U, Th and REE partitioning into sulfide liquids: Implications for reduced planetary bodies

A. WOHLERS[1] AND B.J. WOOD[1]

[1]Department of Earth Sciences, University of Oxford, Oxford OX1 3AN, UK, Anke.Wohlers@earth.ox.ac.uk, Berniew@earth.ox.ac.uk.

We have performed experiments at 1.5GPa over the temperature range 1400-2100ºC to determine the partitioning of lithophile elements (U, Th, Eu, Sm, Nd, Zr, La, Ce, Yb) between sulfide liquid and silicate melt. The initial objective was to investigate the properties of sulfide melts in highly-reduced (low-FeO) Mercury-like bodies. The data demonstrate pronounced increases in partitioning of all the lithophile elements into sulfide at very low FeO contents (<1wt%) of the silicate melt such that D_U (sulfide/silicate) exceeds 1 and may be >10 in some cases. Similarly, D_{Sm} is > 2 under the same conditions of low silicate FeO. The results may be understood in terms of exchange reactions such as:

$$\underset{\text{silicate}}{UO_2} + \underset{\text{sulfide}}{2FeS} = \underset{\text{silicate}}{2FeO} + \underset{\text{sulfide}}{US_2}$$

A recent study showed that, for sulfide-silicate partitioning of element i, $\log D_i$ should generally be proportional to $-\log[FeO]_{sil}$ [1]. For lithophile elements, however, the slopes of the observed dependences of $\log D_i$ on $-\log[FeO]_{sil}$ are much greater than anticipated. Since the low FeO contents of our experimental silicate melts are accompanied by high S contents (up to 11wt%) we infer the dramatic increase in D_i to be due to the well-known mutual compatibility of FeO and S in silicate melts. Thus, increasing S content stabilizes FeO and lowers its activity in the silicate melt, driving the exchange reaction above to the right and increasing D_U. When applied to a putative Mercury-like component of early Earth we find that addition of a planetesimal with a sulfide core could add up to 10 ppb of U to the core, generating, when the accompanying 21 ppb Th is also considered, ~3TW of the energy required for the geodynamo. In this case, the Th/U ratio of silicate Earth would approximate 4.3, within the range of some estimates. Entry of U and Th into the core would be accompanied by a superchondritic Sm/Nd of silicate Earth, with corresponding small (<14ppm) excesses of ^{142}Nd.

We performed additional experiments to determine if the pronounced partitioning of lithophile elements into sulfide also applies to metals poorer in S and hence likely to be more typical of planetary cores. We find, however, that the effect of low FeO on partitioning is uniquely confined to metallic melts close to stoichiometric FeS in composition.

References: [1] Kiseeva & Wood (2013). *EPSL* **383**, 68-81;