Magnesium partitioning between Earth's mantle and core and its consequence on an early geodynamo

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Laser-heated diamond anvil cell experiments were used to investigate magnesium partitioning between metal and silicate between 34 and 138 GPa, 3500 and 5450 K, and for silicate compositions ranging form tholeiitic basalt to pyrolite and peridotite. The 21 measurements, covering the whole range of terrestrial magma ocean P-T-X conditions, were combined with previously published data yielding a total of 48 measurements, allowing to accurately model magnesium metal-silicate partitioning using a thermodynamically consistent model based on the interaction parameter formalism.

We find that magnesium metal-silicate partitioning is best explained either by a dissociation of MgO in the metal. It depends on temperature and metal composition and is independent of pressure and silicate composition. The concentration of magnesium in the core therefore only depends on three parameters at the core-mantle boundary: temperature, magnesium concentration in the overlying silicate, and composition of the core. During core cooling, the MgO exsolution rate varies between 1.6×10^{-6} and 2.4×10^{-6} K^{-1} with a factor 2 uncertainty obtained by propagating all uncertainties on the thermodynamic models. Using a thermal evolution model of the core, the flux of MgO out of the core varies from 60,000 to 20,000 kg/s throughout geological time driving a buoyancy-driven geodynamo prior to inner core growth; this buoyancy flux can further be converted into an effective magnetic field at Earth's surface, yielding a dipolar field ranging between 66 and 36 μT, in the same range as the median Phanerozoic field.