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Is There a CHUR for Mg?

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Introduction

Previous methods (TIMS or SIMS) applied to the search for Mg isotopic variations have an uncertainty of 1 per mil on the instrumental fractionation (α_{inst}). Because of this technical limitation to accurate measurement of α_{inst} of Mg, relatively few investigations have been made of mass dependant fractionation. Original investigations concluded that mass dependent variations of Mg isotopic ratio are restricted to a few per mil (Catanzaro and Murphy, 1966). In addition, observed deviation from mass dependent fractionation processes are clearly related to an excess of ^{26}Mg (^{26}Mg*) from the decay of ^{26}Al (Lee et al., 1976). However, the ^{26}Al initial abundance is so low that the isotopic composition of Mg of bulk meteorites or planets can not significantly be affected. The aim of this study is to investigate the Mg isotopic variations among various meteorite, meteoritic material and the earth mantle and see if, like for some other elements such as Sr or Nd (Jacobsen and Wasserburg, 1980), we can define a single chondritic uniform reservoir (CHUR). In order to be able to measure a small deviation (tenth of a per mil) in the repartition of the 3 isotopes of Mg, we use a multiple collector-inductively coupled mass spectrometry (MC-ICP-MS) for the measurement of Mg isotope ratios.

Methods

Solutions are introduced through into the MC-ICP-MS (Nu Instruments) via a Cetac MCN-6000 nebulizer. Measurement of Mg is accomplished using the 12-faraday collectors over a mass range of 24-26 allowing direct measurement of ^{24}Mg, ^{25}Mg and ^{26}Mg. The α_{inst} has been determined on international isotopic standard (SRM980) and is sensitive to the chemistry of the solution as well as instrumental conditions. Mg-isotopic compositions are expressed as a per mil deviation from the isotopic composition of the SRM980. Prior to isotopic measurement, chemical separation of Mg is accomplished by liquid chromatographic methods. Our method uses Bio-Rad AG50W-X12 resin and >99% recovery of Mg is achieved. The induced isotopic shift is negligible with respect to the MC-ICPMS analytical uncertainty. Based on duplicate chemistry and mass spectrometer measurement of a variety of samples, including Allende matrix, seawater, and foraminifer, the overall reproducibility of our method is 0.06 per mil/amu (2σ, n=15) for Mg.

Results

Based on 32 samples of carbonate, water, chlorophyll and basalt, the Mg-isotopic composition of terrestrial material defines a single mass fractionation curve on the three-isotope plot, termed the terrestrial mass fraction curve (TF). Among them, two continental basalts (BCR1 and BR) having a $\varepsilon_{Nd}(0)$ of -0.2 and +4.8, respectively, have a nearly identical δ^{25}Mg (Figure). The bulk composition of Allende (CV) and the matrix have no measurable ^{26}Mg*. Within 14 chondrules, only 2 lie off the TF, showing a ^{26}Mg* correlated with their Al/Mg ratios. The range of δ^{25}Mg is 1.04 per mil and is the result of a progressive enrichment in the heavy isotopes by volatilisation of Mg during chondrule formation (Galy et al., 2000). The bulk composition of 2 other carbonaceous chondrites (Murchison, CM and Orgueil, CI) lie on TF. Their δ^{25}Mg is less than 0.2 per mil higher than Allende (Figure 1). All the material (3 splits of the matrix of 10 mg in size each and 4 chondrules) from an ordinary chondrite (Chainpur) have a very narrow range of δ^{25}Mg (Figure 1) and are on the TF. Therefore, if we exclude the fractionated chondrules from Allende, all the extraterrestrial materials have a δ^{25}Mg between +1.50 and +1.73 per mil (hatched area in Figure).

Implications

These preliminary results on chondrites suggest a very homogenous isotopic composition of Mg, at least in the locus of formation of the carbonaceous chondrite parent body. Only one ordinary chondrite has been measured so far, but it has the same composition than the carbonaceous chondrites. It is tempting to propose a similar isotopic composition for all chondrites. However, the 0.2 per mil range is well outside the analytical uncertainty. One explanation is that a variable proportion of fractionated material was produced by volatilisation before the formation of meteorite, but this hypothesis needs to be tested with more data. The similarity with terrestrial rocks having a Nd isotopic composition close to the CHUR suggest that, within 2 a.u., the δ^{25}Mg may have a very narrow range of values. In addition, mass-dependant processes can explain the variations observed between all of these Mg-rich bodies.