Development of a comprehensive model for element partitioning between sulphide and silicate liquids

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We recently showed [1] that partitioning of many elements between sulphide and silicate melts is a function of the FeO content of the silicate liquid. The theoretical relationship is a linear one between $\mathrm{Log}D_M$ (D_M=$[M]_{sulph}/[M]_{sil}$) and –log[FeO] with a slope of n/2, where n is the valency of trace element M. In practice we find that the slope deviates from the theoretical one because of the presence of oxygen in the sulphide.

In this study we expand our model and account completely for the effects of temperature and sulphide liquid composition. We parameterise the effects of Ni, Cu and O (or FeO) in sulphide by incorporating the ε-model of non-ideal interactions in metallic liquids, which, we show, can be successfully applied to sulphide liquids. We find that $\varepsilon^{CuS0.5}$ and ε^{NiS} are small or zero for Cu, Ni, Pb, Ag, Zn, Cd, Tl, Mn, In, Co, V, Cr. Significant terms are required for Ti, Ga, Sb and Ge. The effect of oxygen in sulfide, ε^{FeO} is large and negative (lithophile elements) in the order Ta > Nb > Ti > V ~ Ge ~ Ga, near zero for Ni, Pb, Zn, Cd, Mn, In, Sb, Co, Cr and positive for Cu, Ag, Tl.

Our results suggest:

1. About 0.14% sulphide precipitates from MORB liquids during fractionation.

2. Nearly constant Ce/Pb and Nd/Pb ratios which appear to be ~25 and ~20 respectively can be achieved during fractional crystallisation of magmas generated by 10% melting of depleted mantle provided the latter contains >100 ppm S and about 650 ppm Ce, 550 ppm Nd and 27.5 ppb Pb.

3. Sulphide and chalcophile elements played important roles in the accretion and differentiation of the Earth. The pattern of depletion on Earth of such chalcophile elements as Cu, Zn, Ag and Pb could be explained by the late addition to the core of approximately 0.4% of sulphide matte.

[1] Kiseeva E. S., Wood B. J. (2013). *EPSL* **383**, p. 68-81.