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D/H ratios in refractory chondrules: A test for their interaction with the nebular gas

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D/H ratio measurements in matrix and chondrules from primitive carbonaceous chondrites [1-2] have demonstrated that two sources of water were intimately mixed in the solar system. Accordingly, solar system D/H variations may result from mixing between a protosolar (63 x10^{-6} [3]) and an interstellar water (730±120 x10^{-6} [1]). Therefore an interaction between the protosolar nebular gas and primitive silicates such as refractory minerals or chondrules should be characterized by a D depleted hydrogen print. To test this hypothesis, water contents and D/H ratios were determined in different phases (ol, px, gl) of selected refractory type I chondrules from the LL3 Semarkona and the EH3 Sahara 97253 chondrites, using the CRPG Cameca IMS 1270 ion microprobe.

The data obtained on Semarkona chondrules display a large scattering, both for water contents (from 10 to 9 000 ppm) and D/H rations (from –800 to + 800). The olivine is characterized by its low water content, from 10 to several hundreds ppm, and low δD values, in between -800 and -200. Pyroxene and glass display higher water contents up to 10 000 ppm, and δD values. A positive correlation is then observed between the δD values and the water content, suggesting that a primary D depleted water (i.e. a protosolar water) is mixed with a chondritic D enriched water. This suggests that presolar water may have interacted with the chondrules during their early story.

The data obtained on Sahara 97253 EH3 chondrules display a very different pattern, with higher water content from 100 to 15 000 ppm and relatively constant δD values, with all the 35 measured spots in between –220 and –320, without any significant difference between the different analyzed phases (ol, opx, cpx and gl). The homogeneous distribution of water and hydrogen isotopes at the sample scale suggests the formation of these chondrules at equilibrium in a homogeneous part of the nebula. The δD value is significantly lower than the accepted mean chondritic value, suggesting that a larger proportion of presolar water was incorporated in the Enstatite chondrites.

References

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Sulfur isotope signatures of sulfides from Boiskino CM Chondrite

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Boriskino, a CM chondrite, contains two distinct sulfide mineral assemblages: 1) a primary nebular assemblage consisting of pyrrhotite, Ni-bearing monosulfide solid solution, pentlandite, and phosphorous-bearing Fe-Ni sulfide; and 2) a secondary assemblage consisting of pyrrhotite, magnetite, Fe-Ni metal with extremely variable Ni content and rare mackinawite. This assemblage is associated with aqueous alteration and carbonate precipitation and may have formed in a planetary environment. The S isotope signature of the sulfides in both assemblages was determined by SIMS using a Cs+ primary beam and extreme energy filtering to eliminate interferences. Primary pyrrhotites showed positive δS34 values (+1.346 to +5.90 ‰). A single exception was a grain of pyrrhotite which exsolved pentlandite (δS34 -1.278 ‰). The highest degree of S isotope fractionation observed in pentlandite (δS34 + 5.007 ‰) is similar to that observed in pyrrhotite. The δS34 values of pyrrhotite associated with aqueous alterations (+1.14 to +1.318 ‰) overlap with the lowest δS34 values measured for primary pyrrhotite. Boriskino sulfides are isotopically heavier than the sulfides from Murchison CM2 meteorite and the CM clasts in Kaidon meteorite. The S isotope data are consistent with a nebular origin for the primary sulfides. The low δS34 values of secondary pyrrhotites may be attributed to their precipitation under more oxidizing conditions from aqueous fluids that partially dissolved some of the primary sulfides. Under such conditions the sulfides when they coexist with magnetite would have much lower δS34 than that of the fluid. Alternatively, the low δS34 of the secondary sulfides may be attributed to kinetic isotope effects due to lack of equilibration between the sulfur-bearing species in the fluid.