METAL-SILICATE PARTITIONING OF P, V, Co, Mo, Ge, and W AND CORE FORMATION IN THE ANGRITE PARENT BODY. W. van Westrenen¹, E.S. Steenstra¹, J.S. Knibbe¹, Y.H. Lin¹, N. Rai²,3, J. Berndt⁴, ¹Faculty of Earth and Life Sciences, VU University Amsterdam, the Netherlands (w.van.westrenen@vu.nl), ²Centre for Planetary Science, Birkbeck-UCL, UK ³Department of Earth Sciences, Mineral and Planetary Sciences Division, Natural History Museum, London, UK ⁴Department of Mineralogy, University of Münster, Germany.

Introduction: Geochemical models that constrain conditions of core formation in planetary bodies rely on the experimentally determined metal-silicate partitioning behavior of siderophile elements [1,2]. Although it is known that metal-silicate partition coefficients (D) of siderophile elements can depend on silicate melt composition, this dependence is not well constrained for many elements. Here, we study the metal-silicate partitioning of P, V, Co, Mo, Ge, and W as a function of silicate melt composition, with results for a wide range of other elements discussed separately [3]. We apply our results to study core formation in the angrite parent body (APB).

The angrites show siderophile element depletions [4,5] and evidence of a past magnetic field [6], suggesting the presence of a metallic core in the APB. Angrites are among the oldest basaltic meteorites and therefore provide insights into the earliest stages of planet formation and differentiation. However, the physical properties of the APB (e.g., size, core mass) and redox state (fO₂) during core formation are poorly constrained. For example, previous work suggests the APB has a 8-60% mass Fe-Ni-C core which formed at fO₂ ranging anywhere between -1 and +1 log units relative to the iron-wüstite buffer (IW) [4,5].

Approach: We equilibrated silicate-metal mixtures within MgO capsules at 1.5 GPa and 1683-1883 K. The effect of melt composition on D is studied by using the epsilon model [7], assuming valences of 2+ for Co, Ge, 3+ for V, 5+ for P and 6+ for Mo, W [8]. We use the apparent equilibrium constant (K_{App}) which is corrected for solute interaction in the metal.

Experimental results: Preliminary results suggest no effects of silicate melt composition on D(Co,Ge,V).

For data from this study only, we observe that K_{App} Mo, P and W are significantly affected by cCaO (Fig. 1). This is likely due to the formation of CaMO₄ complexes, which reduces siderophile behavior of Mo, P and W with CaO of the silicate melt [8]. We also observe a decrease of K_{App} P with S in the silicate melt, similar to that observed for Pb and Cd [3].

Modeling Core Formation in the APB: To study core formation in the APB, D’s obtained at <5 GPa [3,8-13 and this study] are parameterized to Eq. 1:

\[
\log D = a + b(\Delta IW) + c(nbo/t) + \sum c_i X_i + d(1/T) + e(P/T) + f\ln(1-X_S) + g\ln(1-X_C) + h\ln(1-X_{Ni}) + i(S) \quad (1)
\]

where fO₂ is represented by ΔIW, which defines the deviation in log units from the IW buffer, composition of the silicate melt is represented by molar major oxide fraction terms (cMgO, cSiO₂, cAl₂O₃, cCaO, cFeO) or nbo/t, X_S, X_C, X_{Ni} are the molar fractions of S, C and Ni in the metallic liquid and i(S) is the concentration of S (ppm) in the silicate melt. Using the parameterizations obtained for Ni, Co with nbo/t, and Mo, W, Ga with mole oxide fractions, we model core formation in the APB using a Monte Carlo approach [1,2].

To calculate the required D’s to explain the siderophile element depletions in the APB mantle (D_{cm}), we consider a CV bulk composition [4,5,14,15] and use the APB mantle estimates for Ni, Co, Ga, Mo, W from [5]. Calculating D_{cm} requires constraints on the APB core mass, which is a function of fO₂ and core composition and was calculated using the approach outlined in [1,16] (Fig. 2,3).
Constraints on \( f_O^2 \) in the APB interior are provided by pyroxenes in D’Orbigny, which record \( \DeltaIW-0.7 \pm 0.6 \) [17]. Fig. 2 shows that at \( \DeltaIW-1 \), no core is formed if the core is pure Fe. This is increased to \( \DeltaIW-0.6 \) for a 70% Fe core. The \( f_O^2 \) is therefore constrained to \( \DeltaIW-0.95 \pm 0.35 \). We further assume a CV chondrite APB mantle composition, T ranging between the sol-liq as a function of P determined for Allende composition [18], P = 0.1 GPa relevant for smaller-sized planetary bodies (e.g., Vesta) and \( nbo/t = 2.7 \)–\( 3 \).

**Modeling results:** Preliminary findings suggest that the siderophile elements depletions can be satisfied within a \( f_O^2 \) range of \( \DeltaIW-1.50 \pm 0.45 \), depending on the composition of the core. This \( f_O^2 \) range corresponds to a core mass fraction range of 0.12–0.29 and lies partly within the \( f_O^2 \) range derived by [17]. There are no solutions for all elements for a pure Fe core (Fig. 4a), but a Fe-rich core with 20% Ni provides a \( f_O^2 \) range at which all siderophile element depletions are satisfied (Fig. 4b). The upper bound of the \( f_O^2 \) solution space is provided by the lack of solutions for W and/or Ga, whereas the lower bound is constrained by absence of solutions for Co and Ni. We also observe that an increase of core S content at constant Ni content effectively lowers the \( f_O^2 \) at which all siderophile element depletions are satisfied, similar to what is observed for Mars [19] and Vesta [1] (Fig. 5).

Using the \( f_O^2 \) estimate from pyroxene cores in D’Orbigny [17], we can further constrain the core mass and core composition of the APB. For example, a APB core with 10% Ni leads to more reduced \( f_O^2 \) and is not consistent with independent \( f_O^2 \) estimates from D’Orbigny. To satisfy the D’Orbigny \( f_O^2 \) range, the core must therefore be Ni-rich (>10 wt%). A S-rich APB core is not likely, given that this results in more reduced conditions as well. Using the \( f_O^2 \) of [17], the core mass is constrained to 17±5%.

**Discussion:** As the size of the APB is virtually unconstrained, future models should explore the effect of T and P on these models. We also note that the APB mantle depletion of Ga, a volatile element, can be explained by core formation only, similar to what is observed in the Moon [2] and Vesta [1].