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Volatile depletion in planetary bodies: Insights from K and Rb isotopes

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Volatile depletion is a widespread phenomenon observed across rocky planetary bodies. Compared to CI chondrites that represent the bulk Solar composition, other groups of carbonaceous chondrites (CCs), as well as Earth, Moon, Mars, and Vesta all exhibit varying degrees of depletion in volatile elements. What processes have caused the volatile depletion has been a long-standing question in cosmochemistry and planetary sciences.

Isotopes of moderately volatile elements (MVEs) can provide valuable insights into this question. Among MVEs, K and Rb are relatively new isotopic systems, yet have shown great potential. They are both alkali metals (i.e., similar geochemical behaviors), lithophile (i.e., unaffected by core formation), possess single valence state (i.e., not redox sensitive), but differ in volatilities, making them an ideal pair for tracing volatilization processes during planetary formation.

Isotopic compositions of K and Rb (along with other MVEs) have led to new understandings of the mechanisms driving volatile depletion in planetary bodies. In CCs, they suggest that mixing between CI-like matrix and chondrules, which are volatile depleted due to incomplete condensation of volatile elements upon cooling, is responsible for the observed volatile depletion [1]. Regarding Earth, the mass-independent isotopic composition of K indicates that less than 12 wt% of CC material was accreted to Earth during its formation [2]. In the case of Moon formation, volatile depletion most likely occurred during the proto-lunar disk stage, where volatile elements were vaporized from the proto-lunar disk and accreted onto Earth [3]. In lunar soil regolith, these isotopes provide insights into volatile loss from lunar surface to outer space by space weathering [4]. For Vesta, volatile depletion likely resulted from a setting featuring protracted evaporation of droplet-size objects at a relatively low temperature (~1050 °C) [5].

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