Developing an Integrated Thermochemical Code for Modeling Lunar Magma Ocean Evolution

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Why is this code needed?

For nearly 50 years the Lunar Magma Ocean (LMO) model has been developed by analyzing Apollo samples [e.g., 1], conducting petrological experiments [e.g., 2], and running computer models [e.g., 3]. Yet, a fully-integrated thermochemical model, in which both crystallization of minerals and thermal flux calculations are done self-consistently is not currently available. Having such a model would be beneficial to better understand fundamental questions in lunar science (e.g., how long did the LMO last?) and help to characterize the early evolution of planets in general.

What is this code going to do?

For a given initial chemical composition, depth, and temperature of the LMO, this code will determine mineral assemblages as a function of depth and the corresponding thermal energy that is released. It will then calculate the overall solidification time. Phase relationships will be calculated using the MELTS thermodynamic models of silicate systems, which have been calibrated with a variety of thermochemical and thermodynamic constraints [4]. We use alphaMELTS (v2.0) [5] as an interface that calls pMELTS (v5.6.1) [6]. The code algorithm is shown below.

What was the initial composition of the LMO?

Figure 1: Seven different estimates of the initial LMO composition from the literature. Minor components (e.g., TiO₂ & Cr₂O₃) are used in MELTS modeling but are not shown. MnO was set to zero because adding it is not recommended for MELTS. Trace elements (e.g., Ni & Co) were not included.

Sources


Outlook

TEMPE is being written in Python and will be made available as open source software. MELTS-family models are actively being updated and extended and as such their accuracy and range of applicability will improve with time. Thus, TEMPE will be a valuable tool for the planetary science community to study not only the thermochemical evolution of the Moon, but also the Earth and exoplanets.

References