Goldschmidt 2025 Abstract
https://doi.org/10.7185/gold2025.29136

Mass-independent fractionation of oxygen isotopes during high-temperature condensation in cosmochemical plasmas

NATHAN ASSET[1], MARC CHAUSSIDON[2], GUILLAUME LOMBARDI[3], JOHAN VILLENEUVE[4], ROMAIN TARTESE[5], SMAIL MOSTEFAOUI[6] AND FRANÇOIS ROBERT[7]

[1]Institut de Physique du Globe de Paris, Université Paris Cité
[2]Université Paris Cité, Institut de physique du globe de Paris, CNRS
[3]Laboratoire des Sciences des Procédés et des Matériaux (LSPM—CNRS), Université Sorbonne Paris Nord
[4]CRPG-CNRS, Université de Lorraine
[5]University of Manchester
[6]IMPMC, Muséum National d'Histoire Naturelle, Sorbonne Université, CNRS UMR 7590 (Paris)
[7]Institut Origine et Evolution, Muséum National d'Histoire Naturelle, Sorbonne Université (françois.robert@mnhn.fr).

All the objects from the solar system known for their triple oxygen isotope compositions are distributed on a line of slope 1 in the three oxygen isotope diagram, at variance with all terrestrial rocks [1]. One of the processes which could explain the slope-1 line could be mass-independent isotopic fractionations, similar to those during the formation of ozone [2], which would take place during specific chemical reactions in the protosolar nebula.

To test this possible source, we carried out condensation experiments in a plasma reactor, under conditions (pressure, ionization rate, chemical composition) close to those of the protosolar nebula. The gases used during the experiments are Ar, H_2O, and CH_4. H_2O and CH_4 are abundant in the protosolar nebula [3]. The experiments produced oxygen-bearing carbonaceous condensates with sizes reaching a few micrometers (Fig. 1).

35% of the condensates have triple oxygen isotope compositions distributed on a slope-1 line (Fig. 1) with varying depletion in ^{16}O (up to 61‰) relative to the starting water. This shows that large mass-independent isotopic fractionations occurred during the chemical reactions forming the carbonaceous materials in the plasma. By analogy with the ozone reaction, we propose that this is due to a three-body reaction during which a $[H_2O_2]^*$ complex is stabilized by a redox reaction with methane radicals. Though this reaction cannot be at the origin of the variable ^{16}O depletions relative to the protosolar gas of refractory oxides and silicates from primitive chondrites, it suggests that similar mass-independent reactions might have existed in the protosolar nebula.

References:

[1] Clayton, R. N., Grossman, L. and Mayeda, T. K. *Science* **182** 485–8 (1973)

[2] Heidenreich, J. E. and Thiemens, M. H. *The Journal of Chemical Physics* **78** 892–5 (1983)

[3] Prinn, R. G. and Fegley, B. *SK Atreya, JB Pollack, MS Matthews, Eds* p 78 (1989)

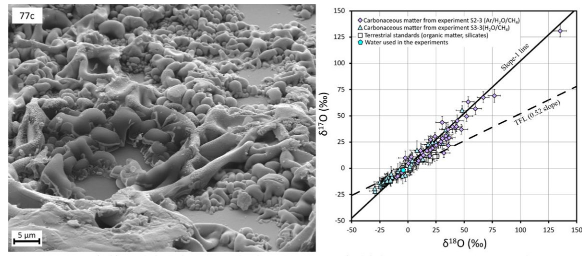

Figure 1: (Left) Morphology of experimental carbonaceous deposits. (Right) The oxygen isotopic compositions of the deposits of two experiments.