

Kinetics of condensation of silicate melt and its role on the chemical composition of chondrules

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The chemical composition of chondrules are characterized by large fractionation in major and minor elements without isotopic mass fractionation with evidence for open system formation. The origin of the compositional variation should be related to the origin of chondrules. Bulk chemical compositions of chondrules were newly obtained with high precision for all the chondrules in thin sections without selection bias. The obtained compositional range is much smaller than that previously reported. We have developed a kinetic condensation model that has a cooling rate as a critical parameter, and the role of cooling rate, degree of supersaturation, and initial composition has been quantitatively evaluated. Comparing the calculation results with the chondrule compositions, we show that all the chondrule composition diversities (except for Al-rich ones) are well reproduced as either liquid condensates or quenched products of coexisting residual gas and that the gas was initially depleted in the refractory component by a quarter and iron by ~80% in a dust-enriched system. The plausible cooling rate of the system is 0.01~1 deg/hour at $P_{\text{tot}}=10^{-4}$ bar under the dust enriched by 500 times of CI. The rate is slightly smaller than the rates previously estimated from textural reproduction experiments. A possible scenario is as follows: dust which are enriched by several hundreds of times relative to the CI abundance and from which some fraction of refractory component (CAIs) and most of metallic iron were fractionated was instantaneously heated to vaporize, then, the gas cooled rapidly and supersaturated partly to form liquid droplets and the residual gas also quenched to form liquid droplets with fractionated composition. This scenario has an advantage that all the chondrules can be formed from a common precursor through a common process.