National Institute of Standards & Technology

Certificate

Standard Reference Material® 4412H

Molybdenum-99 Radioactivity Standard

Lot Number 42

Ampoule 1

This Standard Reference Material (SRM) consists of a solution of a standardized and certified quantity of radioactive molybdenum-99 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. A unit of SRM 4412H consists of approximately 5 mL of a solution, whose composition is specified in Tables 1 and 2, contained in a flame-sealed borosilicate-glass ampoule [1].

The certified **molybdenum-99** massic activity value, at a **Reference Time of 1500 EST, 25 April 2017**, is:

(510.4 ± 5.1) MBq•g^{-1}

A NIST certified value, as used within the context of this certificate, is a value for which NIST has the highest confidence in its uncertainty assessment. It is a "measurement result" [2] obtained directly or indirectly from a "primary reference measurement procedure" [3]. The certified value is traceable to the derived SI unit, the becquerel (Bq).

Additional physical, chemical, and radiological properties for this SRM, as well as details on the standardization method, are given in Tables 1 and 2. Uncertainties for the certified quantities are expanded ($k = 2$). The uncertainties are calculated according to the ISO and NIST Guides [4,5]. Table 3 contains a specification of the components that comprise the uncertainty analyses.

Expiration of Certification: The certification of **SRM 4412H** is valid, within the measurement uncertainty specified, within its half-life-dependent useful lifetime, provided the SRM is handled in accordance with instructions given in this certificate (see "Instructions for Handling and Storage"). The certification is nullified if the SRM is damaged, contaminated, or otherwise modified.

Maintenance of Certification: NIST will monitor this SRM over the period of its certification. If substantive technical changes occur that affect the certification, NIST will notify the purchaser.

Radiological and Chemical Hazard: Consult the Safety Data Sheet (SDS), enclosed with the SRM shipment, for radiological and chemical hazard information.

This SRM was prepared in the Physical Measurement Laboratory, Radiation Physics Division, Radioactivity Group, M.P. Unterweger, Group Leader. The overall production, technical direction and physical measurement leading to certification were provided by W. Regits and K. Neal, Guest Researchers from NRMAP, Incorporated.

Support aspects involved in the issuance of this SRM were coordinated through the NIST Measurement Services Division.

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Table 1. Certified Massic Activity of SRM 4412H, Lot 42, Ampoule 1

Radionuclide	**Molybdenum-99**
Reference time	**1500 EST, 25 April 2017**
Massic activity of the solution	**510.4 MBq•g^{-1}**
Relative expanded uncertainty (k = 2)	**1.0 %**[(a)]

[(a)]The uncertainties on certified values are expanded uncertainties, $U = ku_c$. The quantity u_c is the combined standard uncertainty calculated according to the ISO and NIST Guides [4,5]. The combined standard uncertainty is multiplied by a coverage factor of k = 2 and was chosen to obtain an approximate 95 % level of confidence.

Table 2. Uncertified Information of SRM 4412H, Lot 42, Ampoule 1

Source description	Liquid in a flame-sealed 5-mL NIST borosilicate ampoule [1]
Solution composition	0.1 mol•L^{-1} NaOH with 942 µg Na_2MoO_4 per gram of solution
Solution density	(1.002 ± 0.002) g•mL^{-1} at 20.0 °C[(a)]
Solution mass	(5.0178 ± 0.0003) g[(a)]
Photon-emitting impurities (at reference time)	None detected [(b)]
Half-life used	^{99}Mo: (2.7479 ± 0.0006) d[(c)]
Calibration method (and instruments)	Measurements of ionization current ratios relative to radium-226 reference sources using NIST pressurized "4π"γ ionization chamber "B" calibrated using a molybdenum-99 solution whose activity was determined by the 4πβ-γ coincidence efficiency-extrapolation technique.

[(a)]The stated uncertainty is two times the standard uncertainty.
[(b)]The estimated lower limits of detection for photon-emitting impurities, expressed as massic photon emission rates, as of 3 May 2017 were:

1.0×10^5 s^{-1}•g^{-1} for energies between 35 keV and 50 keV,
3.4×10^4 s^{-1}•g^{-1} for energies between 55 keV and 120 keV,
7.1×10^4 s^{-1}•g^{-1} for energies between 125 keV and 155 keV,
2.0×10^4 s^{-1}•g^{-1} for energies between 160 keV and 195 keV,
1.4×10^4 s^{-1}•g^{-1} for energies between 200 keV and 720 keV,
4.4×10^4 s^{-1}•g^{-1} for energies between 730 keV and 750 keV,
2.6×10^4 s^{-1}•g^{-1} for energies between 760 keV and 790 keV,
5.2×10^3 s^{-1}•g^{-1} for energies between 800 keV and 840 keV,
3.3×10^3 s^{-1}•g^{-1} for energies between 850 keV and 940 keV,
4.7×10^3 s^{-1}•g^{-1} for energies between 950 keV and 980 keV,
2.6×10^3 s^{-1}•g^{-1} for energies between 990 keV and 1430 keV,
3.4×10^3 s^{-1}•g^{-1} for energies between 1440 keV and 1480 keV, and
2.3×10^3 s^{-1}•g^{-1} for energies between 1490 keV and 2000 keV,

provided that any impurity photons are separated by four keV or more from photons emitted in the decay of molybdenum-99/technetium-99m equilibrium mixture.

[(c)]The stated uncertainty is the standard uncertainty. See reference 6.

Table 3. Uncertainty Evaluation for the Massic Activity of SRM 4412H, Lot 42

	Uncertainty component	Assessment Type[(a)]	Relative standard uncertainty contribution on massic activity of molybdenum-99 (%)
1	Ionization-chamber measurement precision for the low-level solution (SRM 4412L, Lot 42); standard deviation of the mean for five sets of measurements on ten ampoules (n=10)	A	0.05
2	"4π"γ ionization-chamber calibration factor	B	0.48
3	Decay correction for radium-226 reference source to correct the calibration factor (for half-life uncertainty of 0.44 %)	B	0.001
4	Radium reference source positioning	B	0.05
5	Radium-226 reference sources ratio	B	0.02
6	Electrometer response linearity	B	0.10
7	Gravimetric mass measurements	B	0.05
8	Gravimetric dilution of SRM 4412H to make SRM 4412L	B	0.05
9	Decay correction for molybdenum-99 (for half-life uncertainty of 0.022 %)	B	0.0001
10	Detection limits for photon-emitting impurities	B	0.003
Relative combined standard uncertainty			**0.50**
Relative expanded uncertainty (k = 2)			**1.0**

[(a)]Type A denotes evaluation by statistical methods; Type B denotes evaluation by other methods.

INSTRUCTIONS FOR HANDLING AND STORAGE

Handling: If the ampoule is transported, it should be packed, marked, labeled, and shipped in accordance with the applicable national, international, and carrier regulations. The solution in the ampoule is a dangerous good (hazardous material) because of the radioactivity. The ampoule should be opened only by persons qualified to handle both radioactive material and alkaline and/or acidic solutions. Appropriate shielding and/or distance should be used to minimize personnel exposure.

Storage: SRM 4412H should be stored and used at a temperature between 5 °C and 65 °C. The ampoule (or any subsequent container) should always be clearly marked as containing radioactive material.

REFERENCES

[1] NIST Physical Measurement Laboratory; *Storage and Handling of Radioactive Standard Reference Materials, Ampoule Specifications and Opening Procedure*; available at http://www.nist.gov/pml/div682/grp04/srm.cfm.

[2] JCGM 200:2012; *International Vocabulary of Metrology - Basic and General Concepts and Associated Terms (VIM)* (2008 version with Minor Corrections), 3rd edition; Joint Committee for Guides in Metrology: BIPM, Sèvres Cedex, France; p. 19 (2012); available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_200_2012.pdf.

[3] JCGM 200:2012; *International Vocabulary of Metrology - Basic and General Concepts and Associated Terms (VIM)* (2008 version with Minor Corrections), 3rd edition; Joint Committee for Guides in Metrology: BIPM, Sèvres Cedex, France; p. 18 (2012); available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_200_2012.pdf.

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

[5] 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 https://www.nist.gov/pml/nist-technical-note-1297.

[6] The Evaluated Nuclear Structure Data File (ENSDF), National Nuclear Data Center, Brookhaven National Laboratory, Upton, New York, full evaluation 2011, Nuclear Data Sheets 112, 275 (2011); available at http://www.nndc.bnl.gov/ensdf/index.jsp (accessed April 2017).

Users of this SRM should ensure that the Certificate 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.