The hidden reservoir of noble gases from the deep Earth

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We determine the chemical behavior of noble gases in the primordial magma ocean (MO) by performing ab initio molecular dynamics simulations at temperatures and pressures along the MO adiabat.

Our simulations show that at the bottom of the magma ocean, He partitions preferentially into the MO rather than the liquid core. The origin of the ocean island basalts reflects a large contribution and contamination from mantle sources and no necessary contribution from the top of the outer core, which is depleted in primordial He. We suggest searching for the He reservoirs at the base of the solid mantle. [1]

At the top of the MO, beneath the hot, dense early atmosphere, He primarily remained in the MO and degassed only later, at low atmospheric pressure. However, we found that the simultaneous presence of incompatible volatiles, such as CO_2 and He, results in significant loss from the MO. Our findings indicate that the early Earth's atmosphere was carbon-rich, with a high concentration of He and other noble gases, and must have been thicker and hotter than previously believed. [2]

Finally, during crystallization, He remains in the melt and continues to accumulate in the melt until the last droplets of the MO solidify. However, the heavier noble gases, such as Xe, which diffuse very slowly, may be partially trapped in the newly forming bridgmanite crystals, while Ne hovers on the brink of crystal entrapment. Consequently, Ar, Kr, and Xe, which are trapped in bridgmanite, would be more evenly distributed throughout the solid mantle, whereas He would concentrate in specific deep reservoirs. [3]

References:

[1] Ozge Ozgurel, Razvan Caracas (2023) The magma ocean was a huge helium reservoir in the early Earth. Geochemical Perspective Letters, 25, 46-590 (2023)

[2] Adrien Saurety, Ozge Ozgurel, Chris Mohn, Razvan Caracas (2024) Diffusion, chemical bonding, and kinetic fractionation of noble gases in the primordial magma ocean. Geochimica et Cosmochimica Acta, 378, 144-152.

[3] Anne H. Davis, Razvan Caracas (2024) Degassing of CO2 triggers large-scale loss of helium from magma oceans. Communications Earth and Environment, 5, 344.