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Implications of the condensation of the bulk silicate Earth for its chemical composition

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The 50 % condensation temperatures of the elements from a gas of solar composition (T_c^{50}) are widely used to infer their volatilities during the formation of planets [1, 2]. However, the weakly siderophile elements In and Ga, in particular, have bulk silicate Earth (BSE) abundances higher than predicted from moderately volatile lithophile elements, indicating that T_c^{50} may not be appropriate to describe volatilities during planetary accretion. An alternative scale that is relevant to the evaporation/condensation of silicate liquids is lacking, owing to the scarcity of independent constraints on trace element activities therein [3 – 6].

Here, we present Knudsen Effusion Mass Spectrometry determinations of the activities of $GaO_{1.5}$ and $InO_{1.5}$ in Anorthite-Diopside eutectic liquids, and combine them with estimates for other rock-forming elements to calculate the condensation path of an anhydrous BSE composition by Gibbs Free Energy minimisation using the FactSage package.

We show that Ga and In are significantly less volatile, relative to other moderately volatile elements, than predicted from their T_c^{50}. Furthermore, during cooling, many elements condense and re-evaporate, making definition of a single condensation temperature problematic. To overcome this degeneracy, we define a ‘volatility factor’ that more accurately represents the integrated volatility of an element during evaporation/condensation of silicate liquids than does T_c^{50}. These volatility factors are well correlated with the observed moderately volatile element abundances in the bulk silicate Earth, providing empirical evidence for the establishment of its composition predominantly by post-nebular processes.

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