Partitioning of P, Cr, Mn and Ti between metal and silicates melts in reduced Mercurian magmas

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The MESSENGER mission shed a light on the unique and diverse surface composition of Mercury marked by the presence of light elements (e.g. S, C) and extremely low iron, which suggests strongly reducing conditions (fO_2 ~IW−3 to IW−7) [1],[2],[3],[4],[6]. Because of these elements, such as Si, being extracted from the silicate mantle and added to the core, while other elements, nominally siderophile (e.g., S, C), become lithophile and concentrate in the silicate portion of the planet. Redox state strongly controls the partitioning of elements between silicate and metals, suggesting that other elements behave differently [1],[2],[3],[4],[6]. MESSANGER and previous experimental and modelling studies have shown the effects of reduced environments on Si, S, and C, the behaviour of minor elements, such as P, Cr, Mn, and Ti, is poorly constrained. Enstatite chondrites have been indicated as representative of Mercury's bulk silicate and similarly have been formed in reduced environments [1],[2],[3],[4]. In these chondrites, the presence of P is mainly detected as form scherbestite (Fe_3P), in the case of Cr, Mn and Ti as daubréelite ($FeCr_2Si_4$), ningerite (Mg, Fe, Mn, Ca, Cr)S, albandite (Fe, Mn)S, TiS and as Cr or Ti bearing troilite (FeS) [2],[3],[5]. Additionally, MESSENGER only found evidence of presence of Cr on the surface, despite its expected siderophile behaviour. This study aims to investigate these minor elements partitioning behaviour of P, Cr, Mn and Ti between metal and silicate melts under reducing conditions relevant to Mercury's interior, with relevance to the BepiColombo mission. We focus on pressures ranging from 1.5 to 8 GPa at temperatures between 1600 and 2000 ºC between Mercury's mantle and its core-mantle boundary (CMB). The experiments are performed using piston-cylinder up to 2 GPa, then Kawaii-multi-anvil press up to 8 GPa, with an assembly consisting of graphite capsules, and an extremely reduced condition will be achieved via Si-SiO_2 buffer by adding Si in the synthetic silicate composition, reassemble enstatite chondrite (EH4 Indarch) [2],[3]. The metal phase was consistent with Fe and synthesised in piston-cylinder as Fe-9Si and Fe-16Si [2]. Preliminary results show that P and Cr strongly partition into the metal phase, whereas Mn and Ti mainly partition into the silicate phase. Pressure shows no clear effect on the partitioning of P, Cr, Mn and Ti. The solubility of these elements' correlates strongly with oxygen fugacity, as observed in previous studies [2],[3]. The partitioning is governed by the distribution of Si between the metal and the silicate, and by the distribution of S in the silicate, these two might control the partitioning of Mn, Ti, and P into the core. Additionally, Si and S indicate that the samples were under reduced conditions (> -4 IW), and the absence of the metal indicates that these are in the silicate form as Ti^{+4}, implying that the samples' fugacity cannot be below -6 IW [3]. The present preliminary results differ from previous studies, as P, Mn, Cr, and Ti were expected to be partitioned into the metal as siderophile elements at low fO_2 conditions [3],[4]. Discrepancies may be attributed to the complexity introduced by the presence of Si in the metal and S in the silicate melt. As these experiments appear not to follow the previous experiment's regime, further work is necessary.

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Keywords: Mercury, metal–silicate partitioning, Fe-Si , enstatite chondrite