



Certified Reference Material CERTIFICATE

IAEA-615

Enriched CO₂

IAEA-616

Environmental CO₂

IAEA-617

Depleted CO₂

Certified values of IAEA-615

Parameter	Certified value	Combined standard uncertainty (k=1)
$\delta(^{13}\text{C})_{\text{VPDB}}^{(a)} [\text{‰}]$	-3.495	0.014
$\delta(^{18}\text{O})_{\text{VPDB-CO}_2}^{(a)} [\text{‰}]$	-14.883	0.047

Certified values of IAEA-616

Parameter	Certified value	Combined standard uncertainty (k=1)
$\delta(^{13}\text{C})_{\text{VPDB}}^{(a)} [\text{‰}]$	-9.660	0.013
$\delta(^{18}\text{O})_{\text{VPDB-CO}_2}^{(a)} [\text{‰}]$	-17.123	0.055

Certified values of IAEA-617

Parameter	Certified value	Combined standard uncertainty (k=1)
$\delta(^{13}\text{C})_{\text{VPDB}}^{(a)} [\text{‰}]$	-42.494	0.017
$\delta(^{18}\text{O})_{\text{VPDB-CO}_2}^{(a)} [\text{‰}]$	-44.000	0.029

^(a) In this work, the expression of the quantity oxygen and hydrogen isotope delta follows Skrzypek et al.[1] Alternative expressions for the quantity, e.g. for oxygen, include $\delta(^{18}\text{O}/^{16}\text{O})$ [1] and more commonly $\delta^{18}\text{O}$ following published guidelines [2].

Origin and preparation of the material

For the production of IAEA-615, IAEA-616, and IAEA-617, three CO₂ gas cylinders were used: a 10 L cylinder supplied by Linde Gas GmbH, Stadl-Paura, Austria (IAEA-615) and two 50 L cylinders supplied by SIAD, Italy (IAEA-616 and IAEA-617). All gases had a purity grade of 5.3.

Copper sample tubes were produced from 50 m copper coils connected to a CO₂ cylinder and regulator, with a pressure gauge and an extended stainless-steel capillary installed to limit back-diffusion of air and stabilize pressure during sealing. Prior to preparation, the entire system was flushed with CO₂ at 100 mL min⁻¹ for approximately 40 minutes to ensure complete volume exchange and leak testing was performed. The tubes were then sealed sequentially using clamps, starting from the position closest to the cylinder, allowing pressure equilibration via the open capillary to ambient air pressure, after each sealing step. Each tube was cut 5 cm from the clamp.

Homogeneity of the material

A homogeneity study was performed in accordance with recommendation given in ISO 33405:2024 [3]. Ten units were randomly selected for each reference material (RM) using a stratified random sampling pattern and 3 analyses were performed for each unit under repeatability conditions.

The homogeneity and the relevant uncertainty due to between-unit and within-unit heterogeneity (u_{het}) were evaluated using one-way ANOVA and are summarized in Table 1 for the three RMs.

Table 1: Uncertainty contribution from heterogeneity (u_{het}) for IAEA-615, IAEA-616, IAEA-617.

	$\delta(^{13}\text{C})$ ‰ vs VPDB u_{het}	$\delta(^{18}\text{O})$ ‰ vs VPDB-CO ₂ u_{het}
IAEA-615	0.004	0.017
IAEA-616	0.006	0.006
IAEA-617	0.005	0.008

Stability of the material

The short-term and long-term stability was evaluated in line with ISO 33405:2024 [3]. Results demonstrate that the material is stable under expected transport conditions and during the validity period of this certificate (as indicated below), assuming the CRM is stored as described in the section ‘Instruction for use, handling and storage’.

Characterization study

Characterization is based on data obtained by Dual Inlet – Isotope Ratio Mass Spectrometry (DI-IRMS) at IAEA [4] and two expert laboratories – Max Planck Institute (MPI, Germany) and Jozef Stefan Institute (JSI, Slovenia). Data from three additional laboratories – National Research Council Canada (NRC, Canada), Stable Isotopes Laboratory of the Geotop Centre at UQAM (Geotop, Canada), and the University of Cape Town (UCT, South Africa) were used for confirming the assigned values.

For each reference material, IAEA-TERC analysed 17 copper tubes in three replicates, and each of the other laboratories received three units of each reference material.

Assignment of values

The assigned values were calculated from the results obtained by a reference measurement procedure (DI-IRMS) in three laboratories in accordance with ISO 33405 [3]. The results were modelled using a hierarchical Bayesian random effects model.

The Reference Materials (RM) Certification Committee accepted these assigned values as certified values as presented in this certificate.

The criteria for certification and details on value assignment are available in [5].

Statement on metrological traceability and uncertainty of assigned values

The $\delta(^{13}\text{C})$ and $\delta(^{18}\text{O})$ values and associated uncertainties are traceable to the VPDB and VPDB- CO_2 delta scale, defined by taking the fixed numerical value of +0.00195 for $\delta(^{13}\text{C})$ in the NBS 19 Reference Material, and by taking the fixed numerical value of –0.0022, for $\delta(^{18}\text{O})$ in the CO_2 gas liberated from the NBS 19 Reference Material in reactions with oversaturated phosphoric acid at 25 °C [6].

The measurement uncertainties associated with the assigned values are expressed as combined standard uncertainties (coverage factor $k = 1$) estimated in accordance with JCGM 100:2008 [7] and ISO 33405 [3].

Absolute isotopic abundances

The absolute isotopic abundances have not been determined.

Intended use

The intended use of IAEA-615, IAEA-616, IAEA-617 is as calibrants in the determination of $\delta(^{13}\text{C})_{\text{VPDB}}$ and $\delta(^{18}\text{O})_{\text{VPDB-}\text{CO}_2}$ values in samples analysed by DI-IRMS, ensuring traceability to the VPDB and VPDB- CO_2 isotope delta scales. These materials can also be used as calibrants of $\delta(^{13}\text{C})_{\text{VPDB}}$ and $\delta(^{18}\text{O})_{\text{VPDB-}\text{CO}_2}$ values in samples analysed by laser spectrometry like TILDAS, after dilution, as described in [5] and by continuous flow (CF)-IRMS.

Users are strongly encouraged to prepare their own internal working standards for daily use and to calibrate these in-house materials against these certified reference materials.

Instructions for use, handling and storage

The three RMs are distributed in copper tubes of 6 mm outer diameter, containing approximately 70 μmol of gas.

Instructions for opening the copper tubes and connecting them to DI-IRMS are reported in the webpage.

Until use, it is recommended that these RMs be stored in their original container at ambient temperature.

Limit of distribution

Only one unit per RM per laboratory may be ordered per year. This strategy helps ensure that the material remains available for international use for as long as possible.

Issue and expiry date

The issue date is 3 September 2026, and the expiry date is 2 September 2036, provided the original containers are handled and stored in accordance with the instructions given in this reference sheet (see “Instructions for use, handling and storage”).

The IAEA is monitoring the long-term stability of the material and customers will be informed in case of any observed change.

Legal disclaimer

The IAEA shall under no circumstances be liable for any loss, damage, liability or expense incurred or suffered that is claimed to have resulted from the use of information contained in this Reference Material Certificate.

Citation of this certificate

It is suggested to cite this certificate according to the following example, as appropriate to the citation format used: INTERNATIONAL ATOMIC ENERGY AGENCY, Certified Reference Material Certificate IAEA-615, IAEA-616, IAEA-617, IAEA, Vienna. (The latest version published applies, see “Note” below).

Note

Certified values as stated in this certificate may be updated if more information becomes available. Users of this material should ensure that the certificate in their possession is current. The current version is available on the IAEA’s Reference Products website:

<https://analytical-reference-materials.iaea.org/stable-isotopes>

Further information

For further information regarding this material, please contact the producer:

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References

- [1] SKRZYPEK, G. et al., Minimum requirements for publishing hydrogen, carbon, nitrogen, oxygen and sulfur stable-isotope delta results (IUPAC Technical Report), Pure Appl. Chem. **94** 11–12 (2022) 1249.
- [2] COPLEN, T.B., Guidelines and recommended terms for expression of stable-isotope-ratio and gas-ratio measurement results, Rapid Commun. Mass Spectrom. **25** 17 (2011) 2538.
- [3] INTERNATIONAL ORGANIZATION FOR STANDARDIZATION, Reference materials — Approaches for characterization and assessment of homogeneity and stability, ISO 33405:2024, ISO, Geneva (2024).
- [4] MOOSSEN, H. et al., How Well Do We Know VPDB—Part 2: Interlaboratory Assessment of Existing $\delta^{13}\text{C}$ VPDB Reference Materials, Rapid Commun. Mass Spectrom. **40** 4 (2026) e10171.
- [5] CAMIN, F. et al., New reference materials IAEA-615, IAEA-616, and IAEA-617 for pure CO₂ gas in copper tubes with certified values of carbon and oxygen isotope deltas on the VPDB and VPDB-CO₂ scales, Submitted (2026).
- [6] CAMIN, F. et al., Stable isotope reference materials and scale definitions—outcomes of the 2024 IAEA experts meeting, Rapid Commun. Mass Spectrom. **39** 14 (2025) e10018.

[7] JOINT COMMITTEE FOR GUIDES IN METROLOGY (JCGM), Evaluation of Measurement data - Guide to the Expression of Uncertainty in Measurement, JCGM 100:2008 (GUM 1995 with minor corrections), (2008).

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The project officer is responsible for the content of this reference sheet.

The Chair of the RM Certification Committee approves this certificate and authorizes its release on behalf of the Committee.