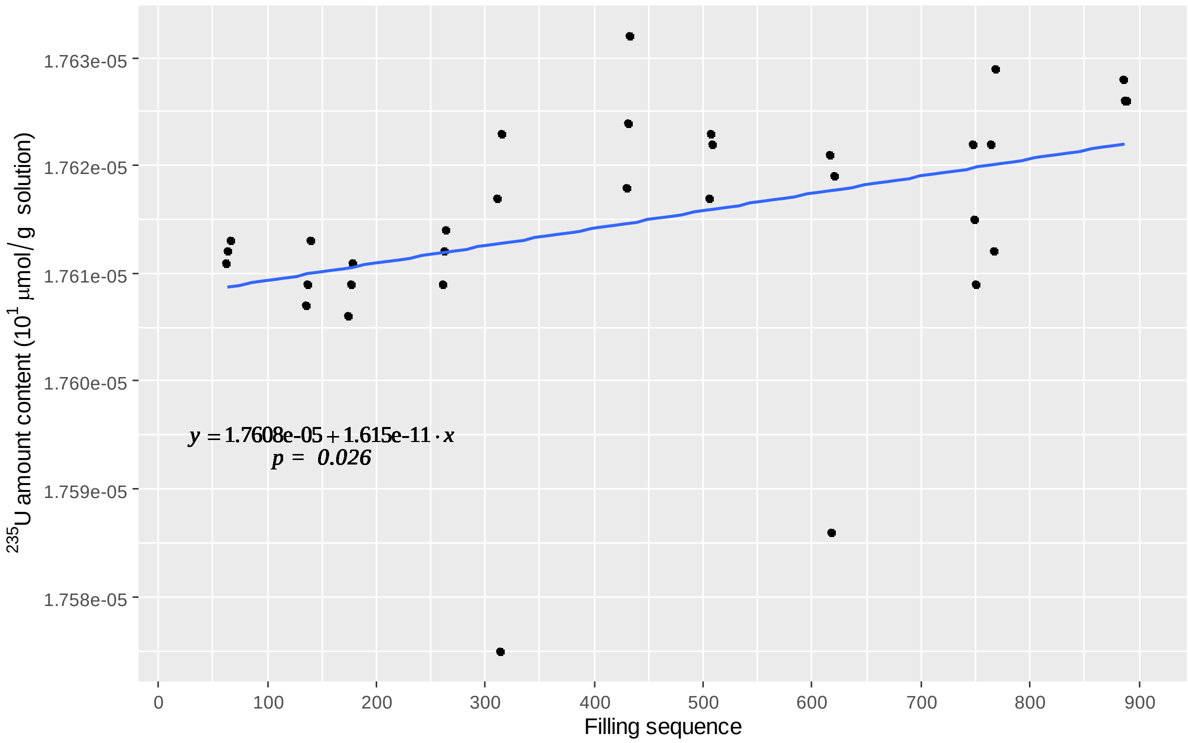

Figure 16 The amount content of ^{235}U from homogeneity study for the 33 replicate measurements (11 selected units, 3 replicates each) are shown as a function of the filling sequence. The x positions are slightly 'dodged' to make overlapping data visible. Significant trend at the 95% CI was observed ($p<0.05$).

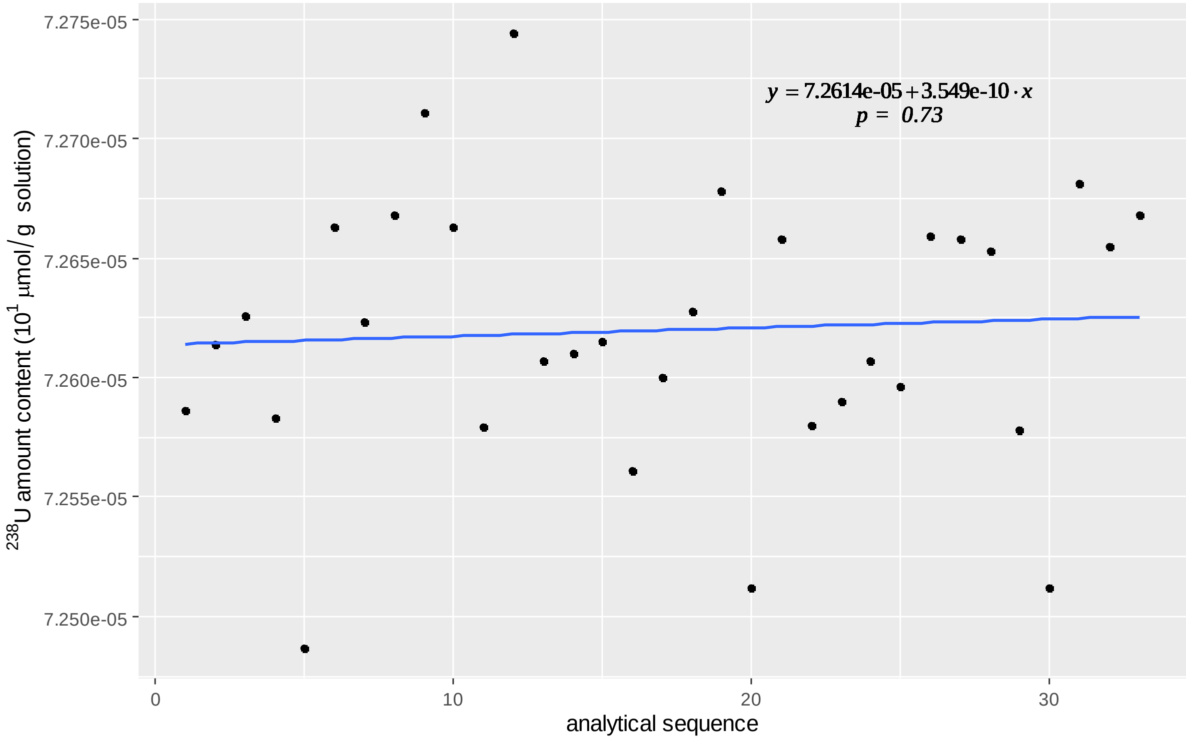

Figure 17 The amount content of ^{238}U from homogeneity study for the 33 replicate measurements (11 selected units, 3 replicates each) are shown as a function of the analytical sequence. No significant trend at the 95% CI was observed.

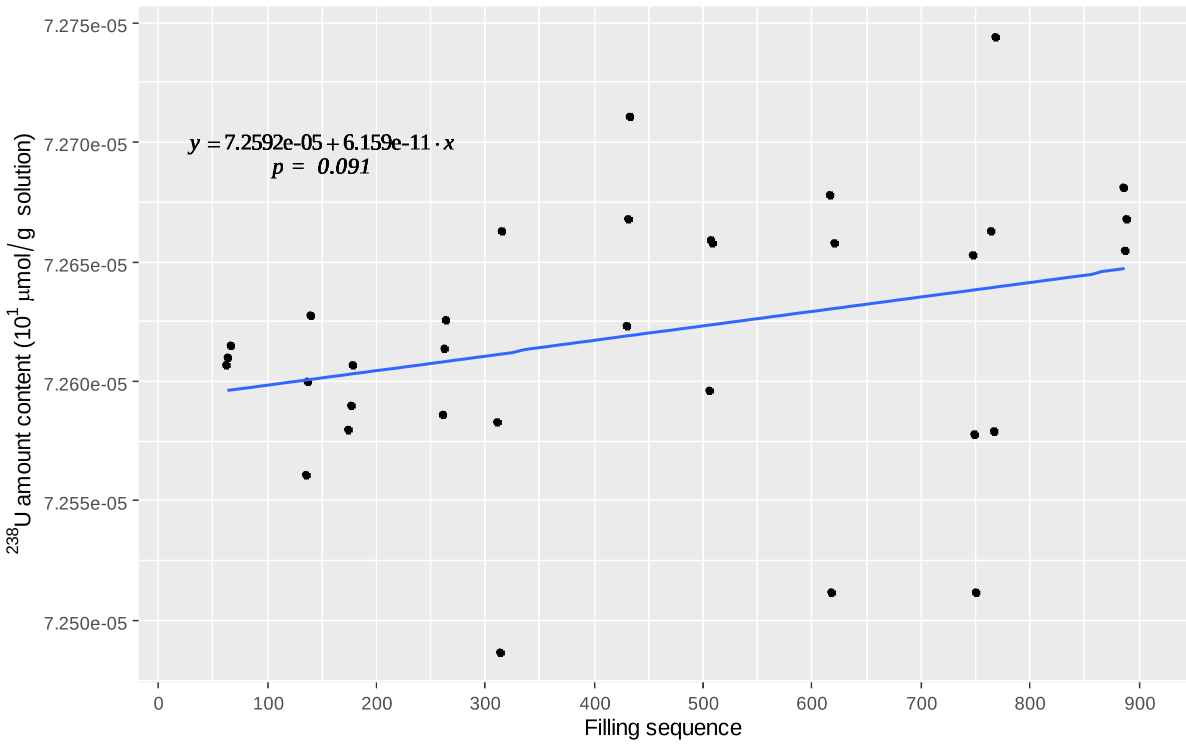

Figure 18 The amount content of ^{238}U from homogeneity study for the 33 replicate measurements (11 selected units, 3 replicates each) are shown as a function of the filling sequence. The positions are slightly 'dodged' to make overlapping data visible. No significant trend at the 95% CI was observed.

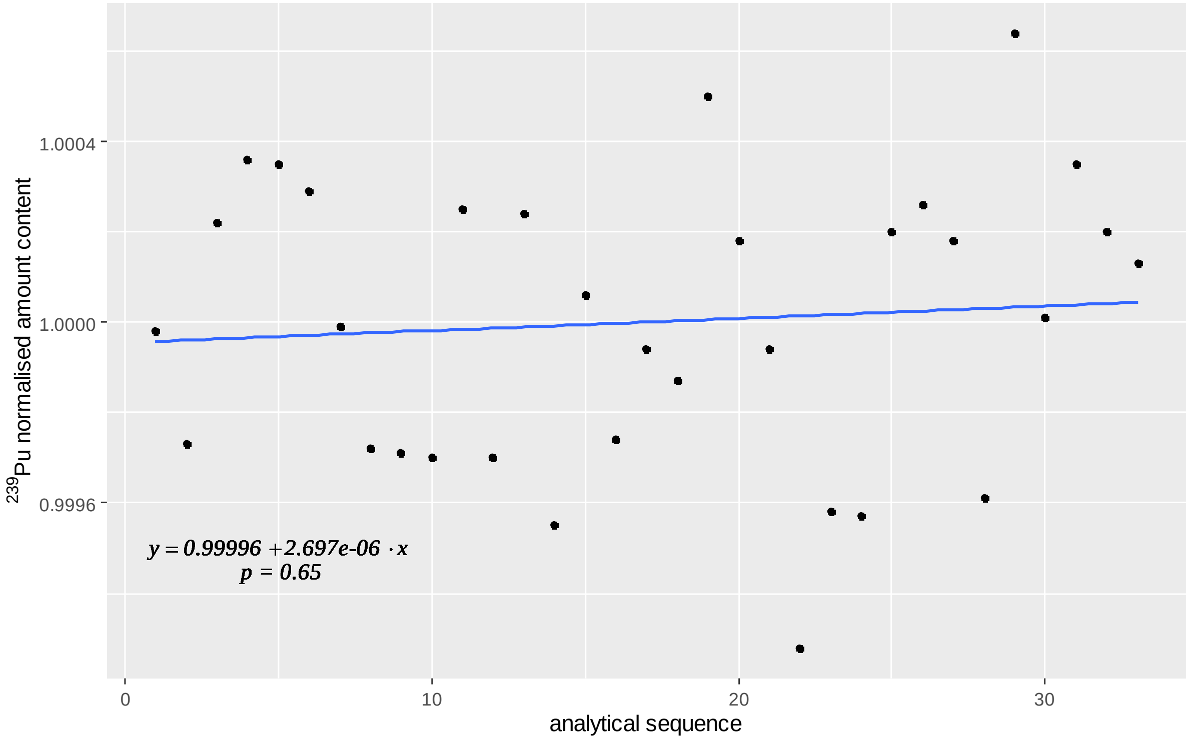

Figure 19 The normalised amount content of ^{239}Pu from homogeneity study for the 33 replicate measurements (11 selected units, 3 replicates each) are shown as a function of the analytical sequence. No significant trend at the 95% CI was observed.

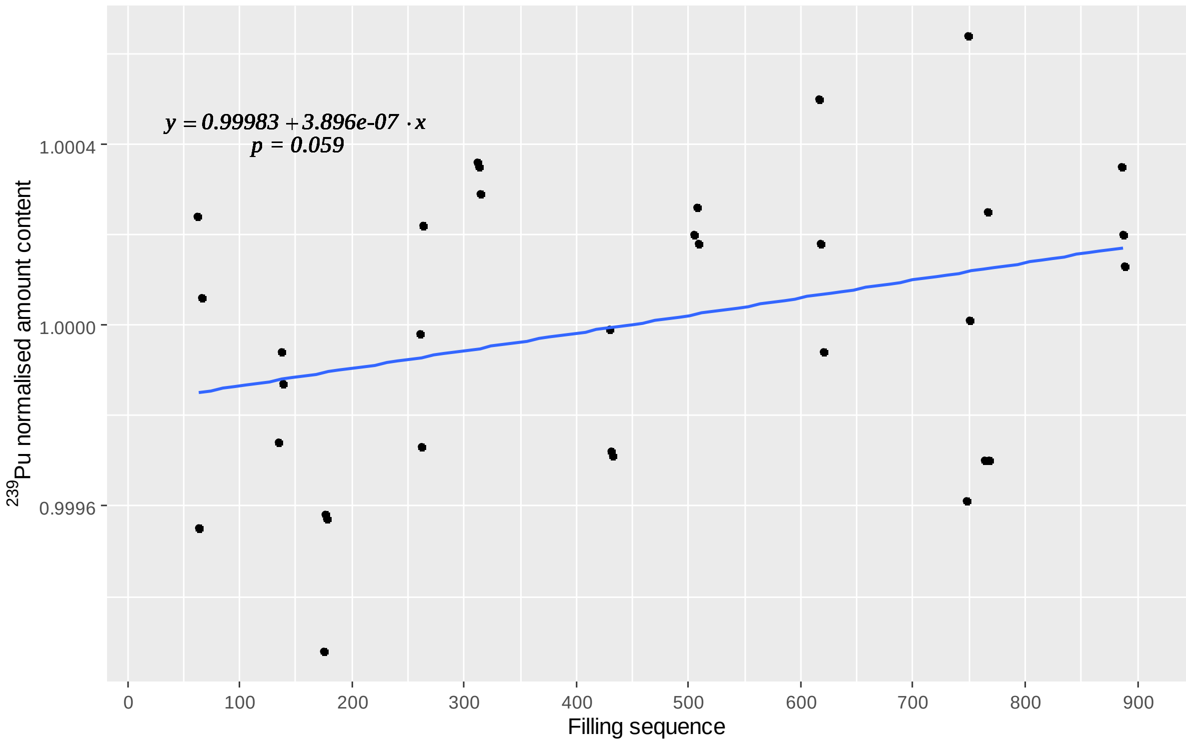

Figure 20 The normalised amount content of ^{239}Pu from homogeneity study for the 33 replicate measurements (11 selected units, 3 replicates each) are shown as a function of the filling sequence. The positions are slightly 'dodged' to make overlapping data visible. No significant trend at the 95% CI was observed.

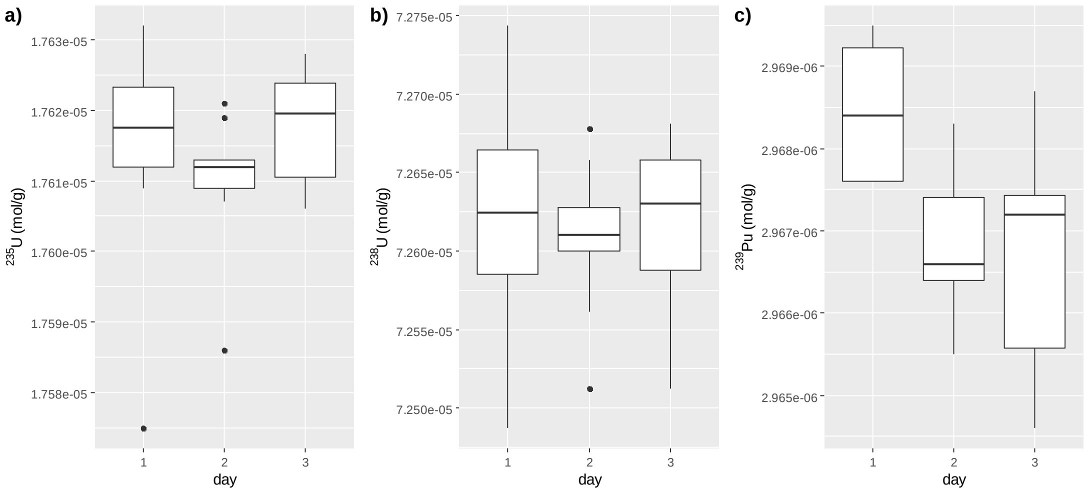

Figure 21 Tukey's boxplot representation of day-to-day differences for a) ^{235}U b) ^{238}U and c) ^{239}Pu amount contents (the latter before normalisation). The boxes represent the interquartile range (IQR) between the first and third quartile, the whiskers represent either the extremes or the 'fences' (1.5*IQR) and the individual dots represent outliers.

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

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

E. 3934 **rev 1** **Issue date:** ~~01/04/2020~~ 19/10/2020 **Page** 1 **of** 13

Applicant: Kalman Toth **Project:** IRMM-1027v certification

Description: Dispensing of IRMM-1027v U/Pu nitrate solution into individual vials

Request for analysis number: n/a **ID number:** n/a

Date of receipt of request: ~~21/01/2020~~ 19/11/2019 **Weighing dates**: 02-06/12/2019

Results:

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

Observations:

The measurements were performed according to Work instruction IMS-JRC.G-C1.1-WIN-0057 "WEIGHING AND MASS METROLOGY IN JRC.G.2 (NUCLEAR SAFEGUARDS TEAM)".

The dispensing and weighing were performed according to work instruction IMS-JRC.G-C1.1-WIN-0060 V1.0 Preparation of large sized dried spikes" on balance Sartorius TE124 installed in the dispensing robot box with inventory No. 2006 00290 17.

The results were corrected for the buoyancy of air and ~~an additional correction factor of +0.0005g~~ the NUCOMAT dispensing factor (E3945) was also applied.

Traceability:

The certified mass values are traceable to the International Kilogram Prototype via regular calibrations of the JRC G2's principal standards. The mass standard identified as H208 (cylinder + vial certificate E3945) 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. All reported uncertainties are expanded uncertainties $U = k \bullet u_c$ where u_c is the combined standard uncertainty calculated according to the ISO/BIPM Guide to the expression of Uncertainty in Measurement. The coverage factor $k = 2$ corresponds to a coverage probability of about 95%.

Rožle Jakopič
Nuclear Chemistry Laboratory responsible

Jeroen Bauwens
Analyst

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

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
001	~~2.4971~~	042	~~2.5001~~	083	~~2.5351~~	124	~~2.5248~~
002	~~2.5315~~	043	~~2.4979~~	084	~~2.5285~~	125	~~2.5458~~
003	~~2.5015~~	044	~~2.5373~~	085	~~2.5493~~	126	~~2.5338~~
004	~~2.4913~~	045	~~2.4965~~	086	~~2.5270~~	127	~~2.5297~~
005	~~2.4924~~	046	~~2.4882~~	087	~~2.5434~~	128	~~2.5319~~
006	~~2.4919~~	047	~~2.5308~~	088	~~2.4946~~	129	~~2.5330~~
007	~~2.4961~~	048	~~2.4998~~	089	~~2.5345~~	130	~~2.5293~~
008	~~2.5293~~	049	~~2.5306~~	090	~~2.5251~~	131	~~2.5353~~
009	~~2.5503~~	050	~~2.5554~~	091	~~2.5395~~	132	~~2.5339~~
010	~~2.5385~~	051	~~2.5313~~	092	~~2.5005~~	133	~~2.5255~~
011	~~2.5008~~	052	~~2.4988~~	093	~~2.5216~~	134	~~2.5301~~
012	~~2.4925~~	053	~~2.5369~~	094	~~2.5007~~	135	~~2.4992~~
013	~~2.5394~~	054	~~2.5393~~	095	~~2.5184~~	136	~~2.5347~~
014	~~2.5322~~	055	~~2.5012~~	096	~~2.5037~~	137	~~2.5259~~
015	~~2.4999~~	056	~~2.4898~~	097	~~2.5267~~	138	~~2.5314~~
016	~~2.5510~~	057	~~2.4918~~	098	~~2.5295~~	139	~~2.5352~~
017	~~2.5378~~	058	~~2.4914~~	099	~~2.5008~~	140	~~2.5188~~
018	~~2.5407~~	059	~~2.5407~~	100	~~2.5312~~	141	~~2.4999~~
019	~~2.5408~~	060	~~2.4908~~	101	~~2.5260~~	142	~~2.5304~~
020	~~2.5458~~	061	~~2.5411~~	102	~~2.5313~~	143	~~2.5297~~
021	~~2.5395~~	062	~~2.5416~~	103	~~2.5035~~	144	~~2.5307~~
022	~~2.5345~~	063	~~2.5374~~	104	~~2.5304~~	145	~~2.5334~~
023	~~2.5016~~	064	~~2.5450~~	105	~~2.5331~~	146	~~2.5224~~
024	~~2.5348~~	065	~~2.4915~~	106	~~2.5433~~	147	~~2.4957~~
025	~~2.4946~~	066	~~2.5260~~	107	~~2.5280~~	148	~~2.5236~~
026	~~2.5024~~	067	~~2.5026~~	108	~~2.5445~~	149	~~2.4889~~
027	~~2.4898~~	068	~~2.4929~~	109	~~2.5309~~	150	~~2.5161~~
028	~~2.5300~~	069	~~2.5355~~	110	~~2.5313~~	151	~~2.4987~~
029	~~2.4999~~	070	~~2.4886~~	111	~~2.5341~~	152	~~2.5289~~
030	~~2.5330~~	071	~~2.4894~~	112	~~2.4893~~	153	~~2.5320~~
031	~~2.5039~~	072	~~2.5424~~	113	~~2.5225~~	154	~~2.5293~~
032	~~2.5339~~	073	~~2.5432~~	114	~~2.4944~~	155	~~2.5342~~
033	~~2.4961~~	074	~~2.5268~~	115	~~2.5326~~	156	~~2.5230~~
034	~~2.5369~~	075	~~2.5043~~	116	~~2.5369~~	157	~~2.5428~~
035	~~2.4999~~	076	~~2.4875~~	117	~~2.5289~~	158	~~2.5320~~
036	~~2.5439~~	077	~~2.5361~~	118	~~2.5348~~	159	~~2.5300~~
037	~~2.5421~~	078	~~2.5361~~	119	~~2.5322~~	160	~~2.5294~~
038	~~2.4898~~	079	~~2.5433~~	120	~~2.5375~~	161	~~2.5310~~
039	~~2.5325~~	080	~~2.4909~~	121	~~2.5402~~	162	~~2.5329~~
040	~~2.5046~~	081	~~2.5291~~	122	~~2.5250~~	163	~~2.5179~~
041	~~2.5275~~	082	~~2.5454~~	123	~~2.5346~~	164	~~2.5425~~

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

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
165	~~2.5307~~	206	~~2.5296~~	247	~~2.5319~~	288	~~2.5260~~
166	~~2.5389~~	207	~~2.5182~~	248	~~2.5327~~	289	~~2.5304~~
167	~~2.5252~~	208	~~2.5427~~	249	~~2.5242~~	290	~~2.5168~~
168	~~2.5283~~	209	~~2.5217~~	250	~~2.4976~~	291	~~2.4951~~
169	~~2.5372~~	210	~~2.5351~~	251	~~2.5224~~	292	~~2.5300~~
170	~~2.5256~~	211	~~2.4886~~	252	~~2.5208~~	293	~~2.5295~~
171	~~2.5339~~	212	~~2.5263~~	253	~~2.4932~~	294	~~2.5201~~
172	~~2.5295~~	213	~~2.5337~~	254	~~2.5252~~	295	~~2.5316~~
173	~~2.5255~~	214	~~2.5275~~	255	~~2.5284~~	296	~~2.5211~~
174	~~2.5364~~	215	~~2.5244~~	256	~~2.5272~~	297	~~2.4939~~
175	~~2.5301~~	216	~~2.5217~~	257	~~2.4911~~	298	~~2.5228~~
176	~~2.5321~~	217	~~2.4967~~	258	~~2.5214~~	299	~~2.5204~~
177	~~2.5257~~	218	~~2.5185~~	259	~~2.5263~~	300	~~2.5385~~
178	~~2.5279~~	219	~~2.5341~~	260	~~2.5271~~	301	~~2.5227~~
179	~~2.5265~~	220	~~2.5271~~	261	~~2.5254~~	302	~~2.4947~~
180	~~2.4967~~	221	~~2.5318~~	262	~~2.5319~~	303	~~2.5204~~
181	~~2.5187~~	222	~~2.5390~~	263	~~2.5259~~	304	~~2.5258~~
182	~~2.5368~~	223	~~2.5232~~	264	~~2.4987~~	305	~~2.5269~~
183	~~2.5341~~	224	~~2.5195~~	265	~~2.5209~~	306	~~2.4933~~
184	~~2.5288~~	225	~~2.5293~~	266	~~2.5286~~	307	~~2.5251~~
185	~~2.5295~~	226	~~2.5410~~	267	~~2.5312~~	308	~~2.5309~~
186	~~2.5231~~	227	~~2.5304~~	268	~~2.5304~~	309	~~2.5205~~
187	~~2.5312~~	228	~~2.5296~~	269	~~2.5276~~	310	~~2.5332~~
188	~~2.5411~~	229	~~2.5304~~	270	~~2.5260~~	311	~~2.5375~~
189	~~2.5227~~	230	~~2.5265~~	271	~~2.4903~~	312	~~2.5244~~
190	~~2.5407~~	231	~~2.5222~~	272	~~2.5235~~	313	~~2.5318~~
191	~~2.5177~~	232	~~2.4933~~	273	~~2.5272~~	314	~~2.5212~~
192	~~2.5400~~	233	~~2.5266~~	274	~~2.5356~~	315	~~2.5334~~
193	~~2.5312~~	234	~~2.5311~~	275	~~2.5273~~	316	~~2.5299~~
194	~~2.5235~~	235	~~2.5292~~	276	~~2.5256~~	317	~~2.5347~~
195	~~2.5382~~	236	~~2.5288~~	277	~~2.5258~~	318	~~2.5267~~
196	~~2.5357~~	237	~~2.5269~~	278	~~2.5338~~	319	~~2.4933~~
197	~~2.5291~~	238	~~2.5368~~	279	~~2.5284~~	320	~~2.5236~~
198	~~2.5324~~	239	~~2.5251~~	280	~~2.5285~~	321	~~2.5171~~
199	~~2.5278~~	240	~~2.5230~~	281	~~2.5216~~	322	~~2.5395~~
200	~~2.5382~~	241	~~2.5380~~	282	~~2.5397~~	323	~~2.5224~~
201	~~2.5244~~	242	~~2.5330~~	283	~~2.5284~~	324	~~2.5398~~
202	~~2.5301~~	243	~~2.5256~~	284	~~2.5226~~	325	~~2.5199~~
203	~~2.5284~~	244	~~2.5239~~	285	~~2.5324~~	326	~~2.4969~~
204	~~2.5320~~	245	~~2.5335~~	286	~~2.5324~~	327	~~2.5202~~
205	~~2.5309~~	246	~~2.5223~~	287	~~2.5356~~	328	~~2.5247~~

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

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
329	~~2.5286~~	370	~~2.5186~~	411	~~2.5475~~	452	~~2.5302~~
330	~~2.5313~~	371	~~2.5300~~	412	~~2.5128~~	453	~~2.5316~~
331	~~2.4936~~	372	~~2.4946~~	413	~~2.5431~~	454	~~2.5300~~
332	~~2.5246~~	373	~~2.5234~~	414	~~2.5263~~	455	~~2.5307~~
333	~~2.5311~~	374	~~2.5240~~	415	~~2.5362~~	456	~~2.5322~~
334	~~2.5279~~	375	~~2.5416~~	416	~~2.5316~~	457	~~2.5303~~
335	~~2.5303~~	376	~~2.5272~~	417	~~2.5261~~	458	~~2.5239~~
336	~~2.5300~~	377	~~2.5326~~	418	~~2.5233~~	459	~~2.4910~~
337	~~2.5337~~	378	~~2.5317~~	419	~~2.4960~~	460	~~2.5299~~
338	~~2.5288~~	379	~~2.5277~~	420	~~2.5161~~	461	~~2.5279~~
339	~~2.5235~~	380	~~2.5304~~	421	~~2.4908~~	462	~~2.5225~~
340	~~2.5321~~	381	~~2.5248~~	422	~~2.5291~~	463	~~2.5324~~
341	~~2.5350~~	382	~~2.5288~~	423	~~2.5229~~	464	~~2.5366~~
342	~~2.5314~~	383	~~2.5271~~	424	~~2.5342~~	465	~~2.5286~~
343	~~2.5270~~	384	~~2.5355~~	425	~~2.4945~~	466	~~2.5344~~
344	~~2.5310~~	385	~~2.5345~~	426	~~2.5257~~	467	~~2.5216~~
345	~~2.5237~~	386	~~2.5278~~	427	~~2.5198~~	468	~~2.5316~~
346	~~2.5374~~	387	~~2.5320~~	428	~~2.5375~~	469	~~2.4933~~
347	~~2.5307~~	388	~~2.5225~~	429	~~2.5334~~	470	~~2.5204~~
348	~~2.5271~~	389	~~2.5350~~	430	~~2.5386~~	471	~~2.5297~~
349	~~2.5260~~	390	~~2.5322~~	431	~~2.5247~~	472	~~2.5371~~
350	~~2.4947~~	391	~~2.5280~~	432	~~2.5336~~	473	~~2.4933~~
351	~~2.5244~~	392	~~2.5230~~	433	~~2.5278~~	474	~~2.5240~~
352	~~2.5283~~	393	~~2.4918~~	434	~~2.5331~~	475	~~2.5308~~
353	~~2.5323~~	394	~~2.5300~~	435	~~2.5287~~	476	~~2.5219~~
354	~~2.5333~~	395	~~2.5242~~	436	~~2.5289~~	477	~~2.5355~~
355	~~2.5274~~	396	~~2.5403~~	437	~~2.5341~~	478	~~2.5276~~
356	~~2.4883~~	397	~~2.5195~~	438	~~2.5304~~	479	~~2.5347~~
357	~~2.5242~~	398	~~2.5281~~	439	~~2.5315~~	480	~~2.4927~~
358	~~2.5365~~	399	~~2.5317~~	440	~~2.5277~~	481	~~2.5278~~
359	~~2.5236~~	400	~~2.4909~~	441	~~2.5332~~	482	~~2.5296~~
360	~~2.5289~~	401	~~2.5267~~	442	~~2.5294~~	483	~~2.5257~~
361	~~2.5324~~	402	~~2.5326~~	443	~~2.5276~~	484	~~2.5392~~
362	~~2.5320~~	403	~~2.5310~~	444	~~2.5300~~	485	~~2.5271~~
363	~~2.5265~~	404	~~2.5271~~	445	~~2.5346~~	486	~~2.5292~~
364	~~2.5291~~	405	~~2.5250~~	446	~~2.5182~~	487	~~2.5320~~
365	~~2.5249~~	406	~~2.4951~~	447	~~2.5405~~	488	~~2.5354~~
366	~~2.5407~~	407	~~2.5276~~	448	~~2.5288~~	489	~~2.5268~~
367	~~2.5296~~	408	~~2.5261~~	449	~~2.5232~~	490	~~2.5314~~
368	~~2.5292~~	409	~~2.5281~~	450	~~2.5454~~	491	~~2.4923~~
369	~~2.4883~~	410	~~2.5286~~	451	~~2.5253~~	492	~~2.5370~~

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

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
493	~~2.5178~~	534	~~2.5320~~	575	~~2.5345~~	616	~~2.5354~~
494	~~2.5292~~	535	~~2.5239~~	576	~~2.5257~~	617	~~2.5256~~
495	~~2.5398~~	536	~~2.5393~~	577	~~2.5352~~	618	~~2.5280~~
496	~~2.5289~~	537	~~2.5298~~	578	~~2.5306~~	619	~~2.4963~~
497	~~2.5371~~	538	~~2.5308~~	579	~~2.5347~~	620	~~2.5298~~
498	~~2.5300~~	539	~~2.5257~~	580	~~2.5334~~	621	~~2.5341~~
499	~~2.5282~~	540	~~2.5331~~	581	~~2.5328~~	622	~~2.5293~~
500	~~2.5354~~	541	~~2.5300~~	582	~~2.5330~~	623	~~2.5344~~
501	~~2.5336~~	542	~~2.5418~~	583	~~2.5213~~	624	~~2.5284~~
502	~~2.5226~~	543	~~2.5361~~	584	~~2.4910~~	625	~~2.5338~~
503	~~2.4944~~	544	~~2.5260~~	585	~~2.5325~~	626	~~2.5261~~
504	~~2.5187~~	545	~~2.5288~~	586	~~2.5281~~	627	~~2.5418~~
505	~~2.4980~~	546	~~2.5318~~	587	~~2.4933~~	628	~~2.5286~~
506	~~2.5187~~	547	~~2.4932~~	588	~~2.5290~~	629	~~2.5384~~
507	~~2.5369~~	548	~~2.5199~~	589	~~2.5320~~	630	~~2.5286~~
508	~~2.4910~~	549	~~2.5296~~	590	~~2.5356~~	631	~~2.5338~~
509	~~2.5270~~	550	~~2.5394~~	591	~~2.5312~~	632	~~2.5339~~
510	~~2.5303~~	551	~~2.5286~~	592	~~2.5308~~	633	~~2.5315~~
511	~~2.5291~~	552	~~2.5365~~	593	~~2.5362~~	634	~~2.5337~~
512	~~2.4914~~	553	~~2.5348~~	594	~~2.5304~~	635	~~2.5312~~
513	~~2.5254~~	554	~~2.5308~~	595	~~2.5237~~	636	~~2.4876~~
514	~~2.5248~~	555	~~2.5336~~	596	~~2.5390~~	637	~~2.5265~~
515	~~2.4922~~	556	~~2.5260~~	597	~~2.5292~~	638	~~2.5351~~
516	~~2.5307~~	557	~~2.5333~~	598	~~2.5351~~	639	~~2.5353~~
517	~~2.5279~~	558	~~2.5369~~	599	~~2.5350~~	640	~~2.5326~~
518	~~2.5328~~	559	~~2.5311~~	600	~~2.5338~~	641	~~2.5325~~
519	~~2.5295~~	560	~~2.5317~~	601	~~2.5331~~	642	~~2.5309~~
520	~~2.4896~~	561	~~2.4903~~	602	~~2.5282~~	643	~~2.5310~~
521	~~2.5239~~	562	~~2.5230~~	603	~~2.5382~~	644	~~2.5360~~
522	~~2.5356~~	563	~~2.5335~~	604	~~2.5301~~	645	~~2.5326~~
523	~~2.5340~~	564	~~2.5289~~	605	~~2.5254~~	646	~~2.5322~~
524	~~2.5270~~	565	~~2.5315~~	606	~~2.5403~~	647	~~2.4888~~
525	~~2.5352~~	566	~~2.5335~~	607	~~2.5400~~	648	~~2.5253~~
526	~~2.5298~~	567	~~2.4887~~	608	~~2.5243~~	649	~~2.5327~~
527	~~2.5300~~	568	~~2.5327~~	609	~~2.5330~~	650	~~2.5304~~
528	~~2.4879~~	569	~~2.5327~~	610	~~2.5268~~	651	~~2.5389~~
529	~~2.5290~~	570	~~2.5272~~	611	~~2.5410~~	652	~~2.5278~~
530	~~2.5257~~	571	~~2.5348~~	612	~~2.5299~~	653	~~2.5364~~
531	~~2.5362~~	572	~~2.5284~~	613	~~2.5349~~	654	~~2.5289~~
532	~~2.5352~~	573	~~2.4953~~	614	~~2.5282~~	655	~~2.5283~~
533	~~2.5307~~	574	~~2.5242~~	615	~~2.5349~~	656	~~2.5319~~

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

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
657	~~2.4942~~	698	~~2.5357~~	739	~~2.5330~~	780	~~2.5327~~
658	~~2.5291~~	699	~~2.5318~~	740	~~2.5320~~	781	~~2.5303~~
659	~~2.5322~~	700	~~2.5265~~	741	~~2.5312~~	782	~~2.5330~~
660	~~2.5351~~	701	~~2.4946~~	742	~~2.4919~~	783	~~2.5398~~
661	~~2.5325~~	702	~~2.5264~~	743	~~2.5257~~	784	~~2.5246~~
662	~~2.5367~~	703	~~2.5353~~	744	~~2.5333~~	785	~~2.4894~~
663	~~2.5309~~	704	~~2.5298~~	745	~~2.5323~~	786	~~2.5361~~
664	~~2.5324~~	705	~~2.5325~~	746	~~2.5310~~	787	~~2.5228~~
665	~~2.5333~~	706	~~2.5312~~	747	~~2.5290~~	788	~~2.5274~~
666	~~2.5240~~	707	~~2.5357~~	748	~~2.4932~~	789	~~2.5389~~
667	~~2.4932~~	708	~~2.5299~~	749	~~2.5243~~	790	~~2.5300~~
668	~~2.5292~~	709	~~2.5319~~	750	~~2.5261~~	791	~~2.5316~~
669	~~2.5329~~	710	~~2.5344~~	751	~~2.4921~~	792	~~2.5368~~
670	~~2.5332~~	711	~~2.5337~~	752	~~2.5248~~	793	~~2.5265~~
671	~~2.5297~~	712	~~2.5288~~	753	~~2.5370~~	794	~~2.5331~~
672	~~2.5347~~	713	~~2.5339~~	754	~~2.5345~~	795	~~2.4947~~
673	~~2.5318~~	714	~~2.5327~~	755	~~2.5302~~	796	~~2.5225~~
674	~~2.5334~~	715	~~2.5292~~	756	~~2.5317~~	797	~~2.5355~~
675	~~2.5325~~	716	~~2.5343~~	757	~~2.5332~~	798	~~2.4892~~
676	~~2.5329~~	717	~~2.5242~~	758	~~2.5312~~	799	~~2.5245~~
677	~~2.5316~~	718	~~2.4939~~	759	~~2.5330~~	800	~~2.5273~~
678	~~2.5273~~	719	~~2.5252~~	760	~~2.5299~~	801	~~2.5394~~
679	~~2.5300~~	720	~~2.5365~~	761	~~2.5354~~	802	~~2.5342~~
680	~~2.5372~~	721	~~2.5351~~	762	~~2.5328~~	803	~~2.5302~~
681	~~2.4934~~	722	~~2.5281~~	763	~~2.5325~~	804	~~2.5336~~
682	~~2.5248~~	723	~~2.5326~~	764	~~2.5343~~	805	~~2.5381~~
683	~~2.5308~~	724	~~2.5321~~	765	~~2.5228~~	806	~~2.5310~~
684	~~2.5281~~	725	~~2.5319~~	766	~~2.5362~~	807	~~2.5295~~
685	~~2.4970~~	726	~~2.5351~~	767	~~2.5333~~	808	~~2.4876~~
686	~~2.5231~~	727	~~2.5296~~	768	~~2.5306~~	809	~~2.5266~~
687	~~2.5267~~	728	~~2.5339~~	769	~~2.5363~~	810	~~2.5337~~
688	~~2.5361~~	729	~~2.5260~~	770	~~2.5341~~	811	~~2.5331~~
689	~~2.4922~~	730	~~2.4938~~	771	~~2.5259~~	812	~~2.5310~~
690	~~2.5275~~	731	~~2.5267~~	772	~~2.4928~~	813	~~2.5276~~
691	~~2.5306~~	732	~~2.5282~~	773	~~2.5281~~	814	~~2.4948~~
692	~~2.5267~~	733	~~2.5381~~	774	~~2.4872~~	815	~~2.5205~~
693	~~2.4911~~	734	~~2.5297~~	775	~~2.5309~~	816	~~2.4935~~
694	~~2.5300~~	735	~~2.5336~~	776	~~2.5249~~	817	~~2.5248~~
695	~~2.4896~~	736	~~2.5315~~	777	~~2.5293~~	818	N/A
696	~~2.5224~~	737	~~2.4893~~	778	~~2.5393~~	819	~~2.4909~~
697	~~2.5330~~	738	~~2.5260~~	779	~~2.5324~~	820	~~2.5273~~

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

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
821	~~2.5341~~	862	~~2.5302~~	903	~~2.5380~~		
822	~~2.5338~~	863	~~2.5416~~	904	~~2.5275~~		
823	~~2.5243~~	864	~~2.4881~~	905	~~2.4922~~		
824	~~2.5348~~	865	~~2.5315~~	906	~~2.5283~~		
825	~~2.4912~~	866	~~2.5344~~	907	~~2.4924~~		
826	~~2.5272~~	867	~~2.5312~~	908	~~2.5288~~		
827	~~2.5292~~	868	~~2.5307~~	909	~~2.5376~~		
828	~~2.4935~~	869	~~2.4892~~	910	~~2.5275~~		
829	~~2.5201~~	870	~~2.5280~~	911	~~2.5328~~		
830	~~2.5361~~	871	~~2.5299~~	912	~~2.4978~~		
831	~~2.4885~~	872	~~2.4927~~				
832	~~2.5234~~	873	~~2.5238~~				
833	~~2.4926~~	874	~~2.4900~~				
834	~~2.5227~~	875	~~2.5285~~				
835	~~2.4909~~	876	~~2.5364~~				
836	~~2.5303~~	877	~~2.5378~~				
837	~~2.5307~~	878	~~2.5311~~				
838	~~2.5341~~	879	~~2.5284~~				
839	~~2.5299~~	880	~~2.4920~~				
840	~~2.5358~~	881	~~2.5269~~				
841	~~2.5375~~	882	~~2.5375~~				
842	~~2.5293~~	883	~~2.5311~~				
843	~~2.5290~~	884	~~2.5355~~				
844	~~2.5430~~	885	~~2.5275~~				
845	~~2.5318~~	886	~~2.5390~~				
846	~~2.5339~~	887	~~2.5243~~				
847	~~2.5272~~	888	~~2.5388~~				
848	~~2.4920~~	889	~~2.5355~~				
849	~~2.5302~~	890	~~2.5357~~				
850	~~2.5351~~	891	~~2.5366~~				
851	~~2.5313~~	892	~~2.5260~~				
852	~~2.5337~~	893	~~2.5347~~				
853	~~2.5332~~	894	~~2.5326~~				
854	~~2.5352~~	895	~~2.4921~~				
855	~~2.5347~~	896	~~2.5256~~				
856	~~2.5254~~	897	~~2.4922~~				
857	~~2.5387~~	898	~~2.5257~~				
858	~~2.4887~~	899	~~2.4960~~				
859	~~2.5245~~	900	~~2.5247~~				
860	~~2.5405~~	901	~~2.5390~~				
861	~~2.5282~~	902	~~2.5260~~				

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

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
001	2.4963	042	2.4993	083	2.5343	124	2.5240
002	2.5307	043	2.4971	084	2.5277	125	2.5450
003	2.5007	044	2.5365	085	2.5484	126	2.5330
004	2.4905	045	2.4957	086	2.5262	127	2.5289
005	2.4916	046	2.4874	087	2.5425	128	2.5311
006	2.4911	047	2.5300	088	2.4938	129	2.5322
007	2.4953	048	2.4990	089	2.5337	130	2.5285
008	2.5285	049	2.5298	090	2.5243	131	2.5345
009	2.5494	050	2.5545	091	2.5387	132	2.5331
010	2.5377	051	2.5305	092	2.4997	133	2.5247
011	2.5000	052	2.4980	093	2.5208	134	2.5293
012	2.4917	053	2.5361	094	2.4999	135	2.4984
013	2.5386	054	2.5385	095	2.5176	136	2.5339
014	2.5314	055	2.5004	096	2.5029	137	2.5251
015	2.4991	056	2.4890	097	2.5259	138	2.5306
016	2.5501	057	2.4910	098	2.5287	139	2.5344
017	2.5370	058	2.4906	099	2.5000	140	2.5180
018	2.5399	059	2.5399	100	2.5304	141	2.4991
019	2.5400	060	2.4900	101	2.5252	142	2.5296
020	2.5449	061	2.5403	102	2.5305	143	2.5289
021	2.5387	062	2.5408	103	2.5027	144	2.5299
022	2.5337	063	2.5366	104	2.5296	145	2.5326
023	2.5008	064	2.5441	105	2.5323	146	2.5216
024	2.5340	065	2.4907	106	2.5425	147	2.4949
025	2.4938	066	2.5252	107	2.5272	148	2.5228
026	2.5016	067	2.5018	108	2.5437	149	2.4881
027	2.4890	068	2.4921	109	2.5301	150	2.5153
028	2.5292	069	2.5347	110	2.5305	151	2.4979
029	2.4991	070	2.4878	111	2.5333	152	2.5281
030	2.5322	071	2.4886	112	2.4885	153	2.5312
031	2.5031	072	2.5415	113	2.5217	154	2.5285
032	2.5331	073	2.5423	114	2.4936	155	2.5334
033	2.4953	074	2.5260	115	2.5318	156	2.5222
034	2.5361	075	2.5035	116	2.5361	157	2.5420
035	2.4991	076	2.4867	117	2.5281	158	2.5312
036	2.5430	077	2.5353	118	2.5340	159	2.5292
037	2.5412	078	2.5353	119	2.5314	160	2.5286
038	2.4890	079	2.5424	120	2.5367	161	2.5302
039	2.5317	080	2.4901	121	2.5394	162	2.5321
040	2.5038	081	2.5283	122	2.5242	163	2.5171
041	2.5267	082	2.5445	123	2.5338	164	2.5417

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

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
165	2.5299	206	2.5288	247	2.5311	288	2.5252
166	2.5381	207	2.5174	248	2.5319	289	2.5296
167	2.5244	208	2.5418	249	2.5234	290	2.5160
168	2.5275	209	2.5209	250	2.4968	291	2.4943
169	2.5364	210	2.5343	251	2.5216	292	2.5292
170	2.5248	211	2.4878	252	2.5200	293	2.5287
171	2.5331	212	2.5255	253	2.4924	294	2.5193
172	2.5287	213	2.5329	254	2.5244	295	2.5308
173	2.5247	214	2.5267	255	2.5276	296	2.5203
174	2.5356	215	2.5236	256	2.5264	297	2.4931
175	2.5293	216	2.5209	257	2.4903	298	2.5220
176	2.5313	217	2.4959	258	2.5206	299	2.5196
177	2.5249	218	2.5177	259	2.5255	300	2.5377
178	2.5271	219	2.5333	260	2.5263	301	2.5219
179	2.5257	220	2.5263	261	2.5246	302	2.4939
180	2.4959	221	2.5310	262	2.5311	303	2.5196
181	2.5179	222	2.5381	263	2.5251	304	2.5250
182	2.5360	223	2.5224	264	2.4979	305	2.5261
183	2.5333	224	2.5187	265	2.5201	306	2.4925
184	2.5280	225	2.5285	266	2.5278	307	2.5243
185	2.5287	226	2.5401	267	2.5304	308	2.5301
186	2.5223	227	2.5296	268	2.5296	309	2.5197
187	2.5304	228	2.5288	269	2.5268	310	2.5324
188	2.5403	229	2.5296	270	2.5252	311	2.5367
189	2.5219	230	2.5257	271	2.4895	312	2.5236
190	2.5399	231	2.5214	272	2.5227	313	2.5310
191	2.5169	232	2.4925	273	2.5264	314	2.5204
192	2.5392	233	2.5258	274	2.5348	315	2.5326
193	2.5304	234	2.5303	275	2.5265	316	2.5291
194	2.5227	235	2.5284	276	2.5248	317	2.5339
195	2.5373	236	2.5280	277	2.5250	318	2.5259
196	2.5349	237	2.5261	278	2.5330	319	2.4925
197	2.5283	238	2.5360	279	2.5276	320	2.5228
198	2.5316	239	2.5243	280	2.5277	321	2.5163
199	2.5270	240	2.5222	281	2.5208	322	2.5387
200	2.5373	241	2.5371	282	2.5388	323	2.5216
201	2.5236	242	2.5322	283	2.5276	324	2.5390
202	2.5293	243	2.5248	284	2.5218	325	2.5191
203	2.5276	244	2.5231	285	2.5316	326	2.4961
204	2.5312	245	2.5327	286	2.5316	327	2.5194
205	2.5301	246	2.5215	287	2.5348	328	2.5239

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

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
329	2.5278	370	2.5178	411	2.5466	452	2.5294
330	2.5305	371	2.5292	412	2.5120	453	2.5308
331	2.4928	372	2.4938	413	2.5423	454	2.5292
332	2.5238	373	2.5226	414	2.5255	455	2.5299
333	2.5303	374	2.5232	415	2.5354	456	2.5314
334	2.5271	375	2.5408	416	2.5308	457	2.5295
335	2.5295	376	2.5264	417	2.5253	458	2.5231
336	2.5292	377	2.5318	418	2.5225	459	2.4902
337	2.5329	378	2.5309	419	2.4952	460	2.5291
338	2.5280	379	2.5269	420	2.5153	461	2.5271
339	2.5227	380	2.5296	421	2.4900	462	2.5217
340	2.5313	381	2.5240	422	2.5283	463	2.5316
341	2.5342	382	2.5280	423	2.5221	464	2.5358
342	2.5306	383	2.5263	424	2.5334	465	2.5278
343	2.5262	384	2.5347	425	2.4937	466	2.5336
344	2.5302	385	2.5337	426	2.5249	467	2.5208
345	2.5229	386	2.5270	427	2.5190	468	2.5308
346	2.5366	387	2.5312	428	2.5367	469	2.4925
347	2.5299	388	2.5217	429	2.5326	470	2.5196
348	2.5263	389	2.5342	430	2.5378	471	2.5289
349	2.5252	390	2.5314	431	2.5239	472	2.5363
350	2.4939	391	2.5272	432	2.5328	473	2.4925
351	2.5236	392	2.5222	433	2.5270	474	2.5232
352	2.5275	393	2.4910	434	2.5323	475	2.5300
353	2.5315	394	2.5292	435	2.5279	476	2.5211
354	2.5325	395	2.5234	436	2.5281	477	2.5347
355	2.5266	396	2.5395	437	2.5333	478	2.5268
356	2.4875	397	2.5187	438	2.5296	479	2.5339
357	2.5234	398	2.5273	439	2.5307	480	2.4919
358	2.5357	399	2.5309	440	2.5269	481	2.5270
359	2.5228	400	2.4901	441	2.5324	482	2.5288
360	2.5281	401	2.5259	442	2.5286	483	2.5249
361	2.5316	402	2.5318	443	2.5268	484	2.5384
362	2.5312	403	2.5302	444	2.5292	485	2.5263
363	2.5257	404	2.5263	445	2.5338	486	2.5284
364	2.5283	405	2.5242	446	2.5174	487	2.5312
365	2.5241	406	2.4943	447	2.5397	488	2.5346
366	2.5399	407	2.5268	448	2.5280	489	2.5260
367	2.5288	408	2.5253	449	2.5224	490	2.5306
368	2.5284	409	2.5273	450	2.5446	491	2.4915
369	2.4875	410	2.5278	451	2.5245	492	2.5362

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

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
493	2.5170	534	2.5312	575	2.5337	616	2.5346
494	2.5284	535	2.5231	576	2.5249	617	2.5248
495	2.5390	536	2.5385	577	2.5344	618	2.5272
496	2.5281	537	2.5290	578	2.5298	619	2.4955
497	2.5363	538	2.5300	579	2.5339	620	2.5290
498	2.5292	539	2.5249	580	2.5326	621	2.5333
499	2.5274	540	2.5323	581	2.5320	622	2.5285
500	2.5346	541	2.5292	582	2.5322	623	2.5336
501	2.5328	542	2.5410	583	2.5205	624	2.5276
502	2.5218	543	2.5353	584	2.4902	625	2.5330
503	2.4936	544	2.5252	585	2.5317	626	2.5253
504	2.5179	545	2.5280	586	2.5273	627	2.5410
505	2.4972	546	2.5310	587	2.4925	628	2.5278
506	2.5179	547	2.4924	588	2.5282	629	2.5376
507	2.5361	548	2.5191	589	2.5312	630	2.5278
508	2.4902	549	2.5288	590	2.5348	631	2.5330
509	2.5262	550	2.5386	591	2.5304	632	2.5331
510	2.5295	551	2.5278	592	2.5300	633	2.5307
511	2.5283	552	2.5357	593	2.5354	634	2.5329
512	2.4906	553	2.5340	594	2.5296	635	2.5304
513	2.5246	554	2.5300	595	2.5229	636	2.4868
514	2.5240	555	2.5328	596	2.5382	637	2.5257
515	2.4914	556	2.5252	597	2.5284	638	2.5343
516	2.5299	557	2.5325	598	2.5343	639	2.5345
517	2.5271	558	2.5361	599	2.5342	640	2.5318
518	2.5320	559	2.5303	600	2.5330	641	2.5317
519	2.5287	560	2.5309	601	2.5323	642	2.5301
520	2.4888	561	2.4895	602	2.5274	643	2.5302
521	2.5231	562	2.5222	603	2.5374	644	2.5352
522	2.5348	563	2.5327	604	2.5293	645	2.5318
523	2.5332	564	2.5281	605	2.5246	646	2.5314
524	2.5262	565	2.5307	606	2.5395	647	2.4880
525	2.5344	566	2.5327	607	2.5392	648	2.5245
526	2.5290	567	2.4879	608	2.5235	649	2.5319
527	2.5292	568	2.5319	609	2.5322	650	2.5296
528	2.4871	569	2.5319	610	2.5260	651	2.5381
529	2.5282	570	2.5264	611	2.5402	652	2.5270
530	2.5249	571	2.5340	612	2.5291	653	2.5356
531	2.5354	572	2.5276	613	2.5341	654	2.5281
532	2.5344	573	2.4945	614	2.5274	655	2.5275
533	2.5299	574	2.5234	615	2.5341	656	2.5311

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

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
657	2.4934	698	2.5349	739	2.5322	780	2.5319
658	2.5283	699	2.5310	740	2.5312	781	2.5295
659	2.5314	700	2.5257	741	2.5304	782	2.5322
660	2.5343	701	2.4938	742	2.4911	783	2.5390
661	2.5317	702	2.5256	743	2.5249	784	2.5238
662	2.5359	703	2.5345	744	2.5325	785	2.4886
663	2.5301	704	2.5290	745	2.5315	786	2.5353
664	2.5316	705	2.5317	746	2.5302	787	2.5220
665	2.5325	706	2.5304	747	2.5282	788	2.5266
666	2.5232	707	2.5349	748	2.4924	789	2.5381
667	2.4924	708	2.5291	749	2.5235	790	2.5292
668	2.5284	709	2.5311	750	2.5253	791	2.5308
669	2.5321	710	2.5336	751	2.4913	792	2.5360
670	2.5324	711	2.5329	752	2.5240	793	2.5257
671	2.5289	712	2.5280	753	2.5362	794	2.5323
672	2.5339	713	2.5331	754	2.5337	795	2.4939
673	2.5310	714	2.5319	755	2.5294	796	2.5217
674	2.5326	715	2.5284	756	2.5309	797	2.5347
675	2.5317	716	2.5335	757	2.5324	798	2.4884
676	2.5321	717	2.5234	758	2.5304	799	2.5237
677	2.5308	718	2.4931	759	2.5322	800	2.5265
678	2.5265	719	2.5244	760	2.5291	801	2.5386
679	2.5292	720	2.5357	761	2.5346	802	2.5334
680	2.5364	721	2.5343	762	2.5320	803	2.5294
681	2.4926	722	2.5273	763	2.5317	804	2.5328
682	2.5240	723	2.5318	764	2.5335	805	2.5373
683	2.5300	724	2.5313	765	2.5220	806	2.5302
684	2.5273	725	2.5311	766	2.5354	807	2.5287
685	2.4962	726	2.5343	767	2.5325	808	2.4868
686	2.5223	727	2.5288	768	2.5298	809	2.5258
687	2.5259	728	2.5331	769	2.5355	810	2.5329
688	2.5353	729	2.5252	770	2.5333	811	2.5323
689	2.4914	730	2.4930	771	2.5251	812	2.5302
690	2.5267	731	2.5259	772	2.4920	813	2.5268
691	2.5298	732	2.5274	773	2.5273	814	2.4940
692	2.5259	733	2.5373	774	2.4864	815	2.5197
693	2.4903	734	2.5289	775	2.5301	816	2.4927
694	2.5292	735	2.5328	776	2.5241	817	2.5240
695	2.4888	736	2.5307	777	2.5285	818	N/A
696	2.5216	737	2.4885	778	2.5385	819	2.4901
697	2.5322	738	2.5252	779	2.5316	820	2.5265

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

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
821	2.5333	862	2.5294	903	2.5372		
822	2.5330	863	2.5408	904	2.5267		
823	2.5235	864	2.4873	905	2.4914		
824	2.5340	865	2.5307	906	2.5275		
825	2.4904	866	2.5336	907	2.4916		
826	2.5264	867	2.5304	908	2.5280		
827	2.5284	868	2.5299	909	2.5368		
828	2.4927	869	2.4884	910	2.5267		
829	2.5193	870	2.5272	911	2.5320		
830	2.5353	871	2.5291	912	2.4970		
831	2.4877	872	2.4919				
832	2.5226	873	2.5230				
833	2.4918	874	2.4892				
834	2.5219	875	2.5277				
835	2.4901	876	2.5356				
836	2.5295	877	2.5370				
837	2.5299	878	2.5303				
838	2.5333	879	2.5276				
839	2.5291	880	2.4912				
840	2.5350	881	2.5261				
841	2.5367	882	2.5367				
842	2.5285	883	2.5303				
843	2.5282	884	2.5347				
844	2.5422	885	2.5267				
845	2.5310	886	2.5382				
846	2.5331	887	2.5235				
847	2.5264	888	2.5380				
848	2.4912	889	2.5347				
849	2.5294	890	2.5349				
850	2.5343	891	2.5358				
851	2.5305	892	2.5252				
852	2.5329	893	2.5339				
853	2.5324	894	2.5318				
854	2.5344	895	2.4913				
855	2.5339	896	2.5248				
856	2.5246	897	2.4914				
857	2.5379	898	2.5249				
858	2.4879	899	2.4952				
859	2.5237	900	2.5239				
860	2.5397	901	2.5382				
861	2.5274	902	2.5252				

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

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

E. 3935 rev 1 **Issue date:** ~~24/01/2020~~ 17/11/2020 **Page** 1 **of** 2

Applicant: Kalman Toth

Project: IRMM-1027v certification

Description: Preparation of IRMM-1027v LSD mother solution

Request for analysis number: 4560

ID number: 31295

Date of receipt of request: 17/10/2019

Weighing dates: 04,11,12,13,19/11/2019 and 02 /12/2019

Results:

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

ID	Mass /g	Uncertainty /g
U metal (EC 101)	40.4621~~0~~1	0.00008
U metal (CRM 116-A)	10.14037	0.00006
Pu metal (MP2)	1.71006	0.00007
Flask + stopper empty	786.34	0.04
Flask + stopper full	3140.18	0.04
crucible	1.34891	0.00006
IRMM-1027v solution	235~~3.85~~2.50	0.04

Observations:

The measurements were performed according to work instruction IMS-JRC.G-C1.1-WIN-0057 "WEIGHING AND MASS METROLOGY IN JRC.G.2 (NUCLEAR SAFEGUARDS TEAM)".
Balances used were Mettler Toledo AT 261DR and with inventory No. 1999 0037 27, Mettler Toledo XPE205 with inventory no 2014 01153 03, and PR 5002 with inventory No. 1997 00368 and PR 5002 with inventory No. 1997 00298 and Mettler Toledo 2kg with certification no. 39494, Mettler Toledo 1kg with certification no. 39493 and 500g Kern-G035558 with certification number G1-245.

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

Traceability:

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

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Uncertainty:

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

Additional information

The density of IRMM-1027v solution was determined to 1204 $kg{\cdot}m^{-3}$,
with an estimated uncertainty (k=2) of 5 $kg{\cdot}m^{-3}$ (copied from E3936 weighing certificate).

Rozle Jakopic
Nuclear Chemistry Laboratory responsible

Jeroen Bauwens/Kalman Toth
Analyst

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

$\gamma_{Umixture}$=($m_{UCRM116A}$*$\eta_{purityCRM116A}$+m_{UEC101}*$\eta_{purityEC101}$ + m_{UMP2})/$m_{solution1027v}$;

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

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

$m_{235Uunit1}$=$\gamma_{235Umixture}$*m1;

$m_{238Uunit1}$=$\gamma_{238Umixture}$*m1;

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

$c_{Umixture}$=$\gamma_{Umixture}$/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} = $R_{233U/238Ua}$/ΣR_{Ua};

f_{234Ua} = $R_{234U/238Ua}$/ΣR_{Ua};

f_{235Ua} = $R_{235U/238Ua}$/ΣR_{Ua};

f_{236Ua} = $R_{236U/238Ua}$/ΣR_{Ua};

f_{238Ua} = 1/ΣR_{Ua};

ΣR_{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} = $R_{233U/235Ub}$/ΣR_{Ub};

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

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

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

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

$w_{233Ub}=f_{233Ub}*M_{233U}/M_{Ub}$;
$w_{234Ub}=f_{234Ub}*M_{234U}/M_{Ub}$;
$w_{235Ub}=f_{235Ub}*M_{235U}/M_{Ub}$;
$w_{236Ub}=f_{236Ub}*M_{236U}/M_{Ub}$;
$w_{238Ub}=f_{238Ub}*M_{238U}/M_{Ub}$;

List of Quantities:

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

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

Quantity	Unit	Definition
$R_{234U/235Ub}$	mol/mol	$^{234}U/^{235}U$ amount ratio in NBL CRM 116-A
$R_{238U/235Ub}$	mol/mol	$^{238}U/^{235}U$ amount ratio in NBL CRM 116-A
$R_{236U/235Ub}$	mol/mol	$^{236}U/^{235}U$ amount ratio in NBL CRM 116-A
ΣR_{U}	mol/mol	Sum of amount ratios in gravimteric mixture, IRMM-1027v
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
$m_{solution1027v}$	g	mass of mother solution 1027v
$m_{235Uunit1}$	g	mass of ^{235}U in 1027v #1
m1	g	dispensed solution mass into 1027v #1
$m_{238Uunit1}$	g	mass of ^{238}U in 1027v #1

$\mathbf{M}_{233U}$: 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)

$\mathbf{M}_{234U}$: Type B normal distribution
Value: 234.0409504 g/mol
Expanded Uncertainty: 0.0000012 g/mol
Coverage Factor: 1

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

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

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

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

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

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

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

m_{UEC101}: Type B normal distribution
Value: 40.46210 g
Expanded Uncertainty: 0.00008 g
Coverage Factor: 2

E3935

$\eta_{purityEC101}$: 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: 10.14037 g
Expanded Uncertainty: 0.00006 g
Coverage Factor: 2

$\eta_{purityCRM116A}$: Type B t-distribution
Value: 0.99945 g/g
Standard Deviation of the Mean: =0.00014/2.4
Degrees of Freedom: 7

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 t-distribution
Value: 0.0000003863 mol/mol
Standard Deviation of the Mean: =0.0000000086/3.3
Degrees of Freedom: 3

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

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

CRM 116-A certificate

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

CRM 116-A certificate

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

CRM 116-A certificate

$n_{234.c}$: Import
Filename: U ingrowth in MP2 on 01 Nov 2019.smu
Symbol: n_{234U}Total

$n_{235.c}$: Import
Filename: U ingrowth in MP2 on 01 Nov 2019.smu
Symbol: n_{235U}Total

$n_{236.c}$: Import
Filename: U ingrowth in MP2 on 01 Nov 2019.smu
Symbol: n_{236U}Total

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

$n_{238.c}$: Import
Filename: U ingrowth in MP2 on 01 Nov 2019.smu
Symbol: n_{238U}Total

m_{UMP2}: Import
Filename: U ingrowth in MP2 on 01 Nov 2019.smu
Symbol: m_UTotal

$m_{solution1027v}$: Type B normal distribution
Value: 2352.50 g
Expanded Uncertainty: 0.04 g
Coverage Factor: 2

m1: Type B normal distribution
Value: 2.4963 g
Expanded Uncertainty: 0.0006 g
Coverage Factor: 2

Input Correlation:

	$n_{234.c}$	$n_{235.c}$	$n_{236.c}$	$n_{238.c}$	m_{UMP2}
$n_{234.c}$	1	0.1876	0.1236	0.0024	0.2257
$n_{235.c}$	0.1876	1	0.5943	0.0118	0.9949
$n_{236.c}$	0.1236	0.5943	1	0.0078	0.6665
$n_{238.c}$	0.0024	0.0118	0.0078	1	0.0119
m_{UMP2}	0.2257	0.9949	0.6665	0.0119	1

Interim Results:

Quantity	Value	Standard Uncertainty	Degrees of Freedom
f_{233U}	$72.860\cdot10^{-9}$ mol/mol	$492\cdot10^{-12}$ mol/mol	3
w_{233U}	$71.506\cdot10^{-9}$ g/g	$482\cdot10^{-12}$ g/g	3
n_{233U}	$15.524\cdot10^{-9}$ mol	$105\cdot10^{-12}$ mol	3
n_{234U}	$474.921\cdot10^{-6}$ mol	$196\cdot10^{-9}$ mol	110
n_{236U}	$381.227\cdot10^{-6}$ mol	$155\cdot10^{-9}$ mol	100
n_{238U}	0.17078907 mol	$4.31\cdot10^{-6}$ mol	110
M_{Ua}	238.02889667 g/mol	$5.58\cdot10^{-6}$ g/mol	120
f_{234Ua}	$55.077\cdot10^{-6}$ mol/mol	$109\cdot10^{-9}$ mol/mol	100
f_{235Ua}	$7.20658\cdot10^{-3}$ mol/mol	$1.77\cdot10^{-6}$ mol/mol	100
f_{236Ua}	$149.9\cdot10^{-9}$ mol/mol	$19.9\cdot10^{-9}$ mol/mol	100
f_{238Ua}	0.99273819 mol/mol	$1.78\cdot10^{-6}$ mol/mol	100
M_{Ub}	235.1857225 g/mol	$55.1\cdot10^{-6}$ g/mol	100
f_{233Ub}	$360.24\cdot10^{-9}$ mol/mol	$2.43\cdot10^{-9}$ mol/mol	3
f_{234Ub}	0.01080225 mol/mol	$4.48\cdot10^{-6}$ mol/mol	100
f_{235Ub}	0.9325468 mol/mol	$18.6\cdot10^{-6}$ mol/mol	120
f_{236Ub}	$8.83243\cdot10^{-3}$ mol/mol	$3.56\cdot10^{-6}$ mol/mol	100
f_{238Ub}	0.0478182 mol/mol	$18.2\cdot10^{-6}$ mol/mol	100
$n_{234.a}$	$9.3611\cdot10^{-6}$ mol	$18.6\cdot10^{-9}$ mol	100
$n_{235.a}$	$1.224850\cdot10^{-3}$ mol	$303\cdot10^{-9}$ mol	100
$n_{236.a}$	$25.48\cdot10^{-9}$ mol	$3.37\cdot10^{-9}$ mol	100
$n_{238.a}$	0.16872845 mol	$4.23\cdot10^{-6}$ mol	100
$n_{233.b}$	$15.524\cdot10^{-9}$ mol	$105\cdot10^{-12}$ mol	3
$n_{234.b}$	$465.498\cdot10^{-6}$ mol	$195\cdot10^{-9}$ mol	100
$n_{235.b}$	0.04018598 mol	$2.48\cdot10^{-6}$ mol	8
$n_{236.b}$	$380.613\cdot10^{-6}$ mol	$155\cdot10^{-9}$ mol	100
$n_{238.b}$	$2.060616\cdot10^{-3}$ mol	$793\cdot10^{-9}$ mol	100
ΣR_U	1.2475224 mol/mol	$16.3\cdot10^{-6}$ mol/mol	13
ΣR_{Ua}	1.00731493 mol/mol	$1.80\cdot10^{-6}$ mol/mol	100
ΣR_{Ub}	1.0723323 mol/mol	$21.4\cdot10^{-6}$ mol/mol	120
w_{234Ua}	$54.154\cdot10^{-6}$ g/g	$107\cdot10^{-9}$ g/g	100
w_{235Ua}	$7.11621\cdot10^{-3}$ g/g	$1.75\cdot10^{-6}$ g/g	100
w_{236Ua}	$148.7\cdot10^{-9}$ g/g	$19.7\cdot10^{-9}$ g/g	100
w_{238Ua}	0.99282949 g/g	$1.76\cdot10^{-6}$ g/g	100
w_{233Ub}	$356.96\cdot10^{-9}$ g/g	$2.41\cdot10^{-9}$ g/g	3
w_{234Ub}	0.01074967 g/g	$4.46\cdot10^{-6}$ g/g	100
w_{235Ub}	0.9319845 g/g	$18.8\cdot10^{-6}$ g/g	120

Quantity	Value	Standard Uncertainty	Degrees of Freedom
w_{236Ub}	$8.86472 \cdot 10^{-3}$ g/g	$3.58 \cdot 10^{-6}$ g/g	100
w_{238Ub}	0.0484007 g/g	$18.4 \cdot 10^{-6}$ g/g	100

Uncertainty Budgets:

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

Quantity	Value	Standard Uncertainty	Degrees of Freedom	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
M_{233U}	233.03963440 g/mol	$2.40\cdot10^{-6}$ g/mol	100	normal	$-26\cdot10^{-15}$	$-63\cdot10^{-21}$ mol/g	0.0 %
M_{234U}	234.04095040 g/mol	$1.20\cdot10^{-6}$ g/mol	100	normal	$-780\cdot10^{-12}$	$-940\cdot10^{-18}$ mol/g	0.0 %
M_{235U}	235.04392820 g/mol	$1.20\cdot10^{-6}$ g/mol	100	normal	$-68\cdot10^{-9}$	$-81\cdot10^{-15}$ mol/g	0.0 %
M_{236U}	236.04556620 g/mol	$1.20\cdot10^{-6}$ g/mol	100	normal	$-640\cdot10^{-12}$	$-770\cdot10^{-18}$ mol/g	0.0 %
M_{238U}	238.05078700 g/mol	$1.60\cdot10^{-6}$ g/mol	100	normal	$-5.6\cdot10^{-9}$	$-9.0\cdot10^{-15}$ mol/g	0.0 %
m_{UEC101}	40.4621000 g	$40.0\cdot10^{-6}$ g	100	normal	$13\cdot10^{-9}$	$510\cdot10^{-15}$ mol/g	0.0 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0\cdot10^{-6}$ g/g	100	normal	$520\cdot10^{-9}$	$13\cdot10^{-12}$ mol/g	0.0 %
$m_{UCRM116A}$	10.1403700 g	$30.0\cdot10^{-6}$ g	100	normal	$1.7\cdot10^{-6}$	$51\cdot10^{-12}$ mol/g	0.2 %
$\eta_{purityCRM116A}$	0.9994500 g/g	$58.3\cdot10^{-6}$ g/g	7	t-distr.	$17\cdot10^{-6}$	$1.0\cdot10^{-9}$ mol/g	86.1 %
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	100	normal	0.0	0.0 mol/g	0.0 %
$R_{234U/238Ua}$	$55.480\cdot10^{-6}$ mol/mol	$110\cdot10^{-9}$ mol/mol	100	normal	$-510\cdot10^{-9}$	$-56\cdot10^{-15}$ mol/g	0.0 %
$R_{235U/238Ua}$	$7.25930\cdot10^{-3}$ mol/mol	$1.80\cdot10^{-6}$ mol/mol	100	normal	$71\cdot10^{-6}$	$130\cdot10^{-12}$ mol/g	1.4 %
$R_{236U/238Ua}$	$151.0\cdot10^{-9}$ mol/mol	$20.0\cdot10^{-9}$ mol/mol	100	normal	$-510\cdot10^{-9}$	$-10\cdot10^{-15}$ mol/g	0.0 %
$R_{233U/235Ub}$	$386.30\cdot10^{-9}$ mol/mol	$2.61\cdot10^{-9}$ mol/mol	3	t-distr.	$-16\cdot10^{-6}$	$-41\cdot10^{-15}$ mol/g	0.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	$4.85\cdot10^{-6}$ mol/mol	100	normal	$-16\cdot10^{-6}$	$-77\cdot10^{-12}$ mol/g	0.5 %
$R_{238U/235Ub}$	0.0512770 mol/mol	$20.5\cdot10^{-6}$ mol/mol	100	normal	$-16\cdot10^{-6}$	$-330\cdot10^{-12}$ mol/g	9.5 %
$R_{236U/235Ub}$	$9.47130\cdot10^{-3}$ mol/mol	$3.85\cdot10^{-6}$ mol/mol	100	normal	$-16\cdot10^{-6}$	$-62\cdot10^{-12}$ mol/g	0.3 %
$n_{234.c}$	$61.517\cdot10^{-9}$ mol	$109\cdot10^{-12}$ mol	110		$-81\cdot10^{-6}$	$-8.9\cdot10^{-15}$ mol/g	0.0 %
$n_{235.c}$	$7.12967\cdot10^{-6}$ mol	$2.55\cdot10^{-9}$ mol	220		$340\cdot10^{-6}$	$880\cdot10^{-15}$ mol/g	0.0 %
$n_{236.c}$	$588.112\cdot10^{-9}$ mol	$320\cdot10^{-12}$ mol	250		$-82\cdot10^{-6}$	$-26\cdot10^{-15}$ mol/g	0.0 %
$n_{233.c}$	0.0 mol	0.0 mol	100	normal	0.0	0.0 mol/g	0.0 %

Quantity	Value	Standard Uncertainty	Degrees of Freedom	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$n_{238.c}$	$13.457 \cdot 10^{-12}$ mol	$128 \cdot 10^{-15}$ mol	170		$-83 \cdot 10^{-6}$	$-11 \cdot 10^{-18}$ mol/g	0.0 %
m_{UMP2}	$1.829007 \cdot 10^{-3}$ g	$653 \cdot 10^{-9}$ g	220		$350 \cdot 10^{-9}$	$230 \cdot 10^{-15}$ mol/g	0.0 %
$m_{solution1027v}$	2352.5000 g	0.0200 g	100	normal	$-7.5 \cdot 10^{-9}$	$-150 \cdot 10^{-12}$ mol/g	1.9 %
$c_{235Umixture}$	$17.60593 \cdot 10^{-6}$ mol/g	$1.07 \cdot 10^{-9}$ mol/g	9				

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

Quantity	Value	Standard Uncertainty	Degrees of Freedom	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
M_{233U}	233.03963440 g/mol	$2.40\cdot10^{-6}$ g/mol	100	normal	$-1.3\cdot10^{-15}$	$-3.2\cdot10^{-21}$ mol/g	0.0 %
M_{234U}	234.04095040 g/mol	$1.20\cdot10^{-6}$ g/mol	100	normal	$-57\cdot10^{-12}$	$-68\cdot10^{-18}$ mol/g	0.0 %
M_{235U}	235.04392820 g/mol	$1.20\cdot10^{-6}$ g/mol	100	normal	$-5.7\cdot10^{-9}$	$-6.8\cdot10^{-15}$ mol/g	0.0 %
M_{236U}	236.04556620 g/mol	$1.20\cdot10^{-6}$ g/mol	100	normal	$-34\cdot10^{-12}$	$-41\cdot10^{-18}$ mol/g	0.0 %
M_{238U}	238.05078700 g/mol	$1.60\cdot10^{-6}$ g/mol	100	normal	$-300\cdot10^{-9}$	$-480\cdot10^{-15}$ mol/g	0.0 %
m_{UEC101}	40.4621000 g	$40.0\cdot10^{-6}$ g	100	normal	$1.8\cdot10^{-6}$	$71\cdot10^{-12}$ mol/g	0.1 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0\cdot10^{-6}$ g/g	100	normal	$72\cdot10^{-6}$	$1.8\cdot10^{-9}$ mol/g	86.2 %
$m_{UCRM116A}$	10.1403700 g	$30.0\cdot10^{-6}$ g	100	normal	$86\cdot10^{-9}$	$2.6\cdot10^{-12}$ mol/g	0.0 %
$\eta_{purityCRM116A}$	0.9994500 g/g	$58.3\cdot10^{-6}$ g/g	7	t-distr.	$880\cdot10^{-9}$	$51\cdot10^{-12}$ mol/g	0.0 %
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	100	normal	0.0	0.0 mol/g	0.0 %
$R_{234U/238Ua}$	$55.480\cdot10^{-6}$ mol/mol	$110\cdot10^{-9}$ mol/mol	100	normal	$-70\cdot10^{-6}$	$-7.7\cdot10^{-12}$ mol/g	0.0 %
$R_{235U/238Ua}$	$7.25930\cdot10^{-3}$ mol/mol	$1.80\cdot10^{-6}$ mol/mol	100	normal	$-70\cdot10^{-6}$	$-130\cdot10^{-12}$ mol/g	0.4 %
$R_{236U/238Ua}$	$151.0\cdot10^{-9}$ mol/mol	$20.0\cdot10^{-9}$ mol/mol	100	normal	$-71\cdot10^{-6}$	$-1.4\cdot10^{-12}$ mol/g	0.0 %
$R_{233U/235Ub}$	$386.30\cdot10^{-9}$ mol/mol	$2.61\cdot10^{-9}$ mol/mol	3	t-distr.	$-810\cdot10^{-9}$	$-2.1\cdot10^{-15}$ mol/g	0.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	$4.85\cdot10^{-6}$ mol/mol	100	normal	$-810\cdot10^{-9}$	$-3.9\cdot10^{-12}$ mol/g	0.0 %
$R_{238U/235Ub}$	0.0512770 mol/mol	$20.5\cdot10^{-6}$ mol/mol	100	normal	$16\cdot10^{-6}$	$330\cdot10^{-12}$ mol/g	3.0 %
$R_{236U/235Ub}$	$9.47130\cdot10^{-3}$ mol/mol	$3.85\cdot10^{-6}$ mol/mol	100	normal	$-820\cdot10^{-9}$	$-3.2\cdot10^{-12}$ mol/g	0.0 %
$n_{234.c}$	$61.517\cdot10^{-9}$ mol	$109\cdot10^{-12}$ mol	110		$-340\cdot10^{-6}$	$-37\cdot10^{-15}$ mol/g	0.0 %
$n_{235.c}$	$7.12967\cdot10^{-6}$ mol	$2.55\cdot10^{-9}$ mol	220		$-340\cdot10^{-6}$	$-860\cdot10^{-15}$ mol/g	0.0 %
$n_{236.c}$	$588.112\cdot10^{-9}$ mol	$320\cdot10^{-12}$ mol	250		$-340\cdot10^{-6}$	$-110\cdot10^{-15}$ mol/g	0.0 %
$n_{233.c}$	0.0 mol	0.0 mol	100	normal	0.0	0.0 mol/g	0.0 %
$n_{238.c}$	$13.457\cdot10^{-12}$ mol	$128\cdot10^{-15}$ mol	170		$83\cdot10^{-6}$	$11\cdot10^{-18}$ mol/g	0.0 %

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Quantity	Value	Standard Uncertainty	Degrees of Freedom	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
m_{UMP2}	$1.829007 \cdot 10^{-3}$ g	$653 \cdot 10^{-9}$ g	220		$1.4 \cdot 10^{-6}$	$940 \cdot 10^{-15}$ mol/g	0.0 %
$m_{solution1027v}$	2352.5000 g	0.0200 g	100	normal	$-31 \cdot 10^{-9}$	$-620 \cdot 10^{-12}$ mol/g	10.2 %
$c_{238Umixture}$	$72.59897 \cdot 10^{-6}$ mol/g	$1.93 \cdot 10^{-9}$ mol/g	130				

$R_{233U/238U}$: $^{233}U/^{238}U$ **amount ratio in IRMM-1027v**

Quantity	Value	Standard Uncertainty	Degrees of Freedom	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
M_{233U}	233.03963440 g/mol	$2.40\cdot10^{-6}$ g/mol	100	normal	$-140\cdot10^{-18}$	$-330\cdot10^{-24}$ mol/mol	0.0 %
M_{234U}	234.04095040 g/mol	$1.20\cdot10^{-6}$ g/mol	100	normal	$-4.1\cdot10^{-12}$	$-4.9\cdot10^{-18}$ mol/mol	0.0 %
M_{235U}	235.04392820 g/mol	$1.20\cdot10^{-6}$ g/mol	100	normal	$-350\cdot10^{-12}$	$-420\cdot10^{-18}$ mol/mol	0.0 %
M_{236U}	236.04556620 g/mol	$1.20\cdot10^{-6}$ g/mol	100	normal	$-3.4\cdot10^{-12}$	$-4.0\cdot10^{-18}$ mol/mol	0.0 %
M_{238U}	238.05078700 g/mol	$1.60\cdot10^{-6}$ g/mol	100	normal	$360\cdot10^{-12}$	$570\cdot10^{-18}$ mol/mol	0.0 %
m_{UEC101}	40.4621000 g	$40.0\cdot10^{-6}$ g	100	normal	$-2.2\cdot10^{-9}$	$-89\cdot10^{-15}$ mol/mol	0.0 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0\cdot10^{-6}$ g/g	100	normal	$-90\cdot10^{-9}$	$-2.2\cdot10^{-12}$ mol/mol	0.0 %
$m_{UCRM116A}$	10.1403700 g	$30.0\cdot10^{-6}$ g	100	normal	$8.9\cdot10^{-9}$	$270\cdot10^{-15}$ mol/mol	0.0 %
$\eta_{purityCRM116A}$	0.9994500 g/g	$58.3\cdot10^{-6}$ g/g	7	t-distr.	$90\cdot10^{-9}$	$5.2\cdot10^{-12}$ mol/mol	0.0 %
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	100	normal	0.0	0.0 mol/mol	0.0 %
$R_{234U/238Ua}$	$55.480\cdot10^{-6}$ mol/mol	$110\cdot10^{-9}$ mol/mol	100	normal	$88\cdot10^{-9}$	$9.6\cdot10^{-15}$ mol/mol	0.0 %
$R_{235U/238Ua}$	$7.25930\cdot10^{-3}$ mol/mol	$1.80\cdot10^{-6}$ mol/mol	100	normal	$88\cdot10^{-9}$	$160\cdot10^{-15}$ mol/mol	0.0 %
$R_{236U/238Ua}$	$151.0\cdot10^{-9}$ mol/mol	$20.0\cdot10^{-9}$ mol/mol	100	normal	$88\cdot10^{-9}$	$1.8\cdot10^{-15}$ mol/mol	0.0 %
$R_{233U/235Ub}$	$386.30\cdot10^{-9}$ mol/mol	$2.61\cdot10^{-9}$ mol/mol	3	t-distr.	0.24	$610\cdot10^{-12}$ mol/mol	100.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	$4.85\cdot10^{-6}$ mol/mol	100	normal	$-83\cdot10^{-9}$	$-400\cdot10^{-15}$ mol/mol	0.0 %
$R_{238U/235Ub}$	0.0512770 mol/mol	$20.5\cdot10^{-6}$ mol/mol	100	normal	$-110\cdot10^{-9}$	$-2.2\cdot10^{-12}$ mol/mol	0.0 %
$R_{236U/235Ub}$	$9.47130\cdot10^{-3}$ mol/mol	$3.85\cdot10^{-6}$ mol/mol	100	normal	$-84\cdot10^{-9}$	$-320\cdot10^{-15}$ mol/mol	0.0 %
$n_{233.c}$	0.0 mol	0.0 mol	100	normal	0.0	0.0 mol/mol	0.0 %
$n_{238.c}$	$13.457\cdot10^{-12}$ mol	$128\cdot10^{-15}$ mol	170		$-530\cdot10^{-9}$	$-68\cdot10^{-21}$ mol/mol	0.0 %
$R_{233U/238U}$	$90.895\cdot10^{-9}$ mol/mol	$613\cdot10^{-12}$ mol/mol	3				

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

Quantity	Value	Standard Uncertainty	Degrees of Freedom	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
M_{233U}	233.03963440 g/mol	$2.40\cdot10^{-6}$ g/mol	100	normal	$-4.1\cdot10^{-12}$	$-9.9\cdot10^{-18}$ mol/mol	0.0 %
M_{234U}	234.04095040 g/mol	$1.20\cdot10^{-6}$ g/mol	100	normal	$-120\cdot10^{-9}$	$-150\cdot10^{-15}$ mol/mol	0.0 %
M_{235U}	235.04392820 g/mol	$1.20\cdot10^{-6}$ g/mol	100	normal	$-11\cdot10^{-6}$	$-13\cdot10^{-12}$ mol/mol	0.0 %
M_{236U}	236.04556620 g/mol	$1.20\cdot10^{-6}$ g/mol	100	normal	$-100\cdot10^{-9}$	$-120\cdot10^{-15}$ mol/mol	0.0 %
M_{238U}	238.05078700 g/mol	$1.60\cdot10^{-6}$ g/mol	100	normal	$11\cdot10^{-6}$	$17\cdot10^{-12}$ mol/mol	0.0 %
m_{UEC101}	40.4621000 g	$40.0\cdot10^{-6}$ g	100	normal	$-67\cdot10^{-6}$	$-2.7\cdot10^{-9}$ mol/mol	0.0 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0\cdot10^{-6}$ g/g	100	normal	$-2.7\cdot10^{-3}$	$-67\cdot10^{-9}$ mol/mol	0.3 %
$m_{UCRM116A}$	10.1403700 g	$30.0\cdot10^{-6}$ g	100	normal	$270\cdot10^{-6}$	$8.0\cdot10^{-9}$ mol/mol	0.0 %
$\eta_{purityCRM116A}$	0.9994500 g/g	$58.3\cdot10^{-6}$ g/g	7	t-distr.	$2.7\cdot10^{-3}$	$160\cdot10^{-9}$ mol/mol	1.9 %
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	100	normal	0.0	0.0 mol/mol	0.0 %
$R_{234U/238Ua}$	$55.480\cdot10^{-6}$ mol/mol	$110\cdot10^{-9}$ mol/mol	100	normal	0.99	$110\cdot10^{-9}$ mol/mol	0.9 %
$R_{235U/238Ua}$	$7.25930\cdot10^{-3}$ mol/mol	$1.80\cdot10^{-6}$ mol/mol	100	normal	$2.6\cdot10^{-3}$	$4.8\cdot10^{-9}$ mol/mol	0.0 %
$R_{236U/238Ua}$	$151.0\cdot10^{-9}$ mol/mol	$20.0\cdot10^{-9}$ mol/mol	100	normal	$2.7\cdot10^{-3}$	$53\cdot10^{-12}$ mol/mol	0.0 %
$R_{233U/235Ub}$	$386.30\cdot10^{-9}$ mol/mol	$2.61\cdot10^{-9}$ mol/mol	3	t-distr.	$-2.5\cdot10^{-3}$	$-6.5\cdot10^{-12}$ mol/mol	0.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	$4.85\cdot10^{-6}$ mol/mol	100	normal	0.23	$1.1\cdot10^{-6}$ mol/mol	96.5 %
$R_{238U/235Ub}$	0.0512770 mol/mol	$20.5\cdot10^{-6}$ mol/mol	100	normal	$-3.2\cdot10^{-3}$	$-66\cdot10^{-9}$ mol/mol	0.3 %
$R_{236U/235Ub}$	$9.47130\cdot10^{-3}$ mol/mol	$3.85\cdot10^{-6}$ mol/mol	100	normal	$-2.5\cdot10^{-3}$	$-9.7\cdot10^{-9}$ mol/mol	0.0 %
$n_{234.c}$	$61.517\cdot10^{-9}$ mol	$109\cdot10^{-12}$ mol	110		5.9	$640\cdot10^{-12}$ mol/mol	0.0 %
$n_{238.c}$	$13.457\cdot10^{-12}$ mol	$128\cdot10^{-15}$ mol	170		-0.016	$-2.1\cdot10^{-15}$ mol/mol	0.0 %
$R_{234U/238U}$	$2.78075\cdot10^{-3}$ mol/mol	$1.15\cdot10^{-6}$ mol/mol	110				

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

Quantity	Value	Standard Uncertainty	Degrees of Freedom	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
M_{233U}	233.03963440 g/mol	$2.40\cdot10^{-6}$ g/mol	100	normal	$-360\cdot10^{-12}$	$-850\cdot10^{-18}$ mol/mol	0.0 %
M_{234U}	234.04095040 g/mol	$1.20\cdot10^{-6}$ g/mol	100	normal	$-11\cdot10^{-6}$	$-13\cdot10^{-12}$ mol/mol	0.0 %
M_{235U}	235.04392820 g/mol	$1.20\cdot10^{-6}$ g/mol	100	normal	$-910\cdot10^{-6}$	$-1.1\cdot10^{-9}$ mol/mol	0.0 %
M_{236U}	236.04556620 g/mol	$1.20\cdot10^{-6}$ g/mol	100	normal	$-8.7\cdot10^{-6}$	$-10\cdot10^{-12}$ mol/mol	0.0 %
M_{238U}	238.05078700 g/mol	$1.60\cdot10^{-6}$ g/mol	100	normal	$920\cdot10^{-6}$	$1.5\cdot10^{-9}$ mol/mol	0.0 %
m_{UEC101}	40.4621000 g	$40.0\cdot10^{-6}$ g	100	normal	$-5.7\cdot10^{-3}$	$-230\cdot10^{-9}$ mol/mol	0.0 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0\cdot10^{-6}$ g/g	100	normal	-0.23	$-5.8\cdot10^{-6}$ mol/mol	13.1 %
$m_{UCRM116A}$	10.1403700 g	$30.0\cdot10^{-6}$ g	100	normal	0.023	$690\cdot10^{-9}$ mol/mol	0.2 %
$\eta_{purityCRM116A}$	0.9994500 g/g	$58.3\cdot10^{-6}$ g/g	7	t-distr.	0.23	$14\cdot10^{-6}$ mol/mol	71.6 %
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	100	normal	0.0	0.0 mol/mol	0.0 %
$R_{234U/238Ua}$	$55.480\cdot10^{-6}$ mol/mol	$110\cdot10^{-9}$ mol/mol	100	normal	0.23	$25\cdot10^{-9}$ mol/mol	0.0 %
$R_{235U/238Ua}$	$7.25930\cdot10^{-3}$ mol/mol	$1.80\cdot10^{-6}$ mol/mol	100	normal	1.2	$2.2\cdot10^{-6}$ mol/mol	1.9 %
$R_{236U/238Ua}$	$151.0\cdot10^{-9}$ mol/mol	$20.0\cdot10^{-9}$ mol/mol	100	normal	0.23	$4.6\cdot10^{-9}$ mol/mol	0.0 %
$R_{233U/235Ub}$	$386.30\cdot10^{-9}$ mol/mol	$2.61\cdot10^{-9}$ mol/mol	3	t-distr.	-0.21	$-560\cdot10^{-12}$ mol/mol	0.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	$4.85\cdot10^{-6}$ mol/mol	100	normal	-0.22	$-1.0\cdot10^{-6}$ mol/mol	0.4 %
$R_{238U/235Ub}$	0.0512770 mol/mol	$20.5\cdot10^{-6}$ mol/mol	100	normal	-0.28	$-5.7\cdot10^{-6}$ mol/mol	12.5 %
$R_{236U/235Ub}$	$9.47130\cdot10^{-3}$ mol/mol	$3.85\cdot10^{-6}$ mol/mol	100	normal	-0.22	$-840\cdot10^{-9}$ mol/mol	0.3 %
$n_{235.c}$	$7.12967\cdot10^{-6}$ mol	$2.55\cdot10^{-9}$ mol	220		5.9	$15\cdot10^{-9}$ mol/mol	0.0 %
$n_{238.c}$	$13.457\cdot10^{-12}$ mol	$128\cdot10^{-15}$ mol	170		-1.4	$-180\cdot10^{-15}$ mol/mol	0.0 %
$R_{235U/238U}$	0.2425094 mol/mol	$16.0\cdot10^{-6}$ mol/mol	13				

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

Quantity	Value	Standard Uncertainty	Degrees of Freedom	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
M_{233U}	233.03963440 g/mol	$2.40\cdot10^{-6}$ g/mol	100	normal	$-3.4\cdot10^{-12}$	$-8.1\cdot10^{-18}$ mol/mol	0.0 %
M_{234U}	234.04095040 g/mol	$1.20\cdot10^{-6}$ g/mol	100	normal	$-100\cdot10^{-9}$	$-120\cdot10^{-15}$ mol/mol	0.0 %
M_{235U}	235.04392820 g/mol	$1.20\cdot10^{-6}$ g/mol	100	normal	$-8.7\cdot10^{-6}$	$-10\cdot10^{-12}$ mol/mol	0.0 %
M_{236U}	236.04556620 g/mol	$1.20\cdot10^{-6}$ g/mol	100	normal	$-83\cdot10^{-9}$	$-99\cdot10^{-15}$ mol/mol	0.0 %
M_{238U}	238.05078700 g/mol	$1.60\cdot10^{-6}$ g/mol	100	normal	$8.7\cdot10^{-6}$	$14\cdot10^{-12}$ mol/mol	0.0 %
m_{UEC101}	40.4621000 g	$40.0\cdot10^{-6}$ g	100	normal	$-54\cdot10^{-6}$	$-2.2\cdot10^{-9}$ mol/mol	0.0 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0\cdot10^{-6}$ g/g	100	normal	$-2.2\cdot10^{-3}$	$-55\cdot10^{-9}$ mol/mol	0.4 %
$m_{UCRM116A}$	10.1403700 g	$30.0\cdot10^{-6}$ g	100	normal	$220\cdot10^{-6}$	$6.5\cdot10^{-9}$ mol/mol	0.0 %
$\eta_{purityCRM116A}$	0.9994500 g/g	$58.3\cdot10^{-6}$ g/g	7	t-distr.	$2.2\cdot10^{-3}$	$130\cdot10^{-9}$ mol/mol	2.0 %
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	100	normal	0.0	0.0 mol/mol	0.0 %
$R_{234U/238Ua}$	$55.480\cdot10^{-6}$ mol/mol	$110\cdot10^{-9}$ mol/mol	100	normal	$2.2\cdot10^{-3}$	$240\cdot10^{-12}$ mol/mol	0.0 %
$R_{235U/238Ua}$	$7.25930\cdot10^{-3}$ mol/mol	$1.80\cdot10^{-6}$ mol/mol	100	normal	$2.2\cdot10^{-3}$	$3.9\cdot10^{-9}$ mol/mol	0.0 %
$R_{236U/238Ua}$	$151.0\cdot10^{-9}$ mol/mol	$20.0\cdot10^{-9}$ mol/mol	100	normal	0.99	$20\cdot10^{-9}$ mol/mol	0.0 %
$R_{233U/235Ub}$	$386.30\cdot10^{-9}$ mol/mol	$2.61\cdot10^{-9}$ mol/mol	3	t-distr.	$-2.0\cdot10^{-3}$	$-5.3\cdot10^{-12}$ mol/mol	0.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	$4.85\cdot10^{-6}$ mol/mol	100	normal	$-2.0\cdot10^{-3}$	$-9.9\cdot10^{-9}$ mol/mol	0.0 %
$R_{238U/235Ub}$	0.0512770 mol/mol	$20.5\cdot10^{-6}$ mol/mol	100	normal	$-2.6\cdot10^{-3}$	$-53\cdot10^{-9}$ mol/mol	0.3 %
$R_{236U/235Ub}$	$9.47130\cdot10^{-3}$ mol/mol	$3.85\cdot10^{-6}$ mol/mol	100	normal	0.23	$900\cdot10^{-9}$ mol/mol	97.2 %
$n_{236.c}$	$588.112\cdot10^{-9}$ mol	$320\cdot10^{-12}$ mol	250		5.9	$1.9\cdot10^{-9}$ mol/mol	0.0 %
$n_{238.c}$	$13.457\cdot10^{-12}$ mol	$128\cdot10^{-15}$ mol	170		-0.013	$-1.7\cdot10^{-15}$ mol/mol	0.0 %
$R_{236U/238U}$	$2.232151\cdot10^{-3}$ mol/mol	$911\cdot10^{-9}$ mol/mol	110				

f_{235U}: ^{235}**U amount fraction in IRMM-1027v**

Quantity	Value	Standard Uncertainty	Degrees of Freedom	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
M_{233U}	233.03963440 g/mol	$2.40\cdot10^{-6}$ g/mol	100	normal	$-230\cdot10^{-12}$	$-550\cdot10^{-18}$ mol/mol	0.0 %
M_{234U}	234.04095040 g/mol	$1.20\cdot10^{-6}$ g/mol	100	normal	$-6.8\cdot10^{-6}$	$-8.2\cdot10^{-12}$ mol/mol	0.0 %
M_{235U}	235.04392820 g/mol	$1.20\cdot10^{-6}$ g/mol	100	normal	$-590\cdot10^{-6}$	$-700\cdot10^{-12}$ mol/mol	0.0 %
M_{236U}	236.04556620 g/mol	$1.20\cdot10^{-6}$ g/mol	100	normal	$-5.6\cdot10^{-6}$	$-6.7\cdot10^{-12}$ mol/mol	0.0 %
M_{238U}	238.05078700 g/mol	$1.60\cdot10^{-6}$ g/mol	100	normal	$590\cdot10^{-6}$	$950\cdot10^{-12}$ mol/mol	0.0 %
m_{UEC101}	40.4621000 g	$40.0\cdot10^{-6}$ g	100	normal	$-3.7\cdot10^{-3}$	$-150\cdot10^{-9}$ mol/mol	0.0 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0\cdot10^{-6}$ g/g	100	normal	-0.15	$-3.7\cdot10^{-6}$ mol/mol	13.1 %
$m_{UCRM116A}$	10.1403700 g	$30.0\cdot10^{-6}$ g	100	normal	0.015	$440\cdot10^{-9}$ mol/mol	0.2 %
$\eta_{purityCRM116A}$	0.9994500 g/g	$58.3\cdot10^{-6}$ g/g	7	t-distr.	0.15	$8.7\cdot10^{-6}$ mol/mol	71.3 %
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	100	normal	0.0	0.0 mol/mol	0.0 %
$R_{234U/238Ua}$	$55.480\cdot10^{-6}$ mol/mol	$110\cdot10^{-9}$ mol/mol	100	normal	$-8.2\cdot10^{-3}$	$-900\cdot10^{-12}$ mol/mol	0.0 %
$R_{235U/238Ua}$	$7.25930\cdot10^{-3}$ mol/mol	$1.80\cdot10^{-6}$ mol/mol	100	normal	0.78	$1.4\cdot10^{-6}$ mol/mol	1.9 %
$R_{236U/238Ua}$	$151.0\cdot10^{-9}$ mol/mol	$20.0\cdot10^{-9}$ mol/mol	100	normal	$-6.9\cdot10^{-3}$	$-140\cdot10^{-12}$ mol/mol	0.0 %
$R_{233U/235Ub}$	$386.30\cdot10^{-9}$ mol/mol	$2.61\cdot10^{-9}$ mol/mol	3	t-distr.	-0.17	$-460\cdot10^{-12}$ mol/mol	0.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	$4.85\cdot10^{-6}$ mol/mol	100	normal	-0.18	$-850\cdot10^{-9}$ mol/mol	0.7 %
$R_{238U/235Ub}$	0.0512770 mol/mol	$20.5\cdot10^{-6}$ mol/mol	100	normal	-0.18	$-3.6\cdot10^{-6}$ mol/mol	12.4 %
$R_{236U/235Ub}$	$9.47130\cdot10^{-3}$ mol/mol	$3.85\cdot10^{-6}$ mol/mol	100	normal	-0.18	$-680\cdot10^{-9}$ mol/mol	0.4 %
$n_{234.c}$	$61.517\cdot10^{-9}$ mol	$109\cdot10^{-12}$ mol	110		-0.91	$-99\cdot10^{-12}$ mol/mol	0.0 %
$n_{235.c}$	$7.12967\cdot10^{-6}$ mol	$2.55\cdot10^{-9}$ mol	220		3.8	$9.7\cdot10^{-9}$ mol/mol	0.0 %
$n_{236.c}$	$588.112\cdot10^{-9}$ mol	$320\cdot10^{-12}$ mol	250		-0.91	$-290\cdot10^{-12}$ mol/mol	0.0 %
$n_{233.c}$	0.0 mol	0.0 mol	100	normal	0.0	0.0 mol/mol	0.0 %
$n_{238.c}$	$13.457\cdot10^{-12}$ mol	$128\cdot10^{-15}$ mol	170		-0.91	$-120\cdot10^{-15}$ mol/mol	0.0 %

Quantity	Value	Standard Uncertainty	Degrees of Freedom
f_{235U}	0.1943928 mol/mol	$10.3 \cdot 10^{-6}$ mol/mol	13

f_{238U}: ^{238}**U amount fraction in IRMM-1027v**

Quantity	Value	Standard Uncertainty	Degrees of Freedom	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
M_{233U}	233.03963440 g/mol	$2.40 \cdot 10^{-6}$ g/mol	100	normal	$230 \cdot 10^{-12}$	$560 \cdot 10^{-18}$ mol/mol	0.0 %
M_{234U}	234.04095040 g/mol	$1.20 \cdot 10^{-6}$ g/mol	100	normal	$7.0 \cdot 10^{-6}$	$8.4 \cdot 10^{-12}$ mol/mol	0.0 %
M_{235U}	235.04392820 g/mol	$1.20 \cdot 10^{-6}$ g/mol	100	normal	$600 \cdot 10^{-6}$	$720 \cdot 10^{-12}$ mol/mol	0.0 %
M_{236U}	236.04556620 g/mol	$1.20 \cdot 10^{-6}$ g/mol	100	normal	$5.7 \cdot 10^{-6}$	$6.9 \cdot 10^{-12}$ mol/mol	0.0 %
M_{238U}	238.05078700 g/mol	$1.60 \cdot 10^{-6}$ g/mol	100	normal	$-600 \cdot 10^{-6}$	$-970 \cdot 10^{-12}$ mol/mol	0.0 %
m_{UEC101}	40.4621000 g	$40.0 \cdot 10^{-6}$ g	100	normal	$3.8 \cdot 10^{-3}$	$150 \cdot 10^{-9}$ mol/mol	0.0 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0 \cdot 10^{-6}$ g/g	100	normal	0.15	$3.8 \cdot 10^{-6}$ mol/mol	13.2 %
$m_{UCRM116A}$	10.1403700 g	$30.0 \cdot 10^{-6}$ g	100	normal	-0.015	$-450 \cdot 10^{-9}$ mol/mol	0.2 %
$\eta_{purityCRM116A}$	0.9994500 g/g	$58.3 \cdot 10^{-6}$ g/g	7	t-distr.	-0.15	$-8.9 \cdot 10^{-6}$ mol/mol	72.1 %
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	100	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	100	normal	-0.78	$-86 \cdot 10^{-9}$ mol/mol	0.0 %
$R_{235U/238Ua}$	$7.25930 \cdot 10^{-3}$ mol/mol	$1.80 \cdot 10^{-6}$ mol/mol	100	normal	-0.78	$-1.4 \cdot 10^{-6}$ mol/mol	1.8 %
$R_{236U/238Ua}$	$151.0 \cdot 10^{-9}$ mol/mol	$20.0 \cdot 10^{-9}$ mol/mol	100	normal	-0.78	$-16 \cdot 10^{-9}$ mol/mol	0.0 %
$R_{233U/235Ub}$	$386.30 \cdot 10^{-9}$ mol/mol	$2.61 \cdot 10^{-9}$ mol/mol	3	t-distr.	-0.010	$-27 \cdot 10^{-12}$ mol/mol	0.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	$4.85 \cdot 10^{-6}$ mol/mol	100	normal	$-9.7 \cdot 10^{-3}$	$-47 \cdot 10^{-9}$ mol/mol	0.0 %
$R_{238U/235Ub}$	0.0512770 mol/mol	$20.5 \cdot 10^{-6}$ mol/mol	100	normal	0.18	$3.7 \cdot 10^{-6}$ mol/mol	12.6 %
$R_{236U/235Ub}$	$9.47130 \cdot 10^{-3}$ mol/mol	$3.85 \cdot 10^{-6}$ mol/mol	100	normal	$-8.5 \cdot 10^{-3}$	$-33 \cdot 10^{-9}$ mol/mol	0.0 %
$n_{234.c}$	$61.517 \cdot 10^{-9}$ mol	$109 \cdot 10^{-12}$ mol	110		-3.8	$-410 \cdot 10^{-12}$ mol/mol	0.0 %
$n_{235.c}$	$7.12967 \cdot 10^{-6}$ mol	$2.55 \cdot 10^{-9}$ mol	220		-3.8	$-9.6 \cdot 10^{-9}$ mol/mol	0.0 %
$n_{236.c}$	$588.112 \cdot 10^{-9}$ mol	$320 \cdot 10^{-12}$ mol	250		-3.8	$-1.2 \cdot 10^{-9}$ mol/mol	0.0 %
$n_{233.c}$	0.0 mol	0.0 mol	100	normal	0.0	0.0 mol/mol	0.0 %
$n_{238.c}$	$13.457 \cdot 10^{-12}$ mol	$128 \cdot 10^{-15}$ mol	170		0.93	$120 \cdot 10^{-15}$ mol/mol	0.0 %

Quantity	Value	Standard Uncertainty	Degrees of Freedom
f_{238U}	0.8015888 mol/mol	$10.5 \cdot 10^{-6}$ mol/mol	13

Results:

Quantity	Value	Expanded Uncertainty	Coverage factor	Coverage
$\gamma_{Umixture}$	0.0215059 g/g	$1.1 \cdot 10^{-6}$ g/g	2.03	95% (t-table 95.45%)
$\gamma_{235Umixture}$	$4.13817 \cdot 10^{-3}$ g/g	$590 \cdot 10^{-9}$ g/g	2.32	95% (t-table 95.45%)
$\gamma_{238Umixture}$	0.01728224 g/g	$920 \cdot 10^{-9}$ g/g	2.00	95% (t-table 95.45%)
$c_{Umixture}$	$90.5688 \cdot 10^{-6}$ mol/g	$4.5 \cdot 10^{-9}$ mol/g	2.03	95% (t-table 95.45%)
$c_{235Umixture}$	$17.6059 \cdot 10^{-6}$ mol/g	$2.5 \cdot 10^{-9}$ mol/g	2.32	95% (t-table 95.45%)
$c_{238Umixture}$	$72.5990 \cdot 10^{-6}$ mol/g	$3.9 \cdot 10^{-9}$ mol/g	2.00	95% (t-table 95.45%)
M_U	237.453749 g/mol	$70 \cdot 10^{-6}$ g/mol	2.21	95% (t-table 95.45%)
$R_{233U/238U}$	$90.9 \cdot 10^{-9}$ mol/mol	$2.0 \cdot 10^{-9}$ mol/mol	3.31	95% (t-table 95.45%)
$R_{234U/238U}$	$2.7807 \cdot 10^{-3}$ mol/mol	$2.3 \cdot 10^{-6}$ mol/mol	2.00	95% (t-table 95.45%)
$R_{235U/238U}$	0.242509 mol/mol	$35 \cdot 10^{-6}$ mol/mol	2.21	95% (t-table 95.45%)
$R_{236U/238U}$	$2.2322 \cdot 10^{-3}$ mol/mol	$1.8 \cdot 10^{-6}$ mol/mol	2.00	95% (t-table 95.45%)
f_{234U}	$2.2290 \cdot 10^{-3}$ mol/mol	$1.8 \cdot 10^{-6}$ mol/mol	2.00	95% (t-table 95.45%)
f_{235U}	0.194393 mol/mol	$23 \cdot 10^{-6}$ mol/mol	2.21	95% (t-table 95.45%)
f_{236U}	$1.7893 \cdot 10^{-3}$ mol/mol	$1.5 \cdot 10^{-6}$ mol/mol	2.00	95% (t-table 95.45%)
f_{238U}	0.801589 mol/mol	$23 \cdot 10^{-6}$ mol/mol	2.21	95% (t-table 95.45%)
w_{234U}	$2.1970 \cdot 10^{-3}$ g/g	$1.8 \cdot 10^{-6}$ g/g	2.00	95% (t-table 95.45%)
w_{235U}	0.192420 g/g	$23 \cdot 10^{-6}$ g/g	2.21	95% (t-table 95.45%)
w_{236U}	$1.7787 \cdot 10^{-3}$ g/g	$1.4 \cdot 10^{-6}$ g/g	2.00	95% (t-table 95.45%)
w_{238U}	0.803604 g/g	$23 \cdot 10^{-6}$ g/g	2.21	95% (t-table 95.45%)
n_{235U}	0.0414180 mol	$5.8 \cdot 10^{-6}$ mol	2.32	95% (t-table 95.45%)
$m_{235Uunit1}$	0.0103301 g	$2.8 \cdot 10^{-6}$ g	2.03	95% (t-table 95.45%)
$m_{238Uunit1}$	0.043142 g	$11 \cdot 10^{-6}$ g	2.00	95% (t-table 95.45%)

Plutonium gravimetric mixture of IRMM-1027v normalised to reference date 01 Nov 2019

Author: Kalman Toth

The plutonium gravimetric mixture was prepared by dissolving plutonium MP2 metal (CEA/CETAMA) in 20 mL 6M hydrochloric acid and in 2+6+8 M nitric acid. Before the dissolution the MP2 metals were electropolished. The dissolution of the metals were done directly in the big flask of the mother soltution.

Input parameters:

1) Mass of plutonium metal and the nitrate solution (E3935) 2) Purity of plutonium metal (MP2 metal certificate) 3) Plutonium isotope amount ratios (IRMM certificate, issued 11 April 2007, date of measurment completed: 7 November 2006) 4) The atomic masses according Wang et al. (The AME 2016 atomic mass evaluation (II). Tables, Graphs and References, Chinese Physics C, Vol. 41, No. 3, 2017). 5) Purity of MP2 metal on 01 Nov 2019 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 01 Nov 2019 (1027v reference date)

No weighing was done before the dispensing thus no evaporation correction was taking into account on the stock solution (the dispensing strted the same day when the weighing was done).

Date of MP2 dissolution:

MP2 unit numbers:

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-1027v, 01 Nov 2019}

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

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

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

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

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

Generated with GUM Workbench Pro Version 2.4.1.458

{Decayed and normalised isotope amount fractions in gravimetric mixture, IRMM-1027v, 01 Nov 2019}

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

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

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

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

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

{Decayed molar mass of plutonium in gravimetric mixtures, IRMM-1027v, 01 Nov 2019}

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

{Decayed and normalised isotope mass fractios in gravimetric mixture, IRMM-1027v, 01 Nov 2019}

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

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

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

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

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

{Decayed amount ratios for purity calculation, 01 Nov 2019}

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

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

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

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

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

{Decayed isotope masses for purity calculation, 01 Nov 2019}

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

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

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

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

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

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

$\eta_{PuMP2Nov2019}=\eta_{PuMP2Jan2007}*\Sigma md_{Pu}/m_{Pu};$

{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-1027v, 01 Nov 2019}

$\gamma_{Pumixture}$=(m_{PuMP2}*$\eta_{PuMP2Nov2019}$)/$m_{solution1027v}$;

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

$m_{239Puunit1}$=$\gamma_{Pumixture239}$*m1;

{Plutonium amount content in gravimetric mixture, IRMM-1027v, 01 Nov 2019}

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

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

List of Quantities:

Quantity	Unit	Definition
$\gamma_{Pumixture}$	g/g	Pu mass fraction in IRMM-1027v
$\gamma_{Pumixture239}$	g/g	^{239}Pu mass fraction in IRMM-1027v
$c_{Pumixture239}$	mol/g	^{239}Pu amount content in IRMM-1027v
$c_{Pumixture}$	mol/g	Pu amount content in IRMM-1027v
$Rd_{238Pu/239Pu}$	mol/mol	decayed ^{238}Pu/^{239}Pu amount ratio in IRMM-1027v, 01 Nov 2019
$Rd_{240Pu/239Pu}$	mol/mol	decayed ^{240}Pu/^{239}Pu amount ratio in IRMM-1027v, 01 Nov 2019
$Rd_{241Pu/239Pu}$	mol/mol	decayed ^{241}Pu/^{239}Pu amount ratio in IRMM-1027v, 01 Nov 2019
$Rd_{242Pu/239Pu}$	mol/mol	decayed ^{242}Pu/^{239}Pu amount ratio in IRMM-1027v, 01 Nov 2019
$R_{238Pu/239Pu}$	mol/mol	^{238}Pu/^{239}Pu amount ratio in MP2, 1 Jan 2007
Δt	a	time difference between certification date MP2 (1 Jan 2007) and the reference date, 01 Nov 2019
$R_{240Pu/239Pu}$	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

Quantity	Unit	Definition
M_{242Pu}	g/mol	Atomic mass of ^{242}Pu
ΣRd_{Pu}	mol/mol	Sum of decayed amount ratios in gravimetric mixture, IRMM-1027v, 01 Nov 2019
$fdnorm_{238Pu}$	mol/mol	Decayed and normalised ^{238}Pu amount fraction in gravimetric mixture, IRMM-1027v, 01 Nov 2019
$fdnorm_{239Pu}$	mol/mol	Decayed and normalised ^{239}Pu amount fraction in gravimetric mixture, IRMM-1027v, 01 Nov 2019
$fdnorm_{240Pu}$	mol/mol	Decayed and normalised ^{240}Pu amount fraction in gravimetric mixture, IRMM-1027v, 01 Nov 2019
$fdnorm_{241Pu}$	mol/mol	Decayed and normalised ^{241}Pu amount fraction in gravimetric mixture, IRMM-1027v, 01 Nov 2019
$fdnorm_{242Pu}$	mol/mol	Decayed and normalised ^{242}Pu amount fraction in gravimetric mixture, IRMM-1027v, 01 Nov 2019
Md_{Pu}	g/mol	Decayed molar mass of Pu in gravimetric mixture, IRMM-1027v, 01 Nov 2019
$wdnorm_{238Pu}$	g/g	Decayed and normalised ^{238}Pu mass fraction in gravimetric mixture, IRMM-1027v, 01 Nov 2019
$wdnorm_{239Pu}$	g/g	Decayed and normalised ^{239}Pu mass fraction in gravimetric mixture, IRMM-1027v, 01 Nov 2019
$wdnorm_{240Pu}$	g/g	Decayed and normalised ^{240}Pu mass fraction in gravimetric mixture, IRMM-1027v, 01 Nov 2019
$wdnorm_{241Pu}$	g/g	Decayed and normalised ^{241}Pu mass fraction in gravimetric mixture, IRMM-1027v, 01 Nov 2019
$wdnorm_{242Pu}$	g/g	Decayed and normalised ^{242}Pu mass fraction in gravimetric mixture, IRMM-1027v, 01 Nov 2019
ln_2		
τ_{238}	a	Half-life ^{238}Pu
τ_{239}	a	Half-life ^{239}Pu
τ_{240}	a	Half-life ^{240}Pu
τ_{241}	a	Half-life ^{241}Pu
τ_{242}	a	Half-life ^{242}Pu
m_{PuMP2}	g	Mass of plutonium MP2 metal
m_{Pu}	g	
md_{238Pu}	g	Decayed mass of ^{238}Pu, from 1 Jan 2007 to 01 Nov 2019
md_{239Pu}	g	Decayed mass of ^{239}Pu, from 1 Jan 2007 to 01 Nov 2019
md_{240Pu}	g	Decayed mass of ^{240}Pu, from 1 Jan 2007 to 01 Nov 2019
md_{241Pu}	g	Decayed mass of ^{241}Pu, from 1 Jan 2007 to 01 Nov 2019
md_{242Pu}	g	Decayed mass of ^{242}Pu, from 1 Jan 2007 to 01 Nov 2019
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

Quantity	Unit	Definition
w_{239Pu}	g/g	^{239}Pu mass fraction in MP2, 1 Jan 2007
w_{240Pu}	g/g	^{240}Pu mass fraction in MP2, 1 Jan 2007
w_{241Pu}	g/g	^{241}Pu mass fraction in MP2, 1 Jan 2007
w_{242Pu}	g/g	^{242}Pu mass fraction in MP2, 1 Jan 2007
fd_{238Pu}	mol/mol	Decayed ^{238}Pu amount fraction in MP2, from 1 Jan 2007 to 01 Nov 2019
fd_{239Pu}	mol/mol	Decayed ^{239}Pu amount fraction in MP2, from 1 Jan 2007 to 01 Nov 2019
fd_{240Pu}	mol/mol	Decayed ^{240}Pu amount fraction in MP2, from 1 Jan 2007 to 01 Nov 2019
fd_{241Pu}	mol/mol	Decayed ^{241}Pu amount fraction in MP2, from 1 Jan 2007 to 01 Nov 2019
fd_{242Pu}	mol/mol	Decayed ^{242}Pu amount fraction in MP2, from 1 Jan 2007 to 01 Nov 2019
$\eta_{PuMP2Nov2019}$	g/g	Purity of enriched plutonium metal, MP2
$m_{solution1027v}$	g	mass of mother solution 1027v
$m_{239Puunit1}$	g	mass of ^{239}Pu in 1027v #1
m1	g	dispensed solution mass into 1027v #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: 12.83231 a

01/01/2007, 01/11/2019, delta t= 4687 days / 365.25 = 12.83231 a

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

IRMM MP2 certificate 2007

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

IRMM MP2 certificate 2007

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

IRMM MP2 certificate 2007

e: Constant
Value: 2.71828182845904523536

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

m_{PuMP2}: Type B normal distribution
Value: 1.71006 g
Expanded Uncertainty: 0.00007 g
Coverage Factor: 2

E3935

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: $\eta_{PuMP2Jan2007}$

$m_{solution1027v}$: Type B normal distribution
Value: 2352.50 g
Expanded Uncertainty: 0.04 g
Coverage Factor: 2

E3935

m1: Type B normal distribution
Value: 2.4963 g
Expanded Uncertainty: 0.0006 g
Coverage Factor: 2

Input Correlation:

The abundance set for Pu is assumed as uncorrelated.

Interim Results:

Quantity	Value	Standard Uncertainty	Degrees of Freedom
M_{Pu}	239.07478914 g/mol	$4.20\cdot10^{-6}$ g/mol	260
f_{238Pu}	$30.143\cdot10^{-6}$ mol/mol	$142\cdot10^{-9}$ mol/mol	100
f_{239Pu}	0.97773050 mol/mol	$2.88\cdot10^{-6}$ mol/mol	170
f_{240Pu}	0.02193284 mol/mol	$2.44\cdot10^{-6}$ mol/mol	100
f_{241Pu}	$232.50\cdot10^{-6}$ mol/mol	$1.52\cdot10^{-6}$ mol/mol	100
f_{242Pu}	$74.014\cdot10^{-6}$ mol/mol	$381\cdot10^{-9}$ mol/mol	100
ΣR_{Pu}	1.02277673 mol/mol	$3.01\cdot10^{-6}$ mol/mol	170
λ_{238}	$7.90001\cdot10^{-3}$ a^{-1}	$2.70\cdot10^{-6}$ a^{-1}	100
λ_{239}	$28.7613\cdot10^{-6}$ a^{-1}	$13.1\cdot10^{-9}$ a^{-1}	100
λ_{240}	$105.647\cdot10^{-6}$ a^{-1}	$113\cdot10^{-9}$ a^{-1}	100
λ_{241}	0.0483872 a^{-1}	$40.5\cdot10^{-6}$ a^{-1}	100
λ_{242}	$1.8583\cdot10^{-6}$ a^{-1}	$14.9\cdot10^{-9}$ a^{-1}	100
ΣRd_{Pu}	1.02264173 mol/mol	$2.71\cdot10^{-6}$ mol/mol	130
md_{238Pu}	$27.121\cdot10^{-6}$ g	$128\cdot10^{-9}$ g	100
md_{239Pu}	0.97727720 g	$2.90\cdot10^{-6}$ g	170
md_{240Pu}	0.02199282 g	$2.45\cdot10^{-6}$ g	100
md_{241Pu}	$125.995\cdot10^{-6}$ g	$824\cdot10^{-9}$ g	100
md_{242Pu}	$74.936\cdot10^{-6}$ g	$386\cdot10^{-9}$ g	100
Σmd_{Pu}	0.999498078 g	$729\cdot10^{-9}$ g	110
w_{238Pu}	$30.014\cdot10^{-6}$ g/g	$141\cdot10^{-9}$ g/g	100
w_{239Pu}	0.97763796 g/g	$2.90\cdot10^{-6}$ g/g	170
w_{240Pu}	0.02202266 g/g	$2.45\cdot10^{-6}$ g/g	100
w_{241Pu}	$234.43\cdot10^{-6}$ g/g	$1.53\cdot10^{-6}$ g/g	100
w_{242Pu}	$74.938\cdot10^{-6}$ g/g	$386\cdot10^{-9}$ g/g	100
fd_{238Pu}	$27.237\cdot10^{-6}$ mol/mol	$128\cdot10^{-9}$ mol/mol	100
fd_{239Pu}	0.97736971 mol/mol	$2.88\cdot10^{-6}$ mol/mol	170
fd_{240Pu}	0.02190313 mol/mol	$2.44\cdot10^{-6}$ mol/mol	100
fd_{241Pu}	$124.959\cdot10^{-6}$ mol/mol	$817\cdot10^{-9}$ mol/mol	100
fd_{242Pu}	$74.012\cdot10^{-6}$ mol/mol	$381\cdot10^{-9}$ mol/mol	100

Uncertainty Budgets:

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

Quantity	Value	Standard Uncertainty	Degrees of Freedom	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$R_{238Pu/239Pu}$	$30.830\cdot10^{-6}$ mol/mol	$145\cdot10^{-9}$ mol/mol	100	normal	$-690\cdot10^{-6}$	$-100\cdot10^{-12}$ g/g	0.0 %
Δt	12.83231 a						
$R_{240Pu/239Pu}$	0.02243240 mol/mol	$2.55\cdot10^{-6}$ mol/mol	100	normal	$-700\cdot10^{-6}$	$-1.8\cdot10^{-9}$ g/g	0.0 %
$R_{241Pu/239Pu}$	$237.80\cdot10^{-6}$ mol/mol	$1.55\cdot10^{-6}$ mol/mol	100	normal	$-700\cdot10^{-6}$	$-1.1\cdot10^{-9}$ g/g	0.0 %
$R_{242Pu/239Pu}$	$75.700\cdot10^{-6}$ mol/mol	$390\cdot10^{-9}$ mol/mol	100	normal	$-700\cdot10^{-6}$	$-270\cdot10^{-12}$ g/g	0.0 %
e	2.718281828459						
M_{238Pu}	238.04955830 g/mol	$1.20\cdot10^{-6}$ g/mol	100	normal	$-89\cdot10^{-12}$	$-110\cdot10^{-18}$ g/g	0.0 %
M_{239Pu}	239.05216170 g/mol	$1.20\cdot10^{-6}$ g/mol	100	normal	$66\cdot10^{-9}$	$80\cdot10^{-15}$ g/g	0.0 %
M_{240Pu}	240.05381180 g/mol	$1.20\cdot10^{-6}$ g/mol	100	normal	$-65\cdot10^{-9}$	$-78\cdot10^{-15}$ g/g	0.0 %
M_{241Pu}	241.05684970 g/mol	$1.20\cdot10^{-6}$ g/mol	100	normal	$-690\cdot10^{-12}$	$-830\cdot10^{-18}$ g/g	0.0 %
M_{242Pu}	242.05874100 g/mol	$1.30\cdot10^{-6}$ g/mol	100	normal	$-220\cdot10^{-12}$	$-290\cdot10^{-18}$ g/g	0.0 %
τ_{238}	87.7400 a	0.0300 a	100	normal	0.0	0.0 g/g	0.0 %
τ_{239}	24100.0 a	11.0 a	100	normal	$11\cdot10^{-12}$	$120\cdot10^{-12}$ g/g	0.0 %
τ_{240}	6561.00 a	7.00 a	100	normal	0.0	$13\cdot10^{-24}$ g/g	0.0 %
τ_{241}	14.3250 a	0.0120 a	100	normal	not valid!	0.0 g/g	0.0 %
τ_{242}	$373.00\cdot10^{3}$ a	3000 a	100	normal	0.0	$13\cdot10^{-24}$ g/g	0.0 %
m_{PuMP2}	1.7100600 g	$35.0\cdot10^{-6}$ g	100	normal	$410\cdot10^{-6}$	$15\cdot10^{-9}$ g/g	1.0 %
m_{Pu}	1.0 g	0.0 g	100	normal	0.0	0.0 g/g	0.0 %
$\eta_{PuMP2Jan2007}$	0.998746 g/g	$200\cdot10^{-6}$ g/g	100		$710\cdot10^{-6}$	$140\cdot10^{-9}$ g/g	98.8 %
$m_{solution1027v}$	2352.5000 g	0.0200 g	100	normal	$-300\cdot10^{-9}$	$-6.0\cdot10^{-9}$ g/g	0.2 %
$\gamma_{Pumixture239}$	$709.504\cdot10^{-6}$ g/g	$143\cdot10^{-9}$ g/g	100				

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

Quantity	Value	Standard Uncertainty	Degrees of Freedom	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$R_{238Pu/239Pu}$	$30.830 \cdot 10^{-6}$ mol/mol	$145 \cdot 10^{-9}$ mol/mol	100	normal	$-2.9 \cdot 10^{-6}$	$-420 \cdot 10^{-15}$ mol/g	0.0 %
Δt	12.83231 a						
$R_{240Pu/239Pu}$	0.02243240 mol/mol	$2.55 \cdot 10^{-6}$ mol/mol	100	normal	$-2.9 \cdot 10^{-6}$	$-7.4 \cdot 10^{-12}$ mol/g	0.0 %
$R_{241Pu/239Pu}$	$237.80 \cdot 10^{-6}$ mol/mol	$1.55 \cdot 10^{-6}$ mol/mol	100	normal	$-2.9 \cdot 10^{-6}$	$-4.5 \cdot 10^{-12}$ mol/g	0.0 %
$R_{242Pu/239Pu}$	$75.700 \cdot 10^{-6}$ mol/mol	$390 \cdot 10^{-9}$ mol/mol	100	normal	$-2.9 \cdot 10^{-6}$	$-1.1 \cdot 10^{-12}$ mol/g	0.0 %
e	2.718281828459						
M_{238Pu}	238.04955830 g/mol	$1.20 \cdot 10^{-6}$ g/mol	100	normal	$-370 \cdot 10^{-15}$	$-450 \cdot 10^{-21}$ mol/g	0.0 %
M_{239Pu}	239.05216170 g/mol	$1.20 \cdot 10^{-6}$ g/mol	100	normal	$-12 \cdot 10^{-9}$	$-15 \cdot 10^{-15}$ mol/g	0.0 %
M_{240Pu}	240.05381180 g/mol	$1.20 \cdot 10^{-6}$ g/mol	100	normal	$-270 \cdot 10^{-12}$	$-330 \cdot 10^{-18}$ mol/g	0.0 %
M_{241Pu}	241.05684970 g/mol	$1.20 \cdot 10^{-6}$ g/mol	100	normal	$-2.9 \cdot 10^{-12}$	$-3.5 \cdot 10^{-18}$ mol/g	0.0 %
M_{242Pu}	242.05874100 g/mol	$1.30 \cdot 10^{-6}$ g/mol	100	normal	$-920 \cdot 10^{-15}$	$-1.2 \cdot 10^{-18}$ mol/g	0.0 %
τ_{238}	87.7400 a	0.0300 a	100	normal	0.0	0.0 mol/g	0.0 %
τ_{239}	24100.0 a	11.0 a	100	normal	$45 \cdot 10^{-15}$	$500 \cdot 10^{-15}$ mol/g	0.0 %
τ_{240}	6561.00 a	7.00 a	100	normal	0.0	$100 \cdot 10^{-27}$ mol/g	0.0 %
τ_{241}	14.3250 a	0.0120 a	100	normal	not valid!	$-52 \cdot 10^{-27}$ mol/g	0.0 %
τ_{242}	$373.00 \cdot 10^{3}$ a	3000 a	100	normal	not valid!	$100 \cdot 10^{-27}$ mol/g	0.0 %
m_{PuMP2}	1.7100600 g	$35.0 \cdot 10^{-6}$ g	100	normal	$1.7 \cdot 10^{-6}$	$61 \cdot 10^{-12}$ mol/g	1.0 %
m_{Pu}	1.0 g	0.0 g	100	normal	0.0	0.0 mol/g	0.0 %
$\eta_{PuMP2Jan2007}$	0.998746 g/g	$200 \cdot 10^{-6}$ g/g	100		$3.0 \cdot 10^{-6}$	$590 \cdot 10^{-12}$ mol/g	98.8 %
$m_{solution1027v}$	2352.5000 g	0.0200 g	100	normal	$-1.3 \cdot 10^{-9}$	$-25 \cdot 10^{-12}$ mol/g	0.2 %
$c_{Pumixture239}$	$2.967986 \cdot 10^{-6}$ mol/g	$598 \cdot 10^{-12}$ mol/g	100				

$Rd_{238Pu/239Pu}$: decayed $^{238}Pu/^{239}Pu$ amount ratio in IRMM-1027v, 01 Nov 2019

Quantity	Value	Standard Uncertainty	Degrees of Freedom	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$R_{238Pu/239Pu}$	$30.830 \cdot 10^{-6}$ mol/mol	$145 \cdot 10^{-9}$ mol/mol	100	normal	0.90	$130 \cdot 10^{-9}$ mol/mol	100.0 %
Δt	12.83231 a						
e	2.718281828459						
τ_{238}	87.7400 a	0.0300 a	100	normal	$32 \cdot 10^{-9}$	$970 \cdot 10^{-12}$ mol/mol	0.0 %
τ_{239}	24100.0 a	11.0 a	100	normal	$-430 \cdot 10^{-15}$	$-4.7 \cdot 10^{-12}$ mol/mol	0.0 %
$Rd_{238Pu/239Pu}$	$27.868 \cdot 10^{-6}$ mol/mol	$131 \cdot 10^{-9}$ mol/mol	100				

$Rd_{240Pu/239Pu}$: decayed $^{240}Pu/^{239}Pu$ amount ratio in IRMM-1027v, 01 Nov 2019

Quantity	Value	Standard Uncertainty	Degrees of Freedom	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
Δt	12.83231 a						
$R_{240Pu/239Pu}$	0.02243240 mol/mol	$2.55 \cdot 10^{-6}$ mol/mol	100	normal	1.0	$2.5 \cdot 10^{-6}$ mol/mol	100.0 %
e	2.718281828459						
τ_{239}	24100.0 a	11.0 a	100	normal	$-340 \cdot 10^{-12}$	$-3.8 \cdot 10^{-9}$ mol/mol	0.0 %
τ_{240}	6561.00 a	7.00 a	100	normal	$4.6 \cdot 10^{-9}$	$32 \cdot 10^{-9}$ mol/mol	0.0 %
$Rd_{240Pu/239Pu}$	0.02241028 mol/mol	$2.55 \cdot 10^{-6}$ mol/mol	100				

$Rd_{241Pu/239Pu}$: decayed $^{241}Pu/^{239}Pu$ amount ratio in IRMM-1027v, 01 Nov 2019

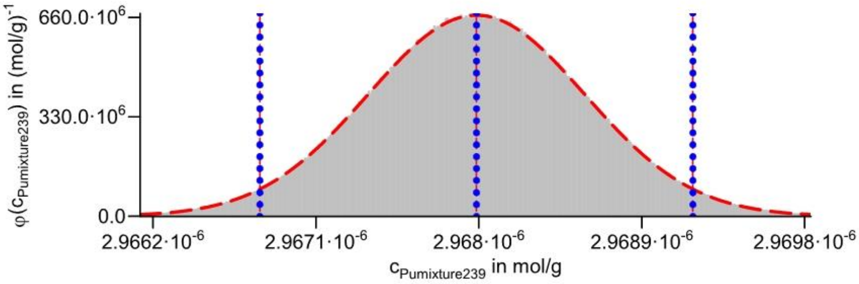
Quantity	Value	Standard Uncertainty	Degrees of Freedom	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
Δt	12.83231 a						
$R_{241Pu/239Pu}$	$237.80 \cdot 10^{-6}$ mol/mol	$1.55 \cdot 10^{-6}$ mol/mol	100	normal	0.54	$830 \cdot 10^{-9}$ mol/mol	99.4 %
e	2.718281828459						
τ_{239}	24100.0 a	11.0 a	100	normal	$-2.0 \cdot 10^{-12}$	$-22 \cdot 10^{-12}$ mol/mol	0.0 %
τ_{241}	14.3250 a	0.0120 a	100	normal	$5.5 \cdot 10^{-6}$	$67 \cdot 10^{-9}$ mol/mol	0.6 %
$Rd_{241Pu/239Pu}$	$127.853 \cdot 10^{-6}$ mol/mol	$836 \cdot 10^{-9}$ mol/mol	100				

$Rd_{242Pu/239Pu}$: decayed $^{242}Pu/^{239}Pu$ amount ratio in IRMM-1027v, 01 Nov 2019

Quantity	Value	Standard Uncertainty	Degrees of Freedom	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
Δt	12.83231 a						
$R_{242Pu/239Pu}$	$75.700 \cdot 10^{-6}$ mol/mol	$390 \cdot 10^{-9}$ mol/mol	100	normal	1.0	$390 \cdot 10^{-9}$ mol/mol	100.0 %
e	2.718281828459						
τ_{239}	24100.0 a	11.0 a	100	normal	$-1.2 \cdot 10^{-12}$	$-13 \cdot 10^{-12}$ mol/mol	0.0 %
τ_{242}	$373.00 \cdot 10^{3}$ a	3000 a	100	normal	$4.8 \cdot 10^{-15}$	$15 \cdot 10^{-12}$ mol/mol	0.0 %
$Rd_{242Pu/239Pu}$	$75.726 \cdot 10^{-6}$ mol/mol	$390 \cdot 10^{-9}$ mol/mol	100				

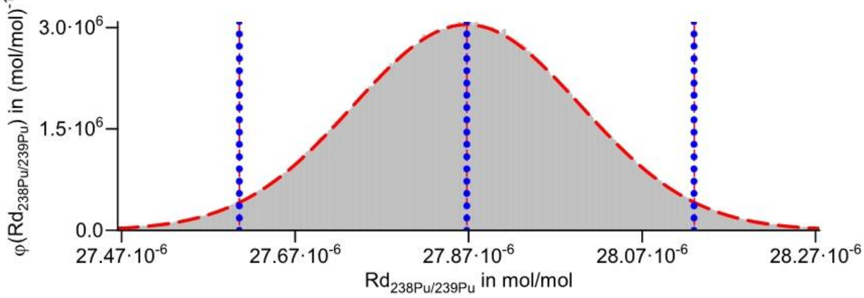
Results:

Quantity	Value	Expanded Uncertainty	Coverage factor	Coverage
$\gamma_{Pumixture}$	$725.64 \cdot 10^{-6}$ g/g	$290 \cdot 10^{-9}$ g/g	2.00	95% (t-table 95.45%)
$\gamma_{Pumixture239}$	$709.50 \cdot 10^{-6}$ g/g	$290 \cdot 10^{-9}$ g/g	2.00	95% (t-table 95.45%)
$c_{Pumixture239}$	$2.9680 \cdot 10^{-6}$ mol/g	$1.2 \cdot 10^{-9}$ mol/g	2.00	95% (t-table 95.45%)
$c_{Pumixture}$	$3.0352 \cdot 10^{-6}$ mol/g	$1.2 \cdot 10^{-9}$ mol/g	2.00	95% (t-table 95.45%)
$Rd_{238Pu/239Pu}$	$27.87 \cdot 10^{-6}$ mol/mol	$260 \cdot 10^{-9}$ mol/mol	2.00	95% (t-table 95.45%)
$Rd_{240Pu/239Pu}$	0.0224103 mol/mol	$5.1 \cdot 10^{-6}$ mol/mol	2.00	95% (t-table 95.45%)
$Rd_{241Pu/239Pu}$	$127.9 \cdot 10^{-6}$ mol/mol	$1.7 \cdot 10^{-6}$ mol/mol	2.00	95% (t-table 95.45%)
$Rd_{242Pu/239Pu}$	$75.73 \cdot 10^{-6}$ mol/mol	$780 \cdot 10^{-9}$ mol/mol	2.00	95% (t-table 95.45%)
$fdnorm_{238Pu}$	$27.25 \cdot 10^{-6}$ mol/mol	$260 \cdot 10^{-9}$ mol/mol	2.00	95% (t-table 95.45%)
$fdnorm_{239Pu}$	0.9778596 mol/mol	$5.2 \cdot 10^{-6}$ mol/mol	2.00	95% (t-table 95.45%)
$fdnorm_{240Pu}$	0.0219141 mol/mol	$4.9 \cdot 10^{-6}$ mol/mol	2.00	95% (t-table 95.45%)
$fdnorm_{241Pu}$	$125.0 \cdot 10^{-6}$ mol/mol	$1.6 \cdot 10^{-6}$ mol/mol	2.00	95% (t-table 95.45%)
$fdnorm_{242Pu}$	$74.05 \cdot 10^{-6}$ mol/mol	$760 \cdot 10^{-9}$ mol/mol	2.00	95% (t-table 95.45%)
Md_{Pu}	239.0745579 g/mol	$6.7 \cdot 10^{-6}$ g/mol	2.00	95% (t-table 95.45%)
$wdnorm_{238Pu}$	$27.13 \cdot 10^{-6}$ g/g	$260 \cdot 10^{-9}$ g/g	2.00	95% (t-table 95.45%)
$wdnorm_{239Pu}$	0.9777680 g/g	$5.2 \cdot 10^{-6}$ g/g	2.00	95% (t-table 95.45%)
$wdnorm_{240Pu}$	0.0220039 g/g	$4.9 \cdot 10^{-6}$ g/g	2.00	95% (t-table 95.45%)
$wdnorm_{241Pu}$	$126.1 \cdot 10^{-6}$ g/g	$1.6 \cdot 10^{-6}$ g/g	2.00	95% (t-table 95.45%)
$wdnorm_{242Pu}$	$74.97 \cdot 10^{-6}$ g/g	$770 \cdot 10^{-9}$ g/g	2.00	95% (t-table 95.45%)
$\eta_{PuMP2Nov2019}$	0.99824 g/g	$400 \cdot 10^{-6}$ g/g	2.00	95% (t-table 95.45%)
$m_{239Puunit1}$	$1.77113 \cdot 10^{-3}$ g	$830 \cdot 10^{-9}$ g	2.00	95% (t-table 95.45%)



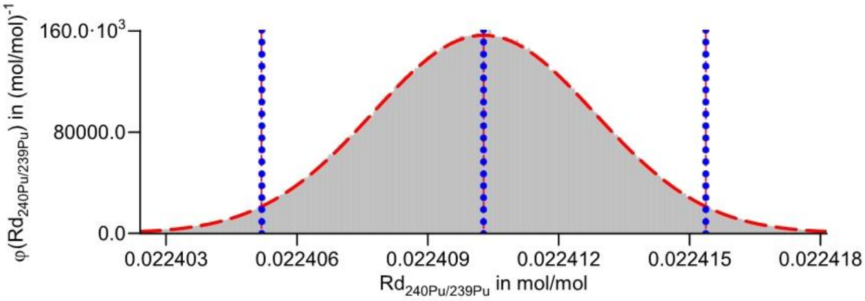
Result of the Monte Carlo Simulation for $c_{Pumixture239}$

Simulator: OMCE V:1.2.19
Mean Value: $2.96799 \cdot 10^{-6}$ mol/g
Standard Uncertainty: $6 \cdot 10^{-10}$ mol/g
Coverage Interval (p=0.9545): [$2.96679 \cdot 10^{-6}$, $2.96918 \cdot 10^{-6}$] mol/g (Probabilistically Symmetric)
Expanded Uncertainty Interval (p=0.9545): ($+1.2 \cdot 10^{-9}$, $-1.2 \cdot 10^{-9}$) mol/g (Probabilistically Symmetric)
Number of Monte Carlo Trials: 2000000
Block size: 10000 runs



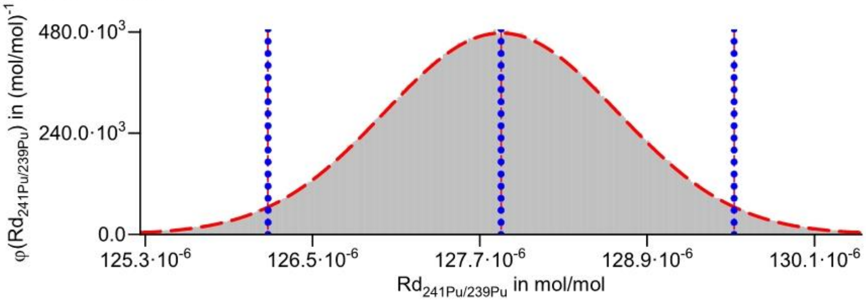
Result of the Monte Carlo Simulation for $Rd_{238Pu/239Pu}$

Simulator: OMCE V:1.2.19
Mean Value: $2.787 \cdot 10^{-5}$ mol/mol
Standard Uncertainty: $1.3 \cdot 10^{-7}$ mol/mol
Coverage Interval (p=0.9545): [$2.761 \cdot 10^{-5}$, $2.813 \cdot 10^{-5}$] mol/mol (Probabilistically Symmetric)
Expanded Uncertainty Interval (p=0.9545): ($+2.6 \cdot 10^{-7}$, $-2.6 \cdot 10^{-7}$) mol/mol (Probabilistically Symmetric)
Number of Monte Carlo Trials: 2000000
Block size: 10000 runs



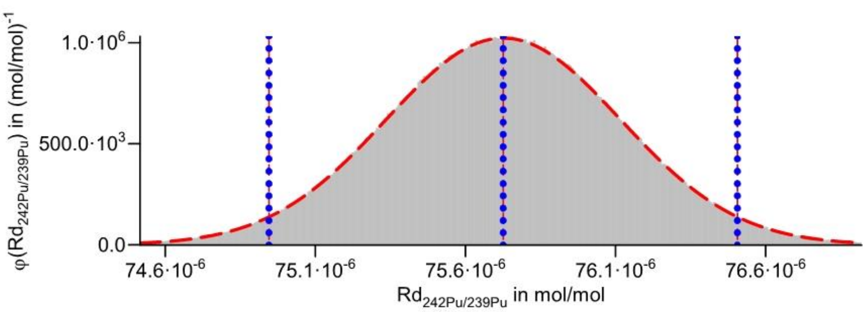
Result of the Monte Carlo Simulation for $Rd_{240Pu/239Pu}$

Simulator: OMCE V:1.2.19
Mean Value: 0.0224103 mol/mol
Standard Uncertainty: $2.5 \cdot 10^{-6}$ mol/mol
Coverage Interval (p=0.9545): [0.0224052, 0.0224154] mol/mol (Probabilistically Symmetric)
Expanded Uncertainty Interval (p=0.9545): $(+5.1 \cdot 10^{-6}, -5.1 \cdot 10^{-6})$ mol/mol (Probabilistically Symmetric)
Number of Monte Carlo Trials: 2000000
Block size: 10000 runs



Result of the Monte Carlo Simulation for $Rd_{241Pu/239Pu}$

Simulator: OMCE V:1.2.19
Mean Value: 0.00012785 mol/mol
Standard Uncertainty: $8.4 \cdot 10^{-7}$ mol/mol
Coverage Interval (p=0.9545): [0.00012618, 0.00012953] mol/mol (Probabilistically Symmetric)
Expanded Uncertainty Interval (p=0.9545): $(+1.7 \cdot 10^{-6}, -1.7 \cdot 10^{-6})$ mol/mol (Probabilistically Symmetric)
Number of Monte Carlo Trials: 2000000
Block size: 10000 runs



Result of the Monte Carlo Simulation for $Rd_{242Pu/239Pu}$

Simulator: OMCE V:1.2.19
Mean Value: $7.573 \cdot 10^{-5}$ mol/mol
Standard Uncertainty: $3.9 \cdot 10^{-7}$ mol/mol
Coverage Interval (p=0.9545): [$7.495 \cdot 10^{-5}$, $7.651 \cdot 10^{-5}$] mol/mol (Probabilistically Symmetric)
Expanded Uncertainty Interval (p=0.9545): ($+7.8 \cdot 10^{-7}$, $-7.8 \cdot 10^{-7}$) mol/mol (Probabilistically Symmetric)
Number of Monte Carlo Trials: 2000000
Block size: 10000 runs

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

E. 3938 rev 1 **Issue date**: ~~30/04/2020~~ 18/03/2021 **Page** 1 **of** 3

Applicant: K. Toth **Project: IRMM-1027v**

Description: Verification of IRMM-1027v individual units with IRMM-046c and QC NBL 126 and CRM 116-A

Request for analysis number: 4589 **ID number:** 31532

Date of receipt of request: 08/01/2020 **Weighing dates**: 27, 28, 30/Jan/2020

Results:

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

ID	Mass IRMM-046c /g	Uncertainty IRMM-046c /g	Coverage factor[a]	Effective degrees of freedom[b]
1027v-64/046c-#1-1	1.99208	0.0000~~8~~9	2.16	17
1027v-137/046c-#1-2	2.41059	0.0001~~1~~6	2.87	4
1027v-176/046c-#1-3	2.01132	0.0001~~1~~8	3.31	3
1027v-262/046c-#1-4	1.99029	0.0000~~8~~9	2.16	17
QC12/046c-#1-5	2.05916	0.0000~~8~~9	2.17	16
1027v-313/046c-#3-1	1.94861	0.0001~~1~~5	2.87	4
1027u-431/046c-#3-2	2.01297	0.0001~~0~~7	3.31	3
1027v-507/046c-#3-3	2.24461	0.00007	2.00	100
1027u-578/046c-#3-4	1.93891	0.00007	2.00	100
QC13/046c-#3-5	1.81470	0.00007	2.00	100
1027v-618/046c-#13-1	1.97365	0.00008	2.06	47
1027v-749/046c-#13-2	2.00067	0.0000~~8~~9	2.11	29
1027v-766/046c-#13-3	2.00759	0.0000~~8~~9	2.11	26
1027v-887/046c-#13-4	2.01734	0.000~~07~~13	2.00	100
QC14/046c-#13-5	2.22460	0.000~~07~~14	2.00	100

ID	NBL-126 Mass /g	Uncertainty /g	Coverage factor[a]	Effective degrees of freedom[b]
NBL-126/ QC12/046c-#1-5	0.50094	0.0000~~8~~9	2.11	26
NBL-126/ QC13/046c-#3-5	0.51284	0.0001~~0~~3	2.65	5
NBL-126/ QC14/046c-#13-5	0.50191	0.0001~~1~~4	2.65	5

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Rozle Jakopič

Nuclear Chemistry Laboratory responsible

Tóth Kálmán

Carmel Hennessy/Kalman Toth

Analyst

Annex 16 The internal test reports (#4589 and #4662) for the selected units of IRMM-1027v. (Typo: the date of the first set of IDMS samples was 20/02/2020 and not 02/02/2020).

Ref. Ares(2021)2470354 - 12/04/2021

EUROPEAN COMMISSION

DIRECTORATE-GENERAL
JOINT RESEARCH CENTRE
Directorate G – Nuclear Safety and Security
Unit JRC G.2 Standards for Nuclear Safety, Security and Safeguards

INTERNAL TEST REPORT # 4589

Requested by: Kalman Toth

Samples

Sample ID	Applicant sample identification
31532	IDMS for U and Pu for IRMM-1027v verification units.

Date of receipt of samples: January 2020

Condition of the samples: Plutonium and uranium nitrate solutions. Radioactive material. Pu/U separation followed by Pu and U chemical purifications (following IMS-JRC.G-C1.1-WIN-0062 V1.0), prior to mass spectrometry measurements by TIMS using the TE method (following IMS-JRC.G-C1.1-WIN-0059 v2.0).

Sample ID	Analyte	Result[3] (expanded uncertainty[1])	Unit	Method[2]
Pu-IDMS, P200220				
Date:	**02/02/2020**			
QC13	$n(^{242}\mathrm{Pu})/n(^{239}\mathrm{Pu})$	0.17683 (18)	mol / mol	TIMS/TE
262-1027v	$n(^{242}\mathrm{Pu})/n(^{239}\mathrm{Pu})$	0.09024 (10)	mol / mol	TIMS/TE
313-1027v	$n(^{242}\mathrm{Pu})/n(^{239}\mathrm{Pu})$	0.091982 (95)	mol / mol	TIMS/TE
431-1027v	$n(^{242}\mathrm{Pu})/n(^{239}\mathrm{Pu})$	0.09533 (10)	mol / mol	TIMS/TE
766-1027v	$n(^{242}\mathrm{Pu})/n(^{239}\mathrm{Pu})$	0.09480 (10)	mol / mol	TIMS/TE
Pu-IDMS, P200310				
Date:	**10/03/2020**			
QC12	$n(^{242}\mathrm{Pu})/n(^{239}\mathrm{Pu})$	0.19723 (21)	mol / mol	TIMS/TE
64-1027v	$n(^{242}\mathrm{Pu})/n(^{239}\mathrm{Pu})$	0.08991 (10)	mol / mol	TIMS/TE
137-1027v	$n(^{242}\mathrm{Pu})/n(^{239}\mathrm{Pu})$	0.10961 (11)	mol / mol	TIMS/TE
578-1027v	$n(^{242}\mathrm{Pu})/n(^{239}\mathrm{Pu})$	0.09145(10)	mol / mol	TIMS/TE
618-1027v	$n(^{242}\mathrm{Pu})/n(^{239}\mathrm{Pu})$	0.09353(10)	mol / mol	TIMS/TE

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Pu-IDMS, P200615				
Date:	**17/06/2020**			
176-1027v	$n(^{242}Pu)/n(^{239}Pu)$	0.091284 (97)	mol / mol	TIMS/TE
507-1027v	$n(^{242}Pu)/n(^{239}Pu)$	0.10580 (11)	mol / mol	TIMS/TE
749-1027v	$n(^{242}Pu)/n(^{239}Pu)$	0.09496(11)	mol / mol	TIMS/TE
887-1027v	$n(^{242}Pu)/n(^{239}Pu)$	0.09573 (10)	mol / mol	TIMS/TE
QC14	$n(^{242}Pu)/n(^{239}Pu)$	0.22185 (23)	mol / mol	TIMS/TE

Sample ID	Analyte	Result[3] (expanded uncertainty[1])	Unit	Method[2]
U-IDMS, T200217				
Date:	**24/02/2020**			
QC13	$n(^{233}U)/n(^{238}U)$	12.088 (19)	mol / mol	TIMS/TE
QC13	$n(^{233}U)/n(^{235}U)$	0.63545 (34)	mol / mol	TIMS/TE
Vial262	$n(^{233}U)/n(^{238}U)$	0.046374 (34)	mol / mol	TIMS/TE
Vial262	$n(^{233}U)/n(^{235}U)$	0.191201 (62)	mol / mol	TIMS/TE
Vial313	$n(^{233}U)/n(^{238}U)$	0.047316 (73)	mol / mol	TIMS/TE
Vial313	$n(^{233}U)/n(^{235}U)$	0.19508 (34)	mol / mol	TIMS/TE
Vial431	$n(^{233}U)/n(^{238}U)$	0.48956 (47)	mol / mol	TIMS/TE
Vial431	$n(^{233}U)/n(^{235}U)$	0.20186 (11)	mol / mol	TIMS/TE
Vial766	$n(^{233}U)/n(^{238}U)$	0.048683 (71)	mol / mol	TIMS/TE
Vial766	$n(^{233}U)/n(^{235}U)$	0.20077 (12)	mol / mol	TIMS/TE
U-IDMS, T200304				
Date:	**05/03/2020**			
QC12	$n(^{233}U)/n(^{238}U)$	12.868 (11)	mol / mol	TIMS/TE
QC12	$n(^{233}U)/n(^{235}U)$	0.67845 (21)	mol / mol	TIMS/TE
Vial064	$n(^{233}U)/n(^{238}U)$	0.046177 (34)	mol / mol	TIMS/TE
Vial064	$n(^{233}U)/n(^{235}U)$	0.190395 (57)	mol / mol	TIMS/TE
Vial137	$n(^{233}U)/n(^{238}U)$	0.056308 (51)	mol / mol	TIMS/TE
Vial137	$n(^{233}U)/n(^{235}U)$	0.232158 (79)	mol / mol	TIMS/TE
Vial578	$n(^{233}U)/n(^{238}U)$	0.046928 (36)	mol / mol	TIMS/TE
Vial578	$n(^{233}U)/n(^{235}U)$	0.193533 (59)	mol / mol	TIMS/TE
Vial618	$n(^{233}U)/n(^{238}U)$	0.048046 (78)	mol / mol	TIMS/TE

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Vial618	$n(^{233}U)/n(^{235}U)$	0.19815 (26)	mol / mol	TIMS/TE
U-IDMS, T200312				
Date:	**13/03/2020**			
Vial176	$n(^{233}U)/n(^{238}U)$	0.046870 (28)	mol / mol	TIMS/TE
Vial176	$n(^{233}U)/n(^{235}U)$	0.193240 (51)	mol / mol	TIMS/TE
Vial507	$n(^{233}U)/n(^{238}U)$	0.054349 (43)	mol / mol	TIMS/TE
Vial507	$n(^{233}U)/n(^{235}U)$	0.224065 (71)	mol / mol	TIMS/TE
Vial749	$n(^{233}U)/n(^{238}U)$	0.048798 (61)	mol / mol	TIMS/TE
Vial749	$n(^{233}U)/n(^{235}U)$	0.201083 (94)	mol / mol	TIMS/TE
Vial887	$n(^{233}U)/n(^{238}U)$	0.049146 (29)	mol / mol	TIMS/TE
Vial887	$n(^{233}U)/n(^{235}U)$	0.202629 (47)	mol / mol	TIMS/TE
QC14	$n(^{233}U)/n(^{238}U)$	15.0808 (96)	mol / mol	TIMS/TE
QC14	$n(^{233}U)/n(^{235}U)$	0.79845 (26)	mol / mol	TIMS/TE

Notes:

Notes		
	1	**Uncertainties are given as *(e.g. expanded (k = 2) uncertainties according to the ISO Guide to the Expression of Uncertainty (GUM), corresponding to an approximate 95% confidence interval)***
	2	**Method used for the measurements (TE: Total Evaporation)**
	3	**For the full dataset including raw data, k-factor and QC samples, the reader is advised to consult the files referred to below.**

Files name(s) of raw data

For Pu measurements:
U:\Nuclear Safeguards\Nuclear\PUTON DATA - SHARED\IRMM LSD 1027v

Data Files:
P200220 Pu IDMS of IRMM-1027v with 046c set QC13.xlsm
P200310 Pu IDMS IRMM-1027v vials with 046c & QC12.xlsm
P200615 Pu IDMS of IRMM-1027v with 046c set QC14.xlsm

For U measurements:
G:\JRC.G.2\Nuclear Safeguards\Nuclear\TRITON DATA - SHARED\LSD 1027v

Data Files:
T200217 IRMM-1027v U-IDMS Vials-Set1.xlsm
T200304 IRMM-1027v U-IDMS Vials-Set2.xlsm
T200312 IRMM-1027v U-IDMS Vials-Set3.xlsm

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

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JOINT RESEARCH CENTRE
Directorate G – Nuclear Safety and Security
Unit JRC G.2 Standards for Nuclear Safety, Security and Safeguards

INTERNAL TEST REPORT # 4662

Requested by: Kalman Toth

Samples

Sample ID	Applicant sample identification
31912	IDMS for U and Pu for IRMM-1027v verification units.

Date of receipt of samples: June 2020

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 IMS-JRC.G-C1.1-WIN-0062 V1.0), using the TE method (following IMS-JRC.G-C1.1-WIN-0059 v2.0).

Sample ID	Analyte	Result[3] (expanded uncertainty[1])	Unit	Method[2]
Pu-IDMS, P200629				
Date:	**01/07/2020**			
QC16	$n(^{242}\mathrm{Pu})/n(^{239}\mathrm{Pu})$	0.12479 (13)	mol / mol	TIMS/TE
5-1027v-046c	$n(^{242}\mathrm{Pu})/n(^{239}\mathrm{Pu})$	0.090879 (94)	mol / mol	TIMS/TE
6-1027v-046c	$n(^{242}\mathrm{Pu})/n(^{239}\mathrm{Pu})$	0.09856 (10)	mol / mol	TIMS/TE
7-1027v-046c	$n(^{242}\mathrm{Pu})/n(^{239}\mathrm{Pu})$	0.10812 (11)	mol / mol	TIMS/TE
8-1027v-046c	$n(^{242}\mathrm{Pu})/n(^{239}\mathrm{Pu})$	0.09634 (10)	mol / mol	TIMS/TE
Pu-IDMS, P200717				
Date:	**20/07/2020**			
1027v32	$n(^{242}\mathrm{Pu})/n(^{239}\mathrm{Pu})$	0.094307 (99)	mol / mol	TIMS/TE
1027v87	$n(^{242}\mathrm{Pu})/n(^{239}\mathrm{Pu})$	0.09360 (10)	mol / mol	TIMS/TE
1027v102	$n(^{242}\mathrm{Pu})/n(^{239}\mathrm{Pu})$	0.09382 (10)	mol / mol	TIMS/TE
1027v558	$n(^{242}\mathrm{Pu})/n(^{239}\mathrm{Pu})$	0.09212 (10)	mol / mol	TIMS/TE
QC17	$n(^{242}\mathrm{Pu})/n(^{239}\mathrm{Pu})$	0.20451(34)	mol / mol	TIMS/TE

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Pu-IDMS, P200722				
Date:	**23/07/2020**			
1027v516	$n(^{242}Pu)/n(^{239}Pu)$	0.09681 (10)	mol / mol	TIMS/TE
1027v190	$n(^{242}Pu)/n(^{239}Pu)$	0.091362 (96)	mol / mol	TIMS/TE
1027v294	$n(^{242}Pu)/n(^{239}Pu)$	0.093229 (96)	mol / mol	TIMS/TE
1027v419	$n(^{242}Pu)/n(^{239}Pu)$	0.04206 (98)	mol / mol	TIMS/TE
QC15	$n(^{242}Pu)/n(^{239}Pu)$	0.12892(13)	mol / mol	TIMS/TE

Sample ID	Analyte	Result[3] (expanded uncertainty[1])	Unit	Method[2]
U-IDMS, P200701				
Date:	**03/07/2020**			
QC16	$n(^{233}U)/n(^{238}U)$	7.4475 (38)	mol / mol	TIMS/TE
QC16	$n(^{233}U)/n(^{235}U)$	0.413123 (83)	mol / mol	TIMS/TE
U5-1027v-046c	$n(^{233}U)/n(^{238}U)$	0.046509 (23)	mol / mol	TIMS/TE
U5-1027v-046c	$n(^{233}U)/n(^{235}U)$	0.158256 (31)	mol / mol	TIMS/TE
U6-1027v-046c	$n(^{233}U)/n(^{238}U)$	0.050387 (57)	mol / mol	TIMS/TE
U6-1027v-046c	$n(^{233}U)/n(^{235}U)$	0.169656 (47)	mol / mol	TIMS/TE
U7-1027v-046c	$n(^{233}U)/n(^{238}U)$	0.055278 (61)	mol / mol	TIMS/TE
U7-1027v-046c	$n(^{233}U)/n(^{235}U)$	0.18222 (13)	mol / mol	TIMS/TE
U8-1027v-046c	$n(^{233}U)/n(^{238}U)$	0.049299 (25)	mol / mol	TIMS/TE
U8-1027v-046c	$n(^{233}U)/n(^{235}U)$	0.167069 (38)	mol / mol	TIMS/TE
U-IDMS, P200706				
Date:	**07/07/2020**			
1027v516	$n(^{233}U)/n(^{238}U)$	0.49599 (22)	mol / mol	TIMS/TE
1027v516	$n(^{233}U)/n(^{235}U)$	0.158954 (33)	mol / mol	TIMS/TE
1027v190	$n(^{233}U)/n(^{238}U)$	0.046783 (25)	mol / mol	TIMS/TE
1027v190	$n(^{233}U)/n(^{235}U)$	0.158577 (36)	mol / mol	TIMS/TE
1027v294	$n(^{233}U)/n(^{238}U)$	0.047752 (22)	mol / mol	TIMS/TE
1027v294	$n(^{233}U)/n(^{235}U)$	0.161310 (28)	mol / mol	TIMS/TE
1027v419	$n(^{233}U)/n(^{238}U)$	0.048246 (23)	mol / mol	TIMS/TE
1027v419	$n(^{233}U)/n(^{235}U)$	0.162666 (30)	mol / mol	TIMS/TE
QC15	$n(^{233}U)/n(^{238}U)$	6.9961 (42)	mol / mol	TIMS/TE

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QC15	$n(^{233}U)/n(^{235}U)$	0.388136 (91)	mol / mol	TIMS/TE
U-IDMS, P200724				
Date:	**27/07/2020**			
1027v732	$n(^{233}U)/n(^{238}U)$	0.48228 (55)	mol / mol	TIMS/TE
1027v732	$n(^{233}U)/n(^{235}U)$	0.166073 (85)	mol / mol	TIMS/TE
1027v87	$n(^{233}U)/n(^{238}U)$	0.047904 (37)	mol / mol	TIMS/TE
1027v87	$n(^{233}U)/n(^{235}U)$	0.161198 (60)	mol / mol	TIMS/TE
1027v102	$n(^{233}U)/n(^{238}U)$	0.048018 (35)	mol / mol	TIMS/TE
1027v102	$n(^{233}U)/n(^{235}U)$	0.162152 (45)	mol / mol	TIMS/TE
1027v558	$n(^{233}U)/n(^{238}U)$	0.047188 (50)	mol / mol	TIMS/TE
1027v558	$n(^{233}U)/n(^{235}U)$	0.157932 (76)	mol / mol	TIMS/TE
QC17	$n(^{233}U)/n(^{238}U)$	7.307 (12)	mol / mol	TIMS/TE
QC17	$n(^{233}U)/n(^{235}U)$	0.40328 (21)	mol / mol	TIMS/TE

Notes:

Notes		
	1	**Uncertainties are given as *(e.g. expanded (k = 2) uncertainties according to the ISO Guide to the Expression of Uncertainty (GUM), corresponding to an approximate 95% confidence interval)***
	2	**Method used for the measurements (TE: Total Evaporation)**
	3	**For the full dataset including raw data, k-factor and QC samples, the reader is advised to consult the files referred to below.**

Files name(s) of raw data

For U and Pu measurements:
G:\JRC.G.2\Nuclear Safeguards\Nuclear\PUTON DATA - SHARED\IRMM LSD 1027v

Data Files for Pu measurements:
P200629 Pu IDMS IRMM-1027v mother_triple spiking_set QC16.xls
P200717 Pu IDMS IRMM-1027v set QC17 triple spiking.xls
P200722 Pu IDMS IRMM-1027v set QC15 triple spiking_ Revision 9.xls

Data Files for U measurements:
P200701 U IDMS IRMM-1027v mother_triple spiking_set QC16.xls
P200706 U IDMS IRMM-1027v set QC15 triple spiking.xls
P200724 U IDMS IRMM-1027v set QC17 triple spiking.xls

....

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

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

INTERNAL TEST REPORT # 4373

Requested by: Renata Bujak

Samples

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

Date of receipt of samples: April 2019

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

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

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

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

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

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

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

Notes:

Notes		
	1	Uncertainties are given as *(e.g. expanded (k = 2) uncertainties according to the ISO Guide to the Expression of Uncertainty (GUM), corresponding to an approximate 95% confidence interval)*
	2	Method used for the measurements (TE: Total Evaporation)
	3	For the full dataset including raw data, k-factor and QC samples, the reader is advised to consult the files referred to below.

Files name(s) of raw data

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

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

14/06/2019 | Stephan Richter

Date | Signature Analyst | Name + Signature Laboratory Responsible

Laboratory Name: NML

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doi:10.2760/59260

ISBN 978-92-76-40041-7