Geophysical Research Abstracts
Vol. 14, EGU2012-1527, 2012
EGU General Assembly 2012

Oxygen isotope evolution in the protosolar disk induced by isotopic exchange reactions

H. Nagahara

University of Tokyo, Department of Earth and Planetary Science, Tokyo, Japan (hiroko@eps.s.u-tokyo.ac.jp)

Oxygen isotopic heterogeneity is one of the most extensively studied and debated topics in planetary science, though no consensus has been achieved yet. We quantitatively examine the role of exchange reactions in mass-dependent oxygen isotope fractionation during evaporation and recondensation of silicate melts in gas with isotopically identical and distinct gases. The results are applied to the CCAM line, mass-dependent oxygen isotopic fractionation of FUN inclusions, and oxygen isotopic variations of Allende chondrules.

We examine the role of oxygen isotopic exchange for silicate melt and ambient gas during evaporation and recondensation in a closed system that monotonically cools from high temperature. Silicate dust aggregates are assumed to be instantaneously heated to an above liquidus temperature. There are three free parameters; one is the efficiency of the isotope ex-change, the second is the cooling rate of the system, and the third is the amount of initial oxygen in the ambient gas.

We found following results : (1) Evolution of oxygen isotopic fractionation is decoupled with chemical fractionation of silicate melt; oxygen isotopic fractionation goes more rapidly than chemical fractionation, of which timing depends on the isotopic exchange efficiency. (2) Mass-dependent oxygen isotopic fractionation of silicate melt is suppressed by isotopic exchange during evaporation/recondensation. If isotopic exchange does not work, oxygen isotopic composition of silicate melt spheres after evaporation / recondensation becomes lighter than the initial one if the silicate and gas have identical oxygen isotopic composition due to more abundance of 16O in the gas. Isotopic exchange homogenizes the compositions effectively to result in the same composition between silicate and gas. (3) Cooling rate of the system affects the evolution time of oxygen isotopic mass fractionation, but the final composition is not affected. In a system with initially different oxygen isotopic compositions between silicate melt and gas, deviation from a straight mixing line to the δ18O-rich side on a three-oxygen isotope plot is inevitable through evaporation/recondensation and isotope exchange. (4) Abundance of oxygen in the initial gas largely affects the degree of deviation from a simple mixing line during the cooling process. The average oxygen abundance in gas of protosolar disk relative to that in silicate ($\sim$10), and silicate melt gets oxygen isotopic composition very close to the gas. (5) Isotopic exchange efficiency plays an important role on evolution and final oxygen isotopic composition of silicate melt heated in gas. Effective isotopic exchange largely suppresses mass dependent isotopoic fractionation, which tends to result in forming a straight "mixing line", whereas, smaller efficiency causes larger degree of mass-dependent isotopic fractionation, and deviation from a straight "mixing line" becomes larger. (6) A straight mixing line such as CCAM line requires the presence of oxygen in the ambient gas more than the average protosolar disk. (7) The mass-dependent oxygen isotope fractionation of FUN inclusions by $\sim$40‰ or more is not achieved by evaporation in a closed system, and almost vacuum condition is required, which was possible by almost complete continuous separation of gas and silicate melt during evaporation. If FUN inclusions were formed from oxygen isotopically light solid, they have suffered a reaction between isotopically heavy gas after vacuum evaporation, where the gas abundance must have been more than 10 times of the average protosolar gas.

In summary, a series of oxygen isotopic composition of CAIs and chondrules reflects the ambient physical conditions such as dust/gas ratio and dust/gas separation of a protosolar disk.