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Reference Material 8599
Henderson Molybdenite
REFERENCE MATERIAL INFORMATION SHEET

Purpose: The non-certified values delivered by this Reference Material (RM) are intended for use in standardizing ^{187}Re-^{187}Os absolute age measurements on molybdenite (MoS_2) ores.

Description: A unit of RM 8599 is supplied in a glass bottle containing approximately 10 g of MoS_2 powder.

Non-Certified Value: A non-certified age for the Henderson Molybdenite is provided in Table 1. A non-certified value [1] is the best estimate of the true value; however, the value does not meet NIST criteria for certification and is provided with associated uncertainties that may reflect only measurement precision and may not include all sources of uncertainty.

Table 1. Non-Certified Age Value for RM 8599

Age[(a)] (Ma)	U[(b)] (Ma)	Data Source
27.66	± 0.10	Reference 2

(a) The ^{187}Re decay constant (λ ^{187}Re) used for the age calculation is 1.666×10^{-11} a^{-1} [3].

(b) The expanded uncertainty for the age, computed as $U = ku_c$, is $k = 3.18$ times the standard uncertainty of the mean, u_c, of the means of the reported values in reference 2, treated as four independent draws from a normal distribution by lab and method. The coverage factor, k, was obtained from the Student's t distribution with 3 degrees of freedom and a confidence level of 95 %.

The non-certified value listed in Table 1 was obtained by combining data from 47 independent isotope dilution measurements utilizing two different mixed Re-Os spikes at two expert labs using solid-source negative thermal ionization mass spectrometers. Details of the experimental procedures and results are published in reference 2. No evidence of isotopic heterogeneity was found and the expanded uncertainty for the age can be treated as reflecting random measurement error as well as the random variation between labs and methods.

Additional Information: Values of potential interest to users and additional information are provided in Appendix A.

Period of Validity: The non-certified values are valid indefinitely, within the measurement uncertainty specified. The value assignments are nullified if the material is stored or used improperly, damaged, contaminated, or otherwise modified.

Maintenance of Non-Certified Values: NIST will monitor this material to the end of its period of validity. If substantive technical changes occur that affect the non-certified values during this period, NIST will update this Reference Material Information Sheet and notify registered users. RM users can register online from a link available on the NIST SRM website or fill out the user registration form that is supplied with the RM. Registration will facilitate notification. Before making use of any of the values delivered by this material, users should verify they have the most recent version of this documentation, available through the NIST SRM website (https://www.nist.gov/srm).

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Chemical Sciences Division
Information Sheet Revision History on Page 2

Steven J. Choquette, Director
Office of Reference Materials

Safety: Please consult the Safety Data Sheet provided with this material.

Storage: Store under normal laboratory conditions. The molybdenite powder should be kept capped in its original glass container in a dry environment when not being used.

REFERENCES

[1] Beauchamp, C.R.; Camara, J.E.; Carney, J.; Choquette, S.J.; Cole, K.D.; DeRose, P.C.; Duewer, D.L.; Epstein, M.S.; Kline, M.C.; Lippa, K.A.; Lucon, E.; Molloy, J.; Nelson, M.A.; Phinney, K.W.; Polakoski, M.; Possolo, A.; Sander, L.C.; Schiel, J.E.; Sharpless, K.E.; Toman, B.; Winchester, M.R.; Windover, D.; *Metrological Tools for the Reference Materials and Reference Instruments of the NIST Material Measurement Laboratory*; NIST Special Publication 260-136, 2021 edition; U.S. Government Printing Office: Washington, DC (2021); available at https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.260-136-2021.pdf (accessed Oct 2022).

[2] Markey, R.; Stein, H.J.; Hannah, J.L., Morgan, J.W.; Zimmerman, A.; Selby, D.; Creaser, R.A.: *Standardizing Re–Os geochronology: A new molybdenite Reference Material (Henderson, USA) and the stoichiometry of Os salts*; Chem. Geol., Vol. 244, pp. 74–87 (2007).

[3] Smoliar, M.I.; Walker, R.J.; Morgan, J.W.: *Re–Os isotope constraints on the age of Group IIA, IIIA, IVA, and IVB iron meteorites*; Science, Vol. 271, pp. 1099–1102 (1996).

[4] Seedorff, E.; Einaudi, M.T.; *Henderson Porphyry Molybdenum System, Colorado: I. Sequence and Abundance of Hydrothermal Mineral Assemblages, Flow Paths of Evolving Fluids, and Evolutionary Style;* Econ. Geol., Vol. 99, pp. 3–37 (2004).

[5] Seedorff, E.; Einaudi, M.T.; *Henderson Porphyry Molybdenum System, Colorado: II. Decoupling of Introduction and Deposition of Metals During Geochemical Evolution of Hydrothermal Fluids;* Econ. Geol., Vol. 99, pp. 39–72 (2004).

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Certain commercial equipment, instruments, or materials may be identified in this Reference Material Information Sheet to adequately specify the experimental procedure. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

Users of this RM should ensure that the Reference Material Information Sheet in their possession is current. This can be accomplished by contacting the Office of Reference Materials 100 Bureau Drive, Stop 2300, Gaithersburg, MD 20899-2300; telephone (301) 975-2200; e-mail srminfo@nist.gov; or the Internet at https://www.nist.gov/srm.

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APPENDIX A

Values of Potential Interest to Users: Values listed in Table A1 were obtained by combining data from 47 independent isotope dilution measurements utilizing two different mixed Re-Os spikes at two expert labs using solid-source negative thermal ionization mass spectrometers. Details of the experimental procedures and results are published in [4]. Statistically speaking, these data sets effectively have only two pieces of information concerning the uncertainty of the Re and ^{187}Os amounts due to between-lab variation. Because the action controlling the uncertainty is the variation between labs, the two different spikes used give information on the within-lab variation with changes in the spike, but that variation is inconsequential when compared with the between-lab differences. The two different spike methods become, in effect, additional replicates that confirm the within-lab variances but give no information concerning the between-lab issue. For this reason, the amount mass fractions for Re and ^{187}Os are presented as values of potential interest to users.

Table A1. Mass Fraction Values of Potential Interest for RM 8599

Re (mg/kg)	^{187}Os (µg/kg)
11.2	3.236

Preparation and Analysis: The molybdenite in this RM was taken from the Henderson mill in the Front Range of the Rocky Mountains, Colorado. The Henderson ore body is a Climax-type stockwork porphyry molybdenum deposit of Oligocene age associated with a granitic intrusive complex. This molybdenite deposit was chosen because the ore was milled on site and only Henderson ore has ever been processed in that mill. The molybdenite ore is nearly mono-mineralic (hexagonal polytype $2H_1$) and emplacement of the ore body is thought to have taken place over a geologically short period of time [4,5]. The deposit is young and contains relatively low concentrations of Re and therefore modest amounts of radiogenic ^{187}Os. The bulk sample of milled molybdenite has a particle size of ≈46 µm (≈300 mesh). After cleaning and purification, the sample was mixed, split, and bottled. Additional geological details are provided in reference 4.

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