United States Geological Survey

Reston Stable Isotope Laboratory

Report of Stable Isotopic Composition

Reference Material GFLES-3-0.25 µL

(Hydrogen and Oxygen Isotopes in Water Sealed in a Silver Tube)

This reference material (RM) is intended for calibration of stable hydrogen (δ^2H) and oxygen (δ^{18}O) measurements of unknown water or hydrogen- or oxygen-bearing substances with a TC/EA (thermal conversion/elemental analyzer) and an isotope-ratio mass spectrometer by quantifying drift with time and isotope-ratio-scale contraction. This RM consists of 0.25 µL of GFLES-3 sealed in a silver tube [1]. This RM is issued in quantities of 50 sealed silver tubes per bottle. There is no limit on distribution. Glass ampoules containing 5 mL of GFLES-3 water are available from the Reston Stable Isotope Laboratory.

Recommended Values: Stable hydrogen and oxygen isotopic compositions are expressed herein as delta values [2] relative to VSMOW (Vienna Standard Mean Ocean Water) on scales normalized such that the δ^2H, δ^{18}O, and δ^{17}O values of SLAP (Standard Light Antarctic Precipitation) are –428 ‰, –55.5 ‰, and –29.70 ‰, respectively [3,4,5]. Each stable isotopic composition is given as a reference isotope-delta value with an estimated combined uncertainty (1 σ) about the reference value that provides an interval that has about a 68-percent probability of encompassing the true value. The isotopic compositions of GFLES-3-0.25 µL are identical to that of GFLES-3, except that each combined standard uncertainty value (μ_C) has been increased to account for hydrogen and oxygen blanks, both of which were below detection.

Stable hydrogen isotopic composition:	$\delta^2H_{VSMOW\text{-}SLAP} = +280.2 \pm 0.5$ ‰
Stable oxygen isotopic compositions:	$\delta^{18}O_{VSMOW\text{-}SLAP} = -6.14 \pm 0.07$ ‰
	$\delta^{17}O_{VSMOW\text{-}SLAP} = -3.28 \pm 0.45$ ‰
Nominal volume of water:	0.25 µL (Although the RSIL attempts to ensure that each silver tube has the same volume of water, slight differences are observed owing to variations of the inside diameter of the silver tubing provided by the manufacturer. The typical relative variation in volume among 50 tubes is ±3 %, but this cannot be guaranteed.)

Technical coordination for this RM was provided by Haiping Qi of the RSIL.

Reston, Virginia 20192
August 12, 2026

Tyler B. Coplen, Director
Reston Stable Isotope Laboratory

Expiration of Reference Value: The reference values for the isotopic composition of GFLES-3-0.25 µL are valid until December 31, 2034, provided the RM is handled in accordance with the instructions given in this Report of Stable Isotopic Composition (see "Instructions for Use"). A reference value is nullified if the RM is damaged by freezing or other means, contaminated, or otherwise modified.

Source of the RM: This reference water was prepared by gravimetrical mixing of International Atomic Energy Agency (IAEA) reference water IAEA-606 (δ^2H = 15993.6 ± 1.0 ‰) with a well-characterised natural water (δ^2H = –42.7 ± 0.4 ‰) by B. Verstappen-Dumoulin under the direction of Prof. H. A. J. Meijer (Centrum voor IsotopenOnderzoek (CIO), University of Groningen, The Netherlands) [6]. The mixing process was conducted along the lines described in Faghihi et al. [6] in which the same batch of natural water was used. Their uncertainty is inherited from the uncertainty in the natural water, with only negligible influence by the uncertainty in the water enriched in ^{2}H.

Maintenance of RM Certification: The Reston Stable Isotope Laboratory (RSIL) will monitor this RM over the period of its certification. The RSIL will notify the purchaser if substantive technical changes occur that affect the certification before the expiration of this report.

Distribution and Stability: GFLES-3-0.25 µL is stable at normal room temperatures. The RSIL has monitored this RM for a period of six months since the reference water was sealed in the silver tubes, and no change in isotopic composition has been observed. To minimize the potential for contamination, it is recommended that this RM be stored in the container in which it is supplied. The RM container should be sealed well after use to minimize tarnishing of the silver tubes. The RM should not be frozen because it can burst. If shipped, the user should take precautions to ensure that the RM does not freeze.

Instructions for Use: The typical sequence of unknown samples and water references for δ^2H and δ^{18}O analysis is 5 reference waters and 10–15 unknown samples, followed by 5 reference waters and 10–15 unknown samples. The sequence ends with 5 reference waters. Ideally, users may choose to use two reference waters with substantially different isotopic compositions. They could be used at the beginning, the middle, and the end of the analysis sequence to enable satisfactory scale correction and correction of drift with time. The amount of hydrogen or oxygen in references and unknowns should be the same or similar to minimize bias in measurement results. Two or three silver tubes containing GFLES-3-0.25 µL can be combined in a single port of a TC/EA carousel to increase the size of the sample. GFLES-3-0.25 µL silver tube samples should not be used for precise quantification of hydrogen and oxygen mass amount in unknown samples.

Reporting of Stable-isotope-delta Values: The following recommendations are provided for reporting stable hydrogen and oxygen isotope-delta values [4]. It is recommended that:

- The δ^2H values of all hydrogen-bearing substances be expressed relative to VSMOW-SLAP on a scale where the δ^2H of SLAP = –428 ‰ exactly.
- The δ^{18}O values of all oxygen-bearing substances be expressed relative to VSMOW-SLAP or relative to Vienna Peedee belemnite (VPDB; for carbonates) on a scale such that the δ^{18}O of SLAP = –55.5 ‰ relative to VSMOW, and for carbonates, that δ^{18}O of NBS 19 = –2.2 ‰.
- Authors report delta values of international distributed (secondary) isotopic reference materials as though they had been interspersed among and used for normalization of unknowns, as

appropriate, for the measurement method. In this manner, measurement results can be adjusted in the future as analytical methods improve and consensus values of internationally distributed isotopic reference materials change.

- Reporting of delta values relative to SMOW and PDB (Peedee belemnite) be discontinued [7].

REFERENCES

[1] Qi, H., Gröning, M., Coplen, T. B., Buck, B., Mroczkowski, S. J., Brand, W. A., Geilmann, H., and Gehre, M., 2010, Novel silver-tubing method for quantitative introduction of water into high-temperature conversion systems for stable hydrogen and oxygen isotopic measurements: Rapid Communications in Mass Spectrometry, v. 24(13), p. 1821–1827. https://doi.org/10.1002/rcm.4559

[2] Coplen, T. B., 2011, Guidelines and recommended terms for expression of stable-isotope-ratio and gas-ratio measurement results: Rapid Communications in Mass Spectrometry, v. 25(17), p. 2538–2560. https://doi.org/10.1002/rcm.5129

[3] Gonfiantini, R., 1978, Standards for stable isotope measurements in natural compounds: Nature, v. 271, p. 534–536. https://doi.org/10.1038/271534a0

[4] Coplen, T. B., 1994, Reporting of stable hydrogen, carbon, and oxygen isotopic abundances: Pure and Applied Chemistry, v. 66(2), p. 273–276. https://publications.iupac.org/pac/pdf/1994/pdf/6602x0273.pdf

[5] Schoenemann, S. W., Schauer, A. J., and Steig, E. J., 2013, Measurement of SLAP2 and GISP ^{17}O and proposed VSMOW-SLAP normalization for ^{17}O and $^{17}O_{excess}$: Rapid Communications in Mass Spectrometry, v. 27(5), p. 582–590. https://doi.org/10.1002/rcm.6486

[6] Faghihi, V., Verstappen-Dumoulin, B.M.A.A., Jansen, H.G., van Dijk, G., Aerts-Bijma, A.T., Kerstel, E.R.T., Groening, M., and Meijer, H.A.J., 2015, A new high-quality set of singly (^{2}H) and doubly (^{2}H and ^{18}O) stable isotope labeled reference waters for biomedical and other isotope-labeled research, Rapid Communications in Mass Spectrometry, v. 29(4), p. 311–321. https://doi.org/10.1002/rcm.7108

[7] Coplen, T. B., 1995, Discontinuance of SMOW and PDB: Nature, v. 375, p. 285. https://doi.org/10.1038/375285a0