Goldschmidt 2023 Abstract
https://doi.org/10.7185/gold2023.15526

Ni and Co metal/silicate partitioning: tracing pressure and oxygen fugacity conditions of planetary differentiation

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Moderately siderophile elements (MSE) are potential tracers of the thermodynamic conditions prevailing during core formation because their metal/silicate partition coefficients ($D^{met/sil}$) vary as a function of P, T, and oxygen fugacity (fO_2). The intrinsic conditions of differentiation therefore lead to planetary mantles with unique MSE depletion signatures. Among the MSE, Ni and Co are excellent and reliable magma ocean barometers because their $D^{met/sil}$ are strongly correlated to pressure, decreasing over almost 3 orders of magnitude between 1 bar and 100 GPa. Current pressure-dependent expressions of $D^{met/sil}$ were calibrated on experiments performed under relatively oxidizing conditions, mostly with fO_2 slightly below the IW buffer, corresponding to the redox conditions of the terrestrial and Martian mantle. However, other planets, planetary embryos, and differentiated planetesimals formed under a wide range of redox conditions going from the most reduced Mercury (fO_2 ~ IW-3 to IW-7) to the most oxidized angrite parent body (fO_2 ~ IW+1). In this study, we performed and analyzed 38 experiments with equilibrated metal and silicate melts over a wide range of pressures (1 bar to 26 GPa) and oxygen fugacities (IW-6.4 to IW-1.9) to expand the Ni and Co $D^{met/sil}$ database to more reducing conditions. Adding previously published data, we then parameterize 350 Ni and Co $D^{met/sil}$ as a function of T, P and fO_2. This parametrization accurately predicts the evolution of Ni and Co $D^{met/sil}$ between 1 bar and 80 GPa, IW to IW-7, and 1550 K to 4450 K. Using our parameterization, we model Ni and Co $D^{met/sil}$ along the liquidus of a chondritic mantle at various P and fO_2, to build an oxy-barometer. Finally, we apply this tool to investigate the thermodynamic equilibrium of various planetary bodies' magma ocean. The P and fO_2 obtained for Earth, Mars, Moon and Vesta are strongly correlated to these planetary sizes and bulk silicate FeO contents, respectively. The P and fO_2 obtained for other achondrites suggest a wide variety of core formation conditions, from the small and oxidized angrite parent body, to a planet-sized and highly reduced aubrite parent body.