THE EFFECTS OF Si AND fO2 ON THE METAL-SILICATE PARTITIONING OF VOLATILE SIDEROPHILE ELEMENTS: IMPLICATIONS FOR THE Se/Te SYSTEMATICS OF THE BULK SILICATE EARTH

A. X. Seegers1, E. S. Steenstra1, R. Putter1, Y. H. Lin1, J. Berndt2, S. Matveev3, N. Rai4, S. Klemme2, W. van Westrenen1 1Faculty of Earth & Life Sciences, Vrije Universiteit Amsterdam, NL (e.s.steenstra@vu.nl), 2Department of Mineralogy, University of Münster, Germany, 3Department of Petrology, Utrecht University, Utrecht, NL, 4Indian Institute of Technology Roorkee, India

Introduction: Siderophile elements have shown to be a useful tool to constrain planetary differentiation conditions, including those in the early Moon [1-4] and the early Earth [5,6]. Some siderophile elements are volatile, and their behavior may provide insight into volatile fluxes in the early solar system. Recent studies suggest that the observed lunar mantle depletions of volatile siderophile elements (VSE) can be explained by their sequestering into the core at high temperatures [2,3,7]. Similar scenarios have also been suggested for the Earth, for example for S [8] and In, Ge, As, Sb [9]. The Earth may have initially accreted under very reducing conditions [5,6] making it likely that the Earth’s core contains significant amounts of Si [10]. Recently, the Se/Te ratios of the BSE have been used to argue for a volatile-rich late veneer [11], but it is unclear to what extent their metal-silicate partitioning and resulting Se/Te ratios are affected by metallic Si at low fO2. Here, we study the effects of fO2 (and Si in metal) on the metal-silicate partitioning of the VSE (Se, Te, As, Cd, In, Pb, Sb) at high pressure (P) and temperature (T). Related work is shown in several companion abstracts at this meeting [12-15].

Approach: Experiments were performed in an endloaded piston cylinder press between 1-2.5 GPa at 1883 K using MgO capsules. Capsules were loaded with synthetic equivalents of A15C green glass or a lunar granite combined with Fe metal plus trace elements. Various amounts of Fe6Si17 were added to generate different fO2 conditions. Samples were embedded in epoxy, polished, and analyzed for major and trace elements with EMPA and LA-ICPMS, respectively.

The effects of Si were quantified by considering K0 or ln(Di/Di∞) for element i with valence n, which removes effects of variable fO2 [16,17]. The K0 values of non-divalent elements were corrected for different activity (γ) of Fe. The slope of K0 versus ln(1-XSi) then yields the interaction coefficient or εsi for element i with Si. The fO2 relative to IW was calculated assuming non-ideal γFe and γFeO = 1 [13].

Results: Run products show well segregated metallic blob(s) within a quenched silicate melt. The fO2 varied significantly (∆IW = -6.9 to -1.7) and Si metal contents ranged between 0 and 11 wt%.

Oxygen fugacity: D(Se, Te) are clearly dependent on the FeO content of the silicate melt, consistent with earlier work [14,18] (Fig. 2). This results in Se and Te behaving lithophile at highly reducing conditions. This is related to changes in γFeO with decreasing fO2 [18].

Fig. 1: BSE image of typical run product.

Fig. 2: Effect of fO2 on D(Se, Te).
**Effect of Si:** Fig. 3 shows the effect of Si on K\textsubscript{D} As, Sb, In: they behave less siderophile with increasing X\textsubscript{Si} of the metal. The slopes of K\textsubscript{D} versus ln(1-X\textsubscript{Si}) are a measure of the interaction between the element and X\textsubscript{Si}. The slopes clearly vary as a function of P in the small P range shown (Fig. 3). This is the subject of another abstract [17]. Similar dependencies are observed for K\textsubscript{D} Pb, Cd. Results suggest a 4+ valence state for Si (Fig. 4). At more reducing conditions, non-ideal behavior is observed, suggesting effects of Si on γSi [17].

![Graph of corrected ln(D/Fe\textsuperscript{5+}) versus Si in metal](image)

**Discussion:** This study has several implications for planetary core formation models. First, we provide clear evidence of significant pressure dependencies on interaction coefficients [see 13, 17]. This implies that siderophile or lithophile behavior inferred for siderophile elements at low pressure, may be completely different at pressures relevant for core formation in the Earth. Pressure seems also to affect the parabolic dependence of D(Se, Te) on melt FeO contents (Fig. 2). At higher pressures, the parabola tightens, resulting in more lithophile behavior at constant fO\textsubscript{2}. It may turn out that Se and Te behave far less siderophile at these conditions, possibly removing the need for a volatile-rich late veneer as suggested by [11], which would be in agreement with other recent work [12,14].


![Graph of log D(Si) versus fO\textsubscript{2}](image)

*Fig. 4. Effect of fO\textsubscript{2} on D(Si). At more reducing conditions, this slope changes due to effects of dissolved Si on D(Si) [see also 17].*