

STABLE ISOTOPE ANALYSIS OF DIATOMIC OXYGEN FROM SNC METEORITES;

C.S. Romanek¹, E.C. Perry², E.K. Gibson, Jr.³, and R.A. Socki⁴. ¹AACES at Savannah River Ecology Lab., Drawer E, Univ. of Georgia, Aiken, SC 29802, ²Dept. of Geology, Northern Illinois Univ., DeKalb, IL 60115, ³SN4, Planetary Sciences Branch, NASA Johnson Space Center, Houston, TX 77058, and ⁴LESC, NASA Rd. 1, Houston, TX 77058.

Laser-fluorination techniques are presently being used to extract oxygen from silicates and oxides for stable isotope analysis. Target samples are reacted with a fluorinating agent (i.e., BrF₅) in the presence of laser irradiation (10.6 μm) to produce O_{2(g)}, which is generally converted to CO₂ for isotopic analysis [1]. While the O₂-CO₂ conversion is routinely used in the preparation of terrestrial materials, it is not used for extraterrestrial samples because the conversion produces ¹³C¹⁶O¹⁶O of nominal mass (45), which is an isobaric interference for the ¹²C¹⁷O¹⁶O molecule. In addition, the conversion process is known to fractionate samples less than about one milligram in size [2,3], so only relatively large samples are analyzed. Since present-day isotope ratio mass spectrometers (IRMS) are capable of measuring samples two orders of magnitude smaller in size (e.g. microgram) a more effective method of analysis is warranted.

We have developed a method whereby O_{2(g)} is introduced directly into an IRMS using a helium cryo-stat [4]. In addition to saving time, lowering blanks and reducing sample size and reagent volume, this configuration will permit the direct measurement of δ¹⁷O and δ¹⁸O for samples at the limit of resolution for dynamic switching IRMS.

Precision and accuracy of the system were quantified using terrestrial standards and SNC meteorites. Replicate analyses of the quartz standard NBS-28 and the garnet standard UWMG-2 provide a precision of less than ±0.2‰ (1σ for N = 23 over six different days) for samples less than 1 mg in size. When the reference gas is normalized to NBS-28, the secondary standard UWMG-2 is 5.56±0.14‰ (for N=9), which is statistically indistinguishable from the accepted value of 5.78‰ [5]. Oxygen isotope compositions (δ¹⁷O and δ¹⁸O) are reported for Martian meteorites (and Allende) in Table 1 and plotted in Figure 1. Comparison of measured and published values [6,7,8] suggest that Δ¹⁷O excesses can be discriminated at a level of ±0.1‰ using the helium cryo-stat.

Oxygen isotope analyses are reported here for the first time for maskelynite glass separates from ALH84001 and iddingsite concentrates (~30 to 50% iddingsite) from Lafayette. Isotopic results from ALH84001 suggest that the maskelynite precursor was a high temperature magmatic mineral that crystallized in or near isotopic equilibrium with orthopyroxene. While it is hard to reconcile the reported 0.6‰ Δ¹⁷O excess on these grounds, the tight controls on sample standardization and calibration support the interpretation of an ¹⁷O enrichment compared with the whole rock value (Δ¹⁷O excess ~0.3‰; [6]). Iddingsite concentrates and altered olivine separates from Lafayette display Δ¹⁷O excesses similar to that for ALH84001, while pristine olivine separates from Lafayette have Δ¹⁷O excesses identical to the whole rock value (Δ¹⁷O~0.3‰). Romanek et al. [8] have examined the implications for the oxygen isotopic enrichments observed for the iddingsite alteration products. Since these phases (excluding Lafayette pyroxene) are minor components of their respective meteorite hosts, the possibility exists that ¹⁷O excess is distributed heterogeneously in the Martian crust as Karlsson et al. [9] suggest. Additional analyses of these and unique phases in this and other laboratories are needed to strengthen these conclusions.

OXYGEN FROM SNC METEORITES. Romanek et al.

Table 1. $\delta^{17}\text{O}$ and $\delta^{18}\text{O}$ values of Martian meteorites and Allende analyzed at JSC.

Sample	$\delta^{17}\text{O}$ (‰)	$\delta^{18}\text{O}$ (‰)	$\Delta^{17}\text{O}$ excess (‰) [†]
ALH84001			
maskelynite	2.86 ± 0.04	4.36 ± 0.03	0.60
	2.77 ± 0.02	4.11 ± 0.02	0.64
	2.89 ± 0.10	4.30 ± 0.03	0.66
Lafayette			
whole rx	2.91	5.06	0.28
	2.99	5.12	0.33
	3.28	5.34	0.50
Iddingsite (~90%)	-	14.4 ± 2.0 ^{††}	
Iddingsite (~30%)	4.32 ± 0.01	7.38 ± 0.02	0.48
	4.05 ± 0.04	6.76 ± 0.03	0.53
	4.14 ± 0.05	7.09 ± 0.02	0.45
Olivine	2.70 ± 0.05	4.15 ± 0.03	0.54
	2.84 ± 0.05	4.47 ± 0.07	0.52
	2.77 ± 0.04	4.40 ± 0.02	0.48
	2.66 ± 0.06	4.35 ± 0.02	0.39
Pyroxene	2.77 ± 0.04	4.73 ± 0.05	0.33
	2.82 ± 0.07	4.87 ± 0.05	0.29
Chassigny			
whole rx	2.44	3.91	0.41
	2.74	4.35	0.48
	2.76	4.69	0.32
	2.89	4.88	0.35
EETA79001A			
whole rx	2.80	4.67	0.37
EETA79001B			
whole rx	2.71	4.64	0.30
Zagami			
whole rx	2.73	4.61	0.33
Allende			
Barred olivine	-0.47	2.23	-
Barred olivine	-1.12	1.42	-
CAI inclusion	-34.41	-32.68	-
CAI inclusion	-30.82	-28.79	-

[†] $\Delta^{17}\text{O}$ excess = $\delta^{17}\text{O}_{\text{sample}} - [0.52 \cdot (\delta^{18}\text{O}_{\text{sample}})]$
^{††} Sample was run at exceptionally low output voltage (0.4V).

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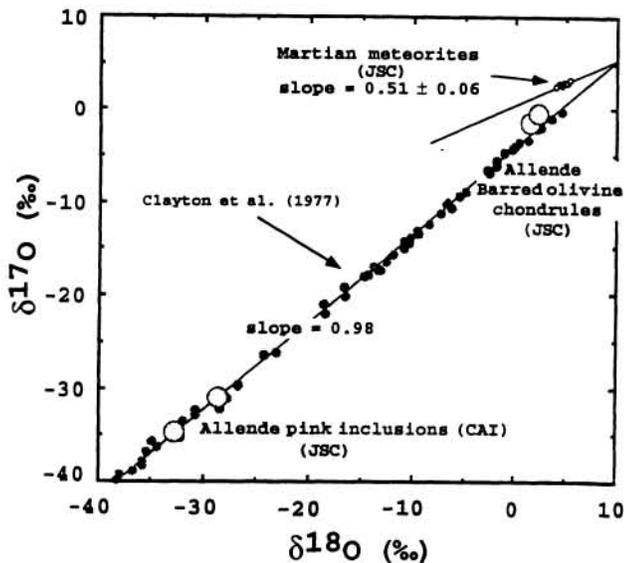


Figure 1. Three-isotope plot showing data for SNC's and selected phases in the Allende meteorite. The Martian meteorite data points and those for Allende pink inclusions (CAIs) and barred olivine chondrules (four large circles) were obtained in the JSC lab. The JSC Allende data points were obtained by *in situ* laser extraction analysis on a meteorite slab. The Clayton et al. [10] data are those for a variety of inclusions within Allende. The plot demonstrates the capabilities of the JSC oxygen isotope lab to obtain isotope compositions for a variety of materials with different oxygen isotopic contents.