United States Geological Survey

Reston Stable Isotope Laboratory

Report of Stable Isotopic Composition

Reference Material VSMOW

(Hydrogen and Oxygen Isotopes in Water)

This reference material (RM) is an international measurement standard [1] that defines the zero of the δ^2H and δ^{18}O Vienna Standard Mean Ocean Water–Standard Light Antarctic Precipitation (VSMOW-SLAP) isotope scales in water [2] and in all other hydrogen-bearing substances and in selected oxygen bearing-substances [3]. VSMOW was prepared by H. Craig (University of California, La Jolla, California, USA) [2]. A unit distributed by the Reston Stable Isotope Laboratory (RSIL) consists of one autoclaved 5-mL glass ampules of VSMOW. The equivalent name for this RM, as used by the International Atomic Energy Agency (IAEA) is VSMOW, and that use by the U.S. National Institute of Standards and Technology (NIST) is RM 8533 [4]. The δ^2H and δ^{18}O expanded uncertainties of VSMOW are both zero because this RM defines the zero points of the δ^2H and δ^{18}O VSMOW-SLAP scales.

Recommended Values: Stable hydrogen and oxygen isotopic compositions are expressed herein as delta values [5] relative to VSMOW (Standard Mean Ocean Water) on scales normalized such that the δ^2H and δ^{18}O values of SLAP (Standard Light Antarctic Precipitation) are –428 ‰ and –55.5 ‰, respectively [2,3].

Stable hydrogen isotopic composition: $\delta^2H_{VSMOW\text{-}SLAP} = 0$ exactly

Stable oxygen isotopic composition: $\delta^{18}O_{VSMOW\text{-}SLAP} = 0$ exactly

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

Reston, Virginia 20192
September 12, 2026

Tyler B. Coplen, Director
Reston Stable Isotope Laboratory

Expiration of Reference Value: The reference values for the isotopic composition of VSMOW are valid until February 25, 2059, provided the RM is handled in accordance with the instructions given in this Report of Stable Isotopic Composition (see "Instructions for Use"). The reference value is nullified if the glass ampule containing the RM is inadvertently broken.

Source of the RM: At the request of the IAEA, H. Craig (University of California, La Jolla, California, USA) collected ocean water from the equator and 180° longitude, distilled it, and slightly adjusted its hydrogen isotopic composition so that it would be in agreement with that of NBS 1 isotopic reference water [6], which is no longer distributed. He assigned the name SMOW-1 to this material (see Figure 1). To avoid confusion with the virtual SMOW defined in terms of NBS 1 reference water [7], it was recommended at the IAEA Consultants' meeting in 1976 that the name be changed to Vienna-SMOW [2], now abbreviated VSMOW. The RM has been sealed in glass ampules having volumes of 5-mL. Each ampule was inverted and autoclaved at ~120 °C for a minimum of 20 minutes. Ampules with leaks in the glass lost water and were discarded.



Figure 1. Original container of SMOW-1 water (now called VSMOW). Note the lower name below "Do Not Move". "V. Craig" is Valerie Craig, wife of Harmon Craig, and she assisted in the collection and preparation of the RM.

Stability: VSMOW is stable at normal room temperatures. The reference values in this Report of Stable Isotopic Composition apply only to freshly opened ampules.

Instructions for Use: This RM is intended for calibration of instrumentation and for calibrating local laboratory isotopic reference waters. The unused fraction of this RM should be discarded after opening an ampule due to the strong possibility of evaporative losses causing significant isotopic fractionation.

Reporting of Stable-isotope-delta Values: The following recommendations are provided for reporting stable hydrogen and oxygen isotope-delta values [3]. 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, such that δ^{18}O of NBS 19 calcium carbonate = –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 [8].

REFERENCES

[1] BIPM. International Vocabulary of Metrology — Basic and General Concepts and Associated Terms (VIM), 3rd Ed., 2012. https://doi.org/https://doi.org/10.59161/JCGM200-2012

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

[3] Coplen, T. B., 1994, Reporting of stable hydrogen, carbon, and oxygen isotopic abundances: Pure and Applied Chemistry, v. 66(2), p. 273–276. https://doi.org/10.1351/pac199466020273

[4] National Institute of Standards and Technology (NIST), https://tsapps.nist.gov/srmext/certificates/archives/8535.pdf

[5] 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

[6] Gonfiantini, Roberto, 1981, The δ-notation and the mass-spectrometric measurement techniques, *in* Stable Isotope Hydrology: Deuterium and Oxygen-18 in the Water Cycle: Technical Report Series No. 210, Gat, J.R., and Gonfiantini, Roberto, Eds., International Atomic Energy Agency, Vienna, Austria, pp. 35–84.

[7] Craig, Harmon, 1961, Standard for reporting concentrations of deuterium and oxygen-18 in natural waters: Science, v. 133(3467), p. 1833–1834. https://doi.org/10.1126/science.133.3467.1833

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