Thermal Release of Labile Elements from Primitive Meteorites: Applications for Asteroid Sample Return Science and ISRU

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Abstract. Quantifying the effects of thermal metamorphism on labile element mobilization in primitive chondritic meteorites is important for constraining the thermal histories of primitive Solar System bodies. Labile elements–elements easily mobilized at low temperatures–provide useful tracers of past temperatures experienced by planetary materials, in particular, asteroids and comets with compositions similar to carbonaceous chondrite meteorites. Laboratory heating experiments of carbonaceous chondrite meteorites from 300–1200 K at a rate of 15 K/minute show mobilization and volatilization of a suite of labile elements (S, Hg, As, Te, Se, Sb, and Cd) at temperatures that could be reached by asteroids that cross Mercury's orbit. Samples became rapidly depleted in labile elements: we see loss of up to 90% of some labile elements at 1200 K. The mobilization and loss of the elements in chondritic material have applications to several aspects of asteroid exploration, including the upcoming OSIRIS-REx asteroid sample return mission to (101955) Bennu. This mission will return samples from this asteroid in 2023. Bennu shows a B-class spectra (Clark et al. 2010); we anticipate that the composition of Bennu will be primitive. Laboratory studies of the Bennu samples will allow for direct measurement of labile element depletion in material from what is likely considered a primitive body. Thermal modeling (Delbo & Michel, 2011) provides maximum temperatures experienced by Bennu based on possible dynamical histories of the asteroid: labile element experiments are a way to connect laboratory results with theoretical models to constrain the past thermal history of a body. Quantifying the amount of labile elements lost on Bennu over its dynamical history can inform models of the thermal effects of the orbital history of Bennu regarding labile element loss. Additionally, being able to preserve the primitive nature asteroid material collected from Bennu is critically important for future laboratory analysis of the sample. Having asteroid material in the sample return canister experience large temperature excursions could thermally metamorphize the material such that labile element mobilization occurs, rendering a previously primitive sample heated to a point where an appreciable percentage of elements are lost.

For future *in situ* resource utilization (ISRU) knowing the amount of volatile elements in a primitive meteorite along with the percentage of water would be useful for future water purification processes to create both drinking water and rocket fuel. Heating primitive meteorites such as Murchison to release water vapor with high concentrations of labile elements, many of which exceed Environmental Protection Agency limits for contaminants in drinking water. Further, high concentrations of sulfur in water vapor can poison platinum electrodes in traditional electrolyzers used to purify water vapor, leading to irreversible losses in platinum electrode performance during the purification process (Kelsey & Lauretta, 2013). Future work must be done to purify water of heavy metals and sulfur without damaging the purification apparatus for ISRU.