

# Kinetics of Metal-Silicate Reactions During Formation of the Earth's Core

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Recent geochemical models of the formation of the Earth's metallic core suggest that liquid metal segregated from silicates in a magma ocean 700-1000 km deep and equilibrated at the base of this magma ocean at a pressure of 25-30 GPa (e.g. Li and Agee, 1996; Richter et al., 1997). The implication is that the liquid metal fraction then sank as large diapirs through the lower mantle without significant chemical re-equilibration at higher pressures. Such models can explain the present abundances of siderophile elements (e.g. Ni and Co) in the Earth's mantle on the basis of experimental studies of element partitioning at high pressures. A consequence of these models is that limited reaction must have occurred during transport of metal through the lower mantle. A further implication is that the metallic core would not be in equilibrium with the lower mantle and that disequilibrium reactions could still be occurring at the core-mantle boundary, depending on their kinetics. Such reactions might involve siderophile elements and also light elements such as oxygen and silicon.

We are studying the kinetics of disequilibrium reactions between lower mantle minerals and Fe-rich liquid metal at high pressure in order to better constrain core formation processes. Preliminary experiments have been performed at 10 GPa and 1900 °C in a multianvil apparatus to study the kinetics of reactions between magnesiowüstite and Fe-rich metal liquids that are supersaturated in oxygen. Mixtures of Fe, Fe<sub>3</sub>O<sub>4</sub> and Ni (~6 wt% oxygen) are contained in an MgO capsule in a multianvil sample assembly. The capsule is fabricated from an MgO single crystal in order to ensure that chemical exchange is controlled by lattice diffusion in the oxide. At the experimental conditions, the metal is liquid and reacts with the MgO. Due to super-saturation in oxygen, reaction initially involves the growth of a FeO-rich rim between the MgO and the liquid

metal, which consumes oxygen. With increasing time, (a) this rim partially equilibrates with the MgO through Fe-Mg interdiffusion, and (b) the composition of the oxide in contact with the liquid metal becomes increasingly rich in MgO. The results indicate that the oxygen fugacity, which controls the partitioning of Fe and Ni between the metal and oxide, decreases with time as the oxygen content of the metal decreases due to reaction. A fit to our earlier experimental data on the solubility of oxygen in liquid metal can be used to quantify this effect. Fe-Mg concentration profiles in the oxide are modelled numerically using a reaction/diffusion model involving a moving interface and changing interface composition. The required cation (e.g. Fe-Mg) diffusion coefficients are a strong function of composition and are consistent with those determined experimentally for magnesiowüstite at 1 bar (S. Mackwell, personal communication), with a small correction for the effects of pressure and oxygen fugacity.

These results indicate that the kinetics of equilibration are controlled primarily by the rates of diffusion of siderophile elements in the solid phase, which in the case of magnesiowüstite can now be quantified. Further experiments are being performed to study the kinetics of similar reactions between liquid metal and silicate perovskite. The results will be used to model the rates and extent of reactions between liquid metal diapirs and silicates/oxides in the lower mantle during the early history of the Earth, as well as reactions at the core-mantle boundary that could be occurring at the present time.

Li J & Agee C, *Nature*, **381**, 686-689, (1996).

Richter K, Drake MJ & Yaxley G, *Phys. Earth Planet. Int.*, **100**, 115-134, (1997).