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Investigating Mercury's internal structure and volatile budget using trace elements partitioning experiments

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The hypothetic existence of an FeS layer at the core-mantle boundary of Mercury and the volatile content of the planet are debated subjects. The study of the distribution of heat-producing elements (HPE) can be used to tackle both of these issues. Here, we report new minor and trace element partitioning coefficient data between silicate melts, FeS, metal melts (Fe-Si) and MgS equilibrated under highly reduced conditions (~IW−8 to ~IW−1), at temperature (1500-1720 °C) and pressure (0.1 – 3GPa) relevant to Mercury's interior. The experiments were carried out on a synthetic composition similar to the silicate fraction of enstatite chondrites, representing the bulk silicate Mercury, with varying amount of Fe, FeS and CaS. Experimental results were combined with literature data to model the behavior of HPE during Mercury's differentiation and partial melting of the mantle. While K, and especially Th, are very lithophile, U becomes chalcophile at low oxygen fugacity (~IW-5). In our model, starting with chondritic bulk Th/U (3.3), we observe that the formation of even a relatively thin FeS layer (~ 20 km) under reducing conditions (<IW-4) increases Th/U ratios above the measured surface ratio (2.5 ± 0.9). Th and U should be further fractionated during partial mantle melting in presence of mantle sulfides such as MgS, which are thought to be abundant in Mercury. While it is possible that the planet formed at higher oxygen fugacity (>IW-4), or that bulk Mercury had Th/U close to the lowest measured in chondrites (<3), the surface Th/U ratio does not support the presence of a thick FeS layer that equilibrated with the silicate magma ocean. Concerning the volatile budget of Mercury, our models suggest that the K/Th (~5200) and K/U (~12500) measured on the surface are respectively 2-4 and 3-6 times lower than what we would expect if the planet formed from materials similar to enstatite chondrites (~26000 and ~90000 respectively). It is very probable that Mercury lost large amounts of K during its history, as observed before on other terrestrial bodies, but there are still uncertainties on the processes responsible for it.