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Origin and abundances of volatiles on Mars from the zinc isotopic composition of Martian meteorites

MARINE PAQUET[1], PAOLO A. SOSSI[2] AND FRÉDÉRIC MOYNIER[3]

[1]Institut de Physique du Globe de Paris
[2]ETH Zürich
[3]Université de Paris, Institut de physique du globe de Paris, CNRS

Presenting Author: paquet@ipgp.fr

Volatile elements are key to understanding the accretion and differentiation processes that formed the terrestrial planets. The terrestrial planets are depleted in moderately volatile elements (MVEs) compared to the Sun, with the Earth being more depleted in MVEs than Mars [e.g., 1]. Mass-dependent and mass-independent stable isotope variations of MVEs, such as Zn, can be used to determine the origin of volatile depletion on Mars. Here we present Zn isotopic compositions of ten Martian meteorites, spanning the major petrologic groups and show that the Zn isotope composition of the Martian mantle, representative of the Bulk Silicate Mars (BSM), has a $\delta^{66}Zn$ (per mille deviation of the $^{66}Zn/^{64}Zn$ from the JMC-Lyon standard) of +0.50 ± 0.18, distinctly heavier than that of the Earth (+0.16 ± 0.06 ‰). The mass-independent Zn isotopic composition of Mars, $e^{66}Zn$ (per 10,000 deviation of the $^{66}Zn/^{64}Zn$ from the terrestrial standard JMC-Lyon, normalized to $^{68}Zn/^{64}Zn$) is intermediate between carbonaceous chondrites (CC) and non-carbonaceous chondrites (NC), but with stronger affinity to the NC compared to that of the Earth. The proportions of CC (taken as Ryugu sample composition [2] and NC required to reproduce Mars' $e^{66}Zn$ which yields to the following proportions are 4 % Ryugu-like material + 96 % NC, representing ~23 % of Mars' Zn delivered by outer solar system material, which is slightly lower than the estimation for the Earth's (~30 %; [3,4]), consistent with dynamical models of planetary formation (e.g., [5-7]). Alternatively, because Mars' $e^{66}Zn$ is close to that of NC, Mars' isotopic signature might also be inherited mainly from its ordinary chondrite-like precursors. Furthermore, the BSM Zn isotope composition is consistent with isotopic fractionation during volatile loss by evaporation as suggested for other volatile elements (e.g., K [8]).

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