

The extent of immiscibility in planetesimal cores: core formation and volatile loss in the early solar system

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Iron meteorites demonstrate that core-formation initiated in rocky planetesimals within 1 Myr of the onset of accretion in the inner solar system. Metal-silicate differentiation within early-formed planetesimals implies partial melting and variable volatile loss, which would have influenced the composition of rocky planets to which these bodies subsequently accreted. However, mechanisms by which planetesimal differentiation occurred, and implications for the extent of devolatilisation, remain poorly constrained. One important process which could have influenced core differentiation within planetesimals is liquid immiscibility. Under moderate pressures of planetesimal interiors (<5 GPa), mixing of light elements such as S, P, C and O in Fe-rich liquids is highly non-ideal. Here we present new experimental data which define the extent of miscibility in core-forming liquids arising from this non-ideality. Immiscibility results in separation of Fe-rich (S-poor, C-rich, P-rich) and FeS-rich (P-poor, C-poor, O-enriched) liquids. The role of immiscibility in planetesimal cores would have been controlled by planetesimal size, due to the effect of pressure on non-ideal behaviour in Fe/Ni-rich liquids, and planetesimal composition.

Calculated parental liquids to iron meteorites have variable S contents, but are C-poor and contain only moderate P. As a consequence, they were likely miscible, single liquids, although the possibility that some were immiscible liquids cannot be discounted. However, the extent to which iron meteorite parental liquids fully reflect planetesimal core compositions is unclear, as liquid compositions could have been modified both during and after planetesimal disruption. Therefore, we also calculate hypothetical planetesimal core compositions based on chondrite data. We argue that model 'chondritic' core compositions and iron meteorite parental liquids bracket the range of core compositions in planetesimals; they provide upper and lower limits, respectively, of the extent to which planetesimals were modified by volatile loss during, and after, core formation. Compared to model 'chondritic' cores, iron meteorite parental liquids are S-, P- and C-depleted, suggesting that they record multiple devolatilisation processes. Independently constraining the role of immiscibility during planetesimal differentiation could, by extension, provide insight into the extent of volatile loss from rocky bodies in the early solar system.