Making Sense of Mercury Isotopic and Abundance Variations in Meteorites

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Intro: Hg in meteorites

There is no correlation between the abundance of Hg in meteorites and the mass-dependent isotopic fractionation (MDF) observed (Fig 1) [1,2,3]. This suggests that different processes are at work, or that enrichment / depletion of Hg does not always go together with isotopic fractionation (e.g., as expected at high temperatures). Furthermore, Hg odd-numbered isotopes show mass-independent fractionation (MIF) in meteorites (Fig 2), with carbonaceous chondrites preferentially enriched in the odd-numbered isotopes, while ordinary chondrites and achondrites are unfractionated or depleted relative to the terrestrial standard.

Results

• All models successfully redistribute Hg from the hot interior to the cold outer crust while introducing MDF and MIF (Fig 5-8).
• No efficient Hg migration for R < 10 km
• No significant MDF, MIF for R > 50 km
• Strong MIF requires late formation:
  • Largest MDF, MIF effects observed for an asteroid with R = 20 km, carbonaceous chondritic composition and formation time = 3.5 Ma
  • The hotter the interior (earlier formation or larger size), the larger the “desicated” center region
  • Sharp transition region, characterized by strong positive MDF (and negative MIF)
• Model cannot reproduce high Hg abundances, high MIF observed in Orgueil (CI1) and Paris (CM2.7). Additional enrichment process required.
• Asteroid break-ups will produce some fragments with local Hg abundance >> solar abundance.
• Terrestrial Hg fractionated towards heavier MDF, but close to bulk solar system in MIF.

Method: Heating & migration

We have developed a Hg migration model based on the asteroid heating models by [4,5] (Fig 3), which yield a temperature at a certain depth within an asteroid as a function of initial $^{26}$Al content (Fig 3). The asteroid is divided in 300 shells of equal mass. For each shell, temperature is determined as a function of time, and Hg vapor pressure (and the temperature-dependent MDF, MIF of vapor-phase Hg [6]) is calculated. All vapor Hg is equilibrated isotopically and redistributed among the shells in inverse proportion to the temperature (assuming uniform pressure and the ideal gas law). This is repeated until 500 Ma after formation of the solar system (Fig 4).

References