



Certificate of Analysis
Certified Reference Material U045 (5 mg)
Uranyl Nitrate Isotopic Standard, 4.5% U-235
5 mg U in Solution Form

Description: Certified Reference Material (CRM) U045 is a uranium isotope-amount ratio standard. Each unit of U045 contains approximately 5 mg of uranium dissolved in approximately 5 mL of a 1 mol L⁻¹ nitric acid solution contained in a sealed 5 mL glass ampoule. Certified isotope composition values are reported in Table 1. Additional non-certified values are provided in Table 2.

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

	$n(^{234}\text{U})/n(^{238}\text{U})$	$n(^{235}\text{U})/n(^{238}\text{U})$	$n(^{236}\text{U})/n(^{238}\text{U})$	
Isotope-Amount Ratio:	0.00040579	0.047310	0.00028983	
Uncertainty:	0.00000031	0.000025	0.00000027	
Isotope-Amount Fraction	$n(^{234}\text{U})/n(\text{U})$	$n(^{235}\text{U})/n(\text{U})$	$n(^{236}\text{U})/n(\text{U})$	$n(^{238}\text{U})/n(\text{U})$
(•100):	0.038720	4.5143	0.027655	95.4193
Uncertainty:	0.000029	0.0023	0.000025	0.0023
Isotope-Mass Fraction	$m(^{234}\text{U})/m(\text{U})$	$m(^{235}\text{U})/m(\text{U})$	$m(^{236}\text{U})/m(\text{U})$	$m(^{238}\text{U})/m(\text{U})$
(•100):	0.038090	4.4599	0.027438	95.4746
Uncertainty:	0.000029	0.0023	0.000025	0.0023
	g mol⁻¹			
Uranium Molar Mass:	237.912937			
Uncertainty:	0.000070			

^(a) Reported numerical uncertainties are expressed as expanded uncertainties (U) at the 95 % level of confidence, where $U = k \cdot u_c$ and k is the coverage factor and u_c is the combined standard uncertainty. The last figure in the reported values and their uncertainties is provided for information purposes only and is not intended to convey a significant degree of reliability.

Intended use: CRM U045 is intended primarily for use as an isotopic standard in mass spectrometric analysis of uranium.

Storage: This material should be stored in its original packaging under normal laboratory environmental conditions.

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

Minimum sample size: The material is considered a pure homogenous solution. No minimum sample size is declared.

Instructions for handling: The ampoule should be handled under proper radiologically-controlled conditions at all times. Care should be taken when scoring and breaking the ampoule to avoid injury and possible contamination. The material in the CRM 113B 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 Safety Data Sheet for further information.

Traceability statement: Certified isotope-amount ratios and fractions are traceable to the SI base unit of the mole. Certified isotope-mass fractions and the uranium molar mass are traceable to the SI base units of the mole and the kilogram.

Additional information: CRM U045 was prepared from CRM 113-B, Uranium Hexafluoride Assay and Isotopic Standard. The solid uranium hexafluoride was hydrolyzed, converted to U_3O_8 by ignition, dissolved in nitric acid, and ampouled. A number of filled and sealed ampoules were selected according to a statistical sampling plan for certification of the uranium isotopic composition.

The uranium isotopic composition and the relative atomic mass of uranium were determined by thermal ionization mass spectrometry. Uranium isotope ratio measurements were performed by two analysts each using different mass spectrometers. The first instrument, utilizing a Total Evaporation procedure, was used to generate values used for the certification of the $^{235}U/^{238}U$ ratio only. A second instrument, utilizing the NBL-Modified Total Evaporation procedure, was used to generate values for all certified ratios. CRMs U030-A, U050 and U500 were used for mass fractionation corrections and quality control. Metrological traceability to the SI base unit of the kilogram for all mass fractions and the molar mass was established through the use and incorporation of uncertainties associated with CRM U030-A. The isotopic analysis results for CRM U045 and CRM 113-B were in very good statistical agreement, except for a small but statistically significant difference in the $^{236}U/^{238}U$ ratios and ^{236}U abundances. The results from the two materials were combined to yield the final certified values for isotopic composition and their uncertainties.

The $^{232}U/^{238}U$ ratio and $^{233}U/^{238}U$ ratio values for this material are also provided as non-certified values, determined in separate studies performed from 2012 to 2013. The $^{232}U/^{238}U$ isotope-amount ratio was measured by α -spectrometry with ^{232}U and ^{234}U converted from α counts to atoms using half-lives provided in the NNDC Nuclear Wallet Card Database (June 1, 2012). The resulting ratio of isotopes was normalized to ^{238}U using the previously certified CRM U045 $^{234}U/^{238}U$ isotope amount ratio. Measurement of the $^{233}U/^{238}U$ ratio was by TIMS using a combined secondary electron multiplier - Faraday Cup method with mass discrimination internally corrected using the previously certified $^{235}U/^{238}U$ ratio. Although these non-certified values represent the best information available for the quantity value and uncertainty of the measurands, they may still reflect unevaluated sources of error and uncertainty and are not certified.

Table 2. Non-Certified Property Values and Uncertainties ^(a)

	$n(^{232}U)/n(^{238}U)$	$n(^{233}U)/n(^{238}U)$
Isotope-Amount Ratio:	8.6×10^{-12}	2.438×10^{-7}
Uncertainty:	1.3×10^{-12}	0.032×10^{-7}

^(a) The reference date for these values is 19 May 2014.

Measurement uncertainty: The expanded uncertainty (U) for a certified property of CRM U045 defines an interval around the value of the property. The magnitude of this interval is obtained by multiplying the combined standard uncertainty (u_c) by a coverage factor (k). The coverage factor, k, is the Student's t factor based on the effective degrees of freedom to provide a 95 % level of confidence. The combined standard uncertainties (u_c) for uranium isotopic parameters consist of Type A components derived from standard deviations associated with isotopic ratio measurements of the samples and the measurements of the $^{235}U/^{238}U$ ratio of CRM U030-A, and Type B components which are based on the standard uncertainties derived from the CRM U030-A certified value for the $^{235}U/^{238}U$ ratio.

Project Support: Characterization analyses for $^{232}U/^{238}U$ isotope-amount ratio and $^{233}U/^{238}U$ isotope ratio measurements were funded by the Department of Homeland Security, National Technical Nuclear Forensic Center (NTNFC) under Inter-Agency Agreement HSHQDC-10-X-00135.

In 2016 NBL 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).