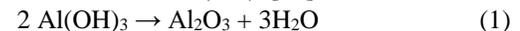


THE EFFECT OF WATER ON THE METAL-SILICATE PARTITIONING BEHAVIOR OF VOLATILE SIDEROPHILE ELEMENTS DURING LUNAR CORE FORMATION. A. X. Seegers¹, E. S. Steenstra¹, A. W. van der Waal², S. Matveev², J. Berndt³, S. Klemme³, W. van Westrenen¹; ¹Faculty of Science, Vrije Universiteit Amsterdam, the Netherlands (a.x.seegers@vu.nl), ²Faculty of Geosciences, Utrecht University, the Netherlands, ³Institute of Mineralogy, University of Münster, Germany

Introduction: Although most of the current geochemical models of the formation and evolution of the Moon are based upon anhydrous conditions, recent studies have found indigenous hydrogen (H) in lunar samples, including lunar volcanic glasses, olivine-hosted melt inclusions, apatites and plagioclase [1-5]. The presence of H within the lunar interior indicates the Moon is not as volatile-depleted relative to Earth as previously thought [6]. This is further supported by recent studies that focused on the volatile siderophile elements (VSE) such as As, In and Sb [7-9]. These studies showed that these elements are not necessarily depleted in the lunar mantle due to degassing only, but are likely to be significantly depleted due to preferential segregation into the lunar core. The presence of H may influence trace element partitioning systematics as it could affect the activity of major element oxide and/or trace element components in the silicate melt. However, the effects of H on metal-silicate partitioning of siderophile elements are not well constrained. Righter and Drake (1999) studied the effects of H on metal-silicate partitioning of refractory siderophile elements, but did not find consistent effects of H [10]. A recent study also found no evidence for effects of H on metal-silicate partitioning of many refractory elements [11]. To additionally explore the feasibility of significant storage of VSE in planetary cores, we performed high pressure (P) – temperature (T) experiments to assess the effects of H on the metal-silicate partitioning of VSE. We apply these results to the Moon and assess the possible effects of H on the outcome of current lunar core formational models.

Approach: High *P-T* metal-silicate partitioning experiments were performed using an end-loaded piston cylinder press. Experiments were conducted at 1 GPa and 1673-1873K using AuPd or Pt outer capsules and graphite inner capsules. Capsules were loaded with a synthetic basalt composition and 0-4 wt.% H₂O, which was added through addition of Al(OH)₃ along with Cs. The metal composition consisted of Fe metal plus trace elements (As, Cd, In, Pb, Sb, Se, Te) [12]. Samples were analysed with EMPA and LA-ICP-MS for major- and trace elements. As H cannot be measured directly with EPMA or LA-ICP-MS, Cs was added as an internal proxy because Cs is known to behave like H⁺ in terms of high volatility and incompatible partitioning behavior [13]. Glassed starting compositions were measured to determine the initial Cs abun-

dance and therefore the H/Cs ratio after addition of Al(OH)₃ to the starting composition. To ensure the accuracy of the Cs proxy method, comparison with another method of calculating the H content is required. As the water was added to the composition through addition of Al(OH)₃, the concentration of H₂O within the experiment can be calculated through the dehydration reaction of Al(OH)₃ [11]:



By subtracting the Al₂O₃ concentrations of the glassed dry starting composition, the excess Al₂O₃ can be calculated. This provides an independent estimate for the concentration of H₂O which can be used to verify the Cs method.

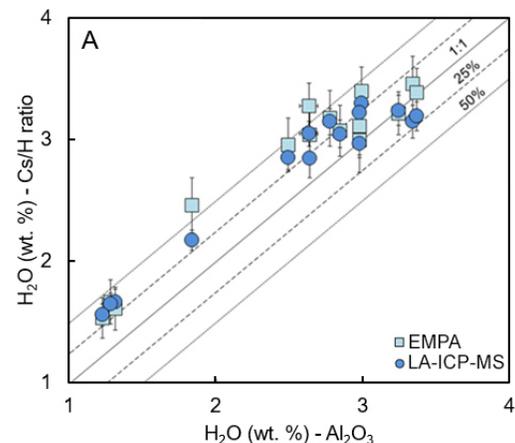


Fig. 1: Experiment H₂O content calculated from Cs and Al₂O₃ abundances.

Results: Run products show a homogeneous silicate melt with well segregated rounded metallic blobs. The experimental *f*O₂ ranged between -2.3 to -0.6 log units below the IW buffer (Δ IW).

Proxy method: Comparing the Cs and Al₂O₃ methods, fig. 1 indicates the H₂O concentrations calculated by the two methods typically show a <25% deviation. Although the Cs method returns slightly increased H₂O concentrations, these results indicate it is an accurate proxy for the H₂O content. We find that LA-ICP-MS Cs measurements provide more accurate H₂O concentrations than EMPA. However, calculated H₂O percentages are significantly lower than the initially added, indicating a consistent H₂O loss of 25% during the experiments. This is the case for both 2wt% and 4wt% H₂O bearing experiments..

The effect of water: Fig. 2 and 3 show the effects of the addition of water on the partitioning of several of the studied VSE. We observe a small decrease in siderophile behavior with water content for In, and a minor increase (or potentially no effect) from water on Pb and Sb (fig. 2). Based on fig. 3 it might be concluded water has no effect on D (Se, Te). However, earlier studies indicate a decrease in siderophile behavior due to the addition of C, which is not observed here [14]. We therefore suggest the addition of water to slightly increase D (Se, Te), counteracting the effects of C.

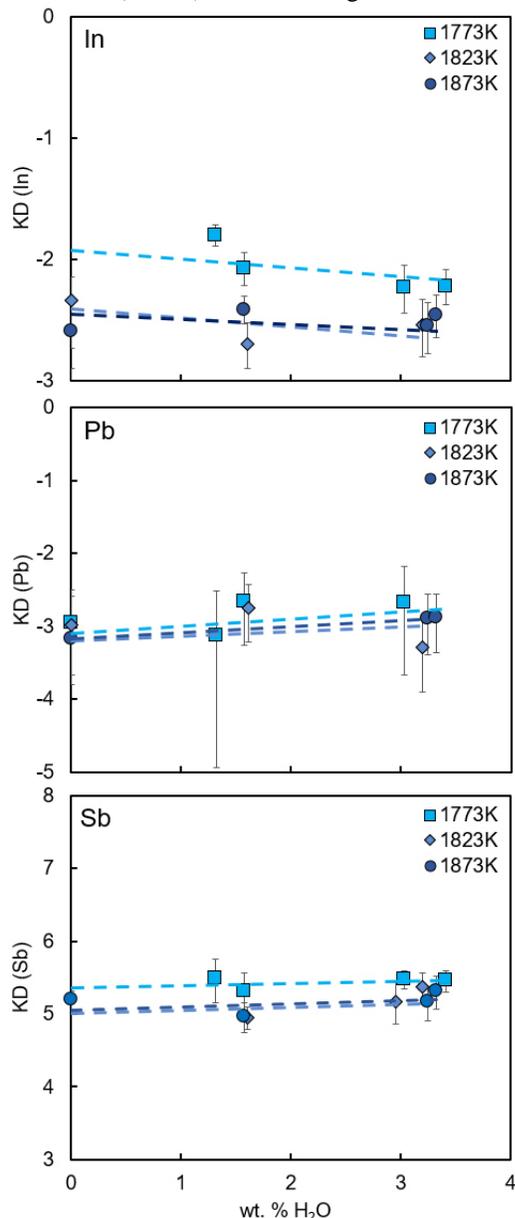


Fig 2: KD (partition coefficient D corrected for changing FeO activity in silicate melt) of In, Pb and Sb against wt.% H_2O .

Discussion: Our experiments were performed with very high water contents. Recent studies indicate that the lunar interior contains variable yet small amounts of H_2O : 40 ppm H_2O in mantle sources of pyroclastic glasses and 133-292 ppm H_2O in the BSM [6, 15-16].

Water contents within this order of magnitude would result only in negligible changes in partitioning behavior of VSE when directly applied to the Moon. Therefore our preliminary results indicate the effect of hydrogen within the lunar interior on the siderophile behavior of VSE during core formation is likely to be limited and potentially insignificant.

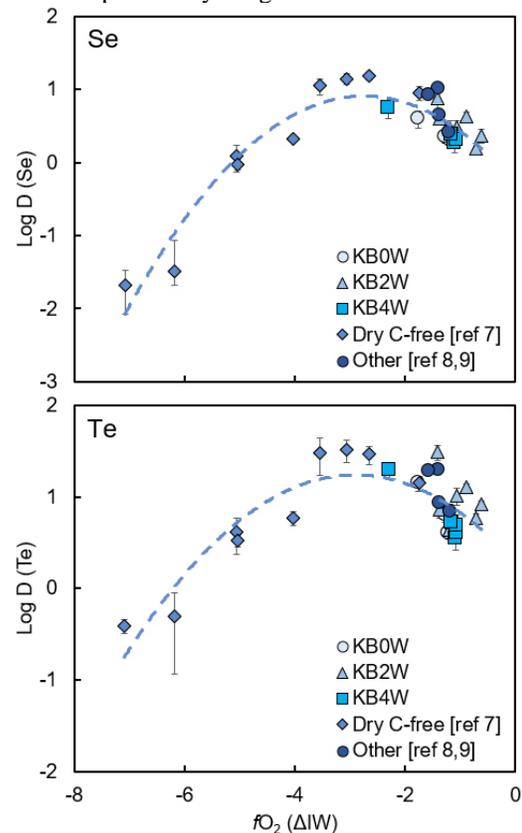


Fig. 3: Calculated Log D (Se, Te) against fO_2 .

References: [1] Saal et al (2008) *Nature* 454, 192 [2] Hauri et al (2011) *Science* 333, 213 [3] Tartese et al (2013) *GCA* 122, 58 [4] Hui et al (2015) *Nat Geosci* 6, 177 [5] Furi et al (2014) *Icarus* 229, 109 [6] Hauri et al (2015) *EPSL* 409, 252 [7] Seegers et al (2017) *LPSC #1053* [8] Steenstra et al (2017) *LPSC #1051* [9] Steenstra et al (2017) *Nature Sci Rep* 7, 14552 [10] Righter and Drake (1999) *EPSL* 171, 383 [11] Clesi et al (2016) *GCA* 192, 97 [12] Righter et al (2011) *EPSL* 304, 158 [13] Kessel et al (2004) *AM* 89, 1078 [14] Seegers et al (2017) *LPSC (this meeting)* [14] Crockett et al (2017) *LPSC #1054* [15] Robinson et al (2016) *GCA* 188, 244 [16] Albarede et al (2014) *MPS* 50, 568