National Institute of Standards & Technology
Certificate

Standard Reference Material® 4321C

Natural Uranium Radioactivity Standard

This Standard Reference Material (SRM) consists of a solution of a standardized and certified quantity of radioactive uranium-238, uranium-235, and uranium-234 in a suitably stable and homogeneous matrix. It is intended primarily for the calibration of instruments that are used to measure radioactivity and for the monitoring of radiochemical procedures. The solution, whose composition is specified in Table 1, is contained in a flame-sealed, 5 mL, NIST, borosilicate-glass ampoule (see Note 1)*.

The certified massic activities for the uranium isotopes at a **Reference Time of 1200 EST, 1 August 1997**, are:

Uranium-238: (242.0 ± 1.5) Bq•g^{-1}

Uranium-235: (11.14 ± 0.07) Bq•g^{-1}

Uranium-234: (233.1 ± 2.2) Bq•g^{-1}

Additional physical, chemical, and radiological properties for the SRM, as well as details on the standardization method, are given in Table 1. Uncertainty intervals for certified quantities are expanded (k = 2) uncertainties calculated according to the JCGM and NIST Guidelines (see Note 2). Table 2 contains a specification of the components that comprise the uncertainty analyses.

The certification of this SRM, within the measurement uncertainties specified, is valid for at least five (5) years after receipt. The solution matrix, in an unopened ampoule, is believed to be indefinitely homogeneous and stable, within its half-life-dependent, useful lifetime. NIST will monitor this material and will report any substantive changes in certification to the purchaser. Should any of the certified values change, purchasers of this SRM will be notified of the change by NIST.

This SRM may represent a radiological hazard and a chemical hazard. Consult the Material Safety Data Sheet (MSDS), enclosed with the SRM shipment, for details (see Note 1).

This Standard Reference Material was prepared in the Physics Laboratory, Radiation Physics Division, Radioactivity Group, Dr. M.P. Unterweger, Acting Group Leader. Overall technical direction and physical measurements leading to certification were provided by Dr. L.L. Lucas of the Radioactivity Group.

Support aspects involved in the preparation, certification, and issuance of this SRM were coordinated through the Office of Reference Materials.

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Certificate Revision History on Last Page

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Table 1. Properties of SRM 4321C

Certified values

Radionuclides	**Natural Uranium (Mixture of ^{238}U, ^{235}U,and ^{234}U)**
Reference time	**1200 EST, 1 August 1997**
Massic activities of the solution	**^{238}U : 242.0 Bq•g^{-1}** **^{235}U : 11.14 Bq•g^{-1}** **^{234}U : 233.1 Bq•g^{-1}**
Relative expanded uncertainties (k = 2)	**^{238}U : 0.60 %** (see Note 2)* **^{235}U : 0.60 %** (see Note 2) **^{234}U : 0.96 %** (see Note 2)

Uncertified information

Source description	Liquid in flame-sealed, 5 mL NIST borosilicate ampoule (see Note 1)
Solution composition	1.0 mol•L^{-1} HNO_3 with 30 mg $UO_2(NO_3)_2$ per gram of solution
Solution density	(1.053 ± 0.001) g•mL^{-1} at 21.4 °C (see Note 3)
Solution mass	(5.258 ± 0.002) g (see Note 3)
Mass fraction of uranium	(0.01960 ± 0.00010) g•g^{-1} (see Note 3)
Photon-emitting impurities	None detected (see Note 4)
Half-lifes used [1]	^{238}U : (4.468 ± 0.003) x 10^9 a ‡ ^{235}U : (7.038 ± 0.005) x 10^8 a ‡ ^{234}U : (2.455 ± 0.006) x 10^5 a ‡
Calibration method (and instruments)	The certified massic activity for natural uranium was obtained by mass spectrometer, silicon surface-barrier detector, and 4παβ liquid scintillation (LS) counting systems.

‡ See Note 5

Table 2. Uncertainty evaluation for the massic activity for SRM 4321C

	Uncertainty component	Assessment Type †	Relative standard uncertainty contribution on massic activity of Natural Uranium (%)
1	Isotopic uranium atom fraction in SRM 960; standard deviation of the mean for replicate mass-spectrometric measurements for ^{238}U	A	0.001
2	Isotopic uranium atom fraction in SRM 960; standard deviation of the mean for replicate mass-spectrometric measurements for ^{235}U	A	0.07
3	Isotopic uranium atom fraction in SRM 960; standard deviation of the mean for replicate mass-spectrometric measurements for ^{234}U	A	0.3
4	Half life of ^{238}U; standard uncertainty of the half-life	A	0.07
5	Half life of ^{235}U; standard uncertainty of the half-life	A	0.07
6	Half life of ^{234}U; standard uncertainty of the half-life	A	0.24
7	Uranium mass fraction in SRM 960; from SRM960 certificate	B	0.003
8	Quantitative dissolution	B	0.25
9	Gravimetric (mass) measurements	B	0.10
10	Limit for photon-emitting impurities	B	0.10
Relative combined standard uncertainty		^{238}U	**0.30**
		^{235}U	**0.30**
		^{234}U	**0.48**
Relative expanded uncertainty (*k* = 2)		^{238}U	**0.60**
		^{235}U	**0.60**
		^{234}U	**0.96**

† = (A) denotes evaluation by statistical methods; (B) denotes evaluation by other methods.

NOTES

Note 1. Refer to http://www.nist.gov/pml/div682/grp04/srm.cfm for the standardized ampoule dimensions and for assistance and instructions on how to properly open an ampoule. Information on additional storage and handling requirements is also included in the website.

Note 2. The uncertainties on certified values are expanded uncertainties, $U = ku_c$. The quantity u_c is the combined standard uncertainty calculated according to the JCGM and NIST Guides (see references 2 and 3). The combined standard uncertainty is multiplied by a coverage factor of $k = 2$ and was chosen to obtain an approximate 95 % level of confidence.

Note 3. The stated uncertainty is two times the standard uncertainty. See reference 3

Note 4. The estimated lower limits of detection for photon-emitting impurities, expressed as massic photon emission rates are:

$1.4\ s^{-1} \cdot g^{-1}$ for $8\ keV < E < 59\ keV$
$1.1\ s^{-1} \cdot g^{-1}$ for $67\ keV < E < 88\ keV$
$0.5\ s^{-1} \cdot g^{-1}$ for $102\ keV < E < 197\ keV$
$0.3\ s^{-1} \cdot g^{-1}$ for $205\ keV < E < 762\ keV$
$0.2\ s^{-1} \cdot g^{-1}$ for $770\ keV < E < 996\ keV$, and
$0.1\ s^{-1} \cdot g^{-1}$ for $1006\ keV < E < 1900\ keV$

provided that the photons are separated in energy by 4 keV or more from photons emitted in the decay of ^{238}U, ^{235}U, ^{234}U, or their progeny

Note 5. The stated uncertainty is the standard uncertainty. See reference 3.

REFERENCES

[1] Brookhaven National Laboratory; Evaluated Nuclear Structure Data File (ENSDF); *National Nuclear Data Center;* BNL, Upton, NY (2007); available at http://www.nndc.bnl.gov/ensdf/ (accessed Aug 2017).

[2] JCGM 100:2008; *Guide to the Expression of Uncertainty in Measurement;* (GUM 1995 with Minor Corrections), Joint Committee for Guides in Metrology: BIPM, Sevres Cedex, France (2008); available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_E.pdf (accessed Aug 2017).

[3] Taylor, B.N.; Kuyatt, C.E.; *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*; NIST Technical Note 1297, U.S. Government Printing Office: Washington, DC (1994); available at http://physics.nist.gov/Pubs/ (accessed Aug 2017).

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Certificate Revision History: 04 August 2017 (Correction to solution composition acid; editorial changes); 12 July 2007 (Change of expiration date; editorial changes); 30 November 1997 (Original certificate date).

Users of this SRM should ensure that the Certificate of Analysis in their possession is current. This can be accomplished by contacting the SRM Program: telephone (301) 975-2200; fax (301) 948-3730; e-mail srminfo@nist.gov; or via the Internet at http://www.nist.gov/srm.