



Nuclear Reference Material Program

U.S. Department of Energy



Certificate of Analysis

Certified Reference Material 125A

Uranium (UO₂) Assay, Isotopic, and Radiochronometric Standard, 4.0 % U-235, 5.4-gram Pellet

Description: Certified Reference Material (CRM) 125A is a uranium mass fraction, isotope-amount ratio, and radiochronometric standard. Each unit of CRM 125A consists of one enriched uranium dioxide (UO₂) pellet with a mass of approximately 5.4 grams. Certified isotope composition, assay, and radiochronometric values are reported in Table 1. Supplemental non-certified values are provided in Table 2.

Table 1. Certified Property Values and Uncertainties ^(a)

	g g⁻¹			g mol⁻¹	
Uranium Mass Fraction:	0.88129			Molar Mass:	237.927291
Uncertainty:	0.00014			Uncertainty:	0.000071
	$n(^{234}\text{U})/n(^{238}\text{U})$	$n(^{235}\text{U})/n(^{238}\text{U})$	$n(^{236}\text{U})/n(^{238}\text{U})$		
Isotope-Amount Ratio:	0.00039130	0.042301	0.0000040754		
Uncertainty:	0.00000038	0.000025	0.0000000047		
	$n(^{234}\text{U})/n(\text{U})$	$n(^{235}\text{U})/n(\text{U})$	$n(^{236}\text{U})/n(\text{U})$	$n(^{238}\text{U})/n(\text{U})$	
Isotope-Amount Fraction (•100):	0.037528	4.0569	0.00039085	95.9052	
Uncertainty:	0.000037	0.0023	0.00000045	0.0023	
	$m(^{234}\text{U})/m(\text{U})$	$m(^{235}\text{U})/m(\text{U})$	$m(^{236}\text{U})/m(\text{U})$	$m(^{238}\text{U})/m(\text{U})$	
Isotope-Mass Fraction (•100):	0.036915	4.0077	0.00038776	95.9550	
Uncertainty:	0.000036	0.0023	0.00000045	0.0023	
	Model Purification Date:		August 18, 1994		
	Uncertainty:		116 days		

^(a) Reported numerical uncertainties for certified 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).

Intended use: CRM 125A is a uranium mass fraction, isotope-amount ratio, and radiochronometric standard intended for use in calibration of and/or quality control for analysis of uranium in fabricated fuel form. The isotope-amount fraction and isotope-mass 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 125A values.

Storage: To maintain the integrity of an unused CRM unit, it should remain in the original packaging and should be stored in a dry, temperature-controlled location.

Period of validity: When stored in its original, unopened container, the certification of this material is valid indefinitely. The NRMP will notify customers should degradation be detected.

Minimum sample size: Certification and/or verification measurements for uranium mass fraction, isotope-amount ratios, and model purification date were performed on a random sampling of UO₂ pellets. All analyses were performed on single pellets that were dissolved in their entirety. Accordingly, the material homogeneity for the attribute values is not certified for samples smaller than a single UO₂ pellet.

Note that small quantities of refractory particulates have been observed following nitric acid-only sample dissolution but do not have a discernible effect on the measurement of values cited in this certificate. The total metal impurity content is estimated to be less than 80 µg g⁻¹ pellet as determined by optical emission spectrometry (See Table 2). This impurity content value is provided for information only and is not certified. Therefore, if this material is analyzed by gravimetry, it is the responsibility of the user to determine and subtract impurity content, as necessary.

Instructions for handling: The material in the unit is radioactive. This radioactive material should be handled only by qualified individuals. To minimize personnel exposure, appropriate facilities and personal protective equipment should be used. Refer to the SDS for further information.

Traceability statement: The certified isotope amount ratios and isotope amount fractions are traceable to the SI unit mole. The certified isotope mass fractions and uranium mass fraction are traceable to the SI unit kilogram. The certified uranium molar mass is traceable to the SI units mole and kilogram..

Measurement uncertainty:

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 certified values consist of both Type A and Type B evaluated components. For the mass fraction, the standard deviation of the titrations is applied as a Type A evaluated component, and the combined standard uncertainty of the CRM 99 oxidimetric standard is applied as a Type B evaluated component. For isotope-amount ratios the standard deviations associated with isotopic ratios measured for the samples and the n(²³⁵U)/n(²³⁸U) ratio of CRM U030A are applied as Type A evaluated components. The combined standard uncertainties for the certificate-derived n(²³⁵U)/n(²³⁸U) ratio of U030A and components to account for additional sources of uncertainty associated with background corrections and analytical biases are applied as Type B evaluated components. Isotope mass fractions incorporate an additional Type B evaluated component associated with the uncertainty of the atomic mass for the U isotopes. For the Model Purification Date, the standard deviation of the replicate age determinations is applied as a Type A evaluated uncertainty component. The SRM 4328C certificate uncertainty, CRM 125A U mass fraction and isotope mass fraction uncertainties, U and Th half-life uncertainties, and Th activity data correction factors are all applied as Type B evaluated uncertainty components. The coverage factor (k) for each expanded uncertainty is the Student's t-factor necessary to provide a 95 % level of confidence (k ≈ 2 for all values cited in this certificate). A more detailed explanation of measurement uncertainty can be obtained upon request from NRMP.

Additional information: In 1994, the New Brunswick Laboratory (NBL) procured UO₂ fuel pellets to serve as CRM 125A from Westinghouse Commercial Nuclear Fuels (CNFD), Analytical Services Laboratories, Columbia, SC. The NBL specified all pellets to be procured from a single production lot, from a single source lot of UF₆, with no scrap recycle. Uranium mass fraction for CRM 125A was originally determined in 1997 by the NBL High Precision Titrimetric method using CRM 99 Potassium Dichromate Oxidimetric Standard as the titrant. The CRM 112A Uranium Metal Assay and Isotopic Standard was used as a control to verify performance of the measurement system. In addition, gravimetric analyses were performed to verify that pellet-to-pellet inhomogeneity was negligible. Traceability of the measurement results is primarily established by direct determination of uranium mass fraction based on the titration of uranium using CRM 99 Potassium Dichromate Oxidimetric Standard.

In 2011 to 2012, a detailed thermal ionization mass spectrometry measurement campaign was performed on the CRM 125A to refine uranium isotope-amount ratios and uncertainties. Mass discrimination calibrations were performed on a sample-turret basis using multiple measurements of CRM U030A Uranium Isotopic Standard. Analyses of CRM U045 Uranium Isotopic Standard were performed to verify that mass spectrometric measurements were in control. Traceability of the isotope-amount ratio measurements for CRM 125A is primarily established by calibration of the mass spectrometer using measurements of CRM U030A Uranium Isotopic Standard that was originally provided by the National Bureau of Standards (now known as the National Institute of Standards and Technology) as SRM U030a Uranium Isotopic Standard.

In 2011 to 2012, a detailed study was performed to determine the model U purification date for the CRM 125A pellets. The certified purification date is a derived value based on the ²³⁴U-²³⁰Th isotope parent daughter system (Equation 1) and is consistent with independent measurements using the ²³⁵U-²³¹Pa isotope parent daughter system. The certified value represents results for combined measurements from 3 laboratories: New Brunswick Laboratory and 2 facilities at Argonne National Laboratory. The variables necessary for the derived value include ²³⁴U content (N_{234U}), ²³⁰Th content (N_{230Th}), and the decay constants of both isotopes (λ_{234U}, λ_{230Th}). The ²³⁴U content was derived from the certified mass fraction and isotope mass fractions. The ²³⁰Th content was determined by isotope dilution α spectrometry using ²²⁹Th Radioactivity Standard, SRM 4328C, provided by the National Institute of Standards and Technology. It is the

direct comparison of measured activity between ^{230}Th in the sample and the SRM 4328C ^{229}Th added to the sample that provides traceability for the measurements used to determine the certified value. The model purification date, based on the combined measurements, is provided as a fixed certified value for this material because the ^{230}Th content of CRM 125A changes continuously due to in-growth. For information purposes, the composite value for ^{230}Th content, as of January 2012, is 7.0×10^{-11} mols/g pellet. The decay constants used for the purification date calculations are $\lambda_{230\text{Th}} = (9.193 \times 10^{-6} \pm 0.073 \times 10^{-6})/\text{year}$ and $\lambda_{234\text{U}} = (2.823 \times 10^{-6} \pm 0.014 \times 10^{-6})/\text{year}$ (calculated from half-lives provided in the NNDC Nuclear Wallet Card Database June 1, 2012).

Equation 1: Model Purification Date:

$$t_{\text{separation}} = \frac{\ln \left[1 - \left(\frac{\lambda_{230\text{Th}} - \lambda_{234}}{\lambda_{234}} \right) \times \left(\frac{N_{230\text{Th}}}{N_{230\text{Th}}} \right) \right]}{(\lambda_{234\text{U}} - \lambda_{230\text{Th}})}$$

$t_{\text{separation}}$ is the date of Th separation for the analysis samples.

Table 2. Non-Certified Values for Trace Impurity Mass Fractions ($\mu\text{g g}^{-1}$)^(a)

Element	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Al	<10.0	<10.0	13.0	<10.0	12.0
Bi	<1.0	<1.0	<1.0	<1.0	<1.0
B	0.3	<0.3	<0.3	<0.3	<0.3
Cd	<0.3	<0.3	<0.3	<0.3	<0.3
Ca	<10	<10.0	<10.0	<10.0	<10.0
Cr	1.7	1.8	1.9	1.4	1.0
Co	<0.5	0.6	0.7	0.9	0.8
Cu	<1.0	<1.0	<1.0	<1.0	<1.0
In	<0.5	<0.5	<0.5	<0.5	<0.5
Fe	<10	<10	<10	<10	<10
Pb	<0.5	<0.5	<0.5	<0.5	<0.5
Mg	<0.5	<0.5	0.8	<0.5	<0.5
Mn	<1.0	1.3	1.4	1.1	1.0
Mo	0.9	6.4	0.9	0.8	0.7
Ni	<5.0	<5.0	<5.0	<5.0	<5.0
Si	<10	<10.0	<10.0	<10.0	<10.0
Sn	<0.5	<0.5	<0.5	<0.5	<0.5
Ti	<1.0	<1.0	<1.0	<1.0	<1.0
W	<10	<10.0	<10.0	<10.0	<10.0
V	<0.5	<0.5	<0.5	<0.5	<0.5
Zn	<1.0	<1.0	<1.0	<1.0	<1.0
Ba	<10	<10.0	<10.0	<10.0	<10.0
Na	<4.0	<4.0	<4.0	<4.0	<4.0
Zr	<50	<50	<50	<50	<50
EBC ^(b)	0.455	0.459	0.459	0.459	0.457

^(a) The reported values were received from Westinghouse Commercial Nuclear Fuels (CNFD), Analytical Services Laboratories, and are believed to have been performed on samples of the source UO_2 powder prior to production of the pellets. Limited information on analytical methods was provided, though a note was included mentioning carrier distillation optical emission spectrometry. This data was reported on August 8, 1994.

^(b) EBC = "equivalent boron content" - refers to apparent cross-section.

In 2016 the New Brunswick Laboratory transitioned to a program office within the Department of Energy and is now operating within the National Nuclear Security Administration (NNSA) as the Nuclear Reference Material Program (NRMP).

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