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Effective metal-silicate equilibrium temperature during core formation

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It has been long known that the formation of the core transforms gravitational energy into heat and is able to heat up the whole Earth by about 2000 K. However, the distribution of this energy within the Earth is still debated and depends on the core formation process considered. Iron rain in the surface magma ocean is supposed to be the first mechanism of separation for large planets, iron then coalesces to form a pond at the base of the magma ocean. In this process, equilibrium between metal and silicate is achieved within several seconds [Ichikawa et al., 2010].

Experimental studies of metal-silicate partition coefficient show that pressure-temperature conditions for metal-silicate equilibrium are far beyond the liquidus or solidus temperature for several hundred kelvin [e.g. Wade and Wood, 2005]. However, because equilibration was considered to occur in at the surface of metal pond at the silicate solidus, such high temperature equilibration was rejected as implausible. Instead, lower temperature equilibration with variable oxygen fugacity was proposed as an alternative, although the plausibility of the physical mechanisms invoked in this scenario is also questionable.

In this study, we model iron rain and heating of the magma by viscous dissipation to calculate the effective pressure-temperature conditions for partitioning in this scenario based on parameterizations derived from direct numerical simulation results of a 10cm-scale emulsion of liquid iron in liquid silicates. We have found effective temperature is much higher than melting temperature of silicate due to the release of gravitational potential energy.

Keywords: magma ocean, metal-silicate equilibrium, iron rain, numerical simulation