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Magnesium isotope composition of chondrules and CAIs in Allende

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Magnesium isotopes are useful for reconstructing the history of the early solar system for two reasons. First, the decay of the short-lived nuclide ^{26}Al (half-life = 0.73 million years) is preserved in Mg isotopes and is a powerful chronometer of processes that occurred in the solar nebula. Second, stable mass dependent Mg isotope variations may record physico-chemical processes and mixing of materials in the solar nebula. Here we report Mg isotope data for the carbonaceous chondrite Allende including high precision in situ Mg isotope data for chondrules and fine grained type A Ca-Al-rich inclusions (CAIs). Samples were collected from polished sections using a UV-laser (GeoLas200Q, MicroLas, Göttingen, Germany). Subsequently samples were dissolved by HF-HNO_3 digestion. Three separate stages of ion exchange chromatography were used to separate Fe, Al, Ca and Na. Isotopic compositions of Mg were measured by MC-ICPMS using the Nu 1700 at a mass resolution of m/Δm ~ 2500 and sample-standard bracketing with DSM3 as a reference [1]. The δ^{26}Mg and δ^{25}Mg values measured for a homogenized Allende sample are -0.315±0.027‰ and -0.170±0.013‰ (2σ SD) respectively. δ^{26}Mg and δ^{25}Mg of chondrules vary from -0.2‰ to +0.5‰ and -0.1‰ to +0.2‰, respectively. δ^{26}Mg and δ^{25}Mg values of CAIs average +0.07±0.13‰ (2σ SD) and +0.03±0.05 ‰ (2σ SD). Excess ^{26}Mg* has been detected for both CAIs and chondrules. The ^{27}Al/^{24}Mg ratios of chondrules are too low for a precise age calculation. For the two CAIs, with ^{27}Al/^{24}Mg ~ 1.7 and measured excess ^{26}Mg* (δ^{26}Mg* = +0.120±0.026‰ and +0.104 ± 0.026‰, errors are 2SE), a last equilibration age between 1.5 to 2 Myrs after the CAIs formed has been calculated, assuming homogeneous distribution of ^{26}Al in the early solar system and an initial ^{26}Al/^{27}Al = 5.4x10^{-5}. The Mg isotope data for chondrules are consistent with formation under high gas pressures in the solar nebula [2]. That Mg isotope ratios of the CAIs fall within the range measured for chondrules most likely provides evidence for equilibration of CAIs and chondrules within the same reservoir. The ^{26}Al-^{26}Mg-chronometer dates this event between 1.5 and 2 Myrs after CAI formation. Therefore, the CAIs studied here provide evidence that last equilibration of Mg isotopes, including alteration of the original mineral paragenesis, and chondrule formation took place at the same time in the solar nebula [3].

References

[1] Galy *et al*. (2003) *JAAS* **18**, 1352-1356.
[2] Galy *et al.* (2000) *Science* **290**, 1751-1753.
[3] Amelin et al. (2002) *Science* **297**, 1678-1683.

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Pb isotopic age of the CB chondrite Gujba, and the duration of the chondrule formation interval

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Chondrules are among the earliest solid objects that formed in the solar system. We have determined the ages of chondrules from several carbonaceous chondrites using the Pb-Pb isochron method. High precision Pb isotope dates are obtained for multiple fractions from five silicate clasts (large chondrules) from the CBa (Bencubbin-like) chondrite Gujba. Eleven fractions from three clasts give a well-constrained Pb-Pb age of 4562.7±0.5 Ma, MSWD=1.3. Nine points from two other clasts yield an errorchron date of 4545.4±3.9 Ma, MSWD=3.6. These dates suggest a possible disturbance, post-dating the chondrule formation by 15-20 m.y. or more.

Additional analyses of chondrules from the CV3 chondrite Allende allowed to improve precision of the age. Pb-Pb ages of chondrules from carbonaceous chondrites are summarized below:

Meteorite	Pb-Pb isochron age (Ma)	Reference
Allende (CV3)	4566.7±1.0	study in progress
Acfer 059 (CR2)	4564.7±0.7	[1]
Gujba (CBa)	4562.7±0.5	this study

From these data, we deduce that the period of chondrule formation started simultaneously with, or shortly after the CAI formation (4567.2±0.6 Ma, [1]), and continued for at least 4.0±1.5 m.y. If the dates of the chondrules reflect their timing of formation, then there were probably a variety of processes occurring over at least 4-5 m.y. that we now combine under the umbrella name of "chondrule formation". More high-precision Pb-Pb and extinct nuclide dating, as well as geochemical and petrologic studies of chondrules from primitive meteorites, will be required to distinguish individual processes of chondrule formation.

Reference

[1] Amelin Y., Krot A.N., Hutcheon I.D. and Ulyanov A.A. (2002) *Science* **297,** 1678-1683.