

High-Precision Oxygen-Isotope Measurements with SHRIMP SI. T. R. Ireland, M. Sapah, J. N. Ávila, P. Holden, and P. Lanc. Research School of Earth Sciences, The Australian National University, Canberra ACT 2601.

Introduction:

Determination of oxygen isotope ratios are fundamental to characterisation of materials from the early solar system [1]. In refractory inclusions [also known as Calcium, Aluminum-rich Inclusions, CAIs] variations in oxygen isotope compositions range from $\delta^{18}\text{O} \approx \delta^{17}\text{O}$ of -50 ‰ to close to terrestrial compositions. In this case high precision is generally not an issue in terms of the range of composition. However, achondrites show more subtle variations between individual types (e.g. SNC meteorites at $\Delta^{17}\text{O}$ of +0.3 ‰ and HED at -0.2 ‰, where $\Delta^{17}\text{O}$ is the mass-fractionation corrected ^{17}O abundance given by $\Delta^{17}\text{O} \approx \delta^{17}\text{O} - 0.5 \cdot \delta^{18}\text{O}$ [2]). In this case the range of compositions requires extremely high levels of precision if different source protoliths are to be characterised.

Analytical Methods:

SHRIMP SI is a new version of SHRIMP designed to optimise the analysis of light stable isotopes. The main changes from the SHRIMP II design are in the source chamber and collector chamber. The chamber itself has been produced from a single piece of 316 stainless steel thereby minimising potential leaks. The primary column is designed around Kohler illumination of imaging apertures with a demagnification of a factor of 10. The secondary ion extraction plate has been electrically isolated and divided into four to allow steering directly from the emission site. The secondary ion beam is transferred to the quadrupole triplet beam matching system held in a differentially pumped chamber. The mass analyser is the same design as SHRIMP II producing ca. 5,000 M/ Δ M for 100 μm source and exit slits. The multiple collector includes three collector heads on fixed length lead-throughs to facilitate charge-mode collection [3]. Each head has manually interchangeable slits. Faraday cups can be operated with either feedback resistors in current mode (10^{10} , 10^{11} or 10^{12} Ω), or with a feedback capacitor (22 pF) in charge mode. Charge mode has lower effective noise than current-mode measurement; the present noise floor is approximately 10,000 c/s. For this work, ^{16}O has been measured on a 10^{11} Ω resistor, with ^{17}O and ^{18}O on 10^{12} Ω resistors. Beam intensity for $^{16}\text{O}^-$ is approximately 10^9 c/s.

Results:

We analysed samples E44 and SJ101 (from the Allende CV3 meteorite) that have been previously analysed, and analysed newly characterised CAIs from NWA4502 CV3 meteorite. [4-7]. The distribution of ^{16}O enrichment in the Allende (CV3)

inclusions shows the typical maximum enrichment in pyroxene and spinel (at $\delta^{18}\text{O}$ close to -50 ‰) with melilite showing compositions closer to the terrestrial fractionation line. In the NWA4502 CAI melilite is quite variable with compositions ranging from compositions similar to pyroxene, hibonite, and spinel at -50 ‰, to values similar to the Allende CAI. The melilites are therefore somewhat unusual for CV3 CAIs and may provide insight into the mechanism for overprinting of the original near-solar composition of the CAIs by planetary-type oxygen.

These CAIs have been analysed to a precision of ± 0.6 ‰ (on average) using a methodology based on propagation of uncertainties from the individual $\delta^{18}\text{O}$ and $\delta^{17}\text{O}$ determinations.

Following modifications to the detector heads, we have been able to run with a wider source slit allowing better precision. $\Delta^{17}\text{O}$ measurements on olivine from terrestrial and meteoritic sources have been made to a precision of 0.2-0.3 ‰ (95% confidence limits).

Implementation of a scan-by-scan calculation of $\Delta^{17}\text{O}$ produces approximately a factor of two smaller uncertainty because of the removal of variation caused by the correlated component of instrumental mass fractionation.

Our goal is to achieve approximately 0.1 ‰ uncertainty (95% confidence limits) in $\Delta^{17}\text{O}$. Further improvements in precision (per unit time) will come through improved secondary-ion transmission and improvements to the detector system. This level of precision will be used in the assessment of mineral components in heterogeneous meteorites such as howardites and ureilites.

References:

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