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Experimental constraints on volatile element evaporation into air and CO-CO_2

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The volatility of metals and semi-metals is relevant for volcanic emanations and impact vaporization at different scales. Furthermore, elemental fractionations in the early solar system scale with the volatility of elements. Nonetheless, our understanding for the evaporation and condensation behavior in geo- and cosmochemical environments is far from complete.

Whether an element behaves volatile or refractory depends strongly on temperature and oxygen fugacity. Thus, we performed volatility experiments with 17 elements (Li, K, Na, Cr, Mn, Co, Cu, Zn, Ga, Rb, Cd, In, Sn, Sb, Te, Cs, Tl). We applied a modified mechanically assisted equilibration technique (MMAE - at LMU München), where *ca.* 60 g of a haplobasaltic starting composition (An-Di) was doped with up to 5000 ppm of volatile elements and heated to run temperatures at different oxygen fugacities at atmospheric pressure:

Experiment SV1: CO-CO_2 atmosphere; $\log fO_2$ = -11.3 at 1580 K for 72 h.

Experiment SV2: in air; $\log fO_2$ = -0.7 at 1589 K for 336 h.

Up to 46 samples were taken from the melt by time-series sampling to monitor the volatility related loss. Two Al_2O_3 plates served as condensation traps. Thus, the evaporation and condensation behavior of the elements is recorded simultaneously.

For the melt samples, volatile element concentrations were determined by laser-ablation-ICP-MS (Universität Frankfurt). For a subset of melt samples, some major and all volatile elements were determined by solution-ICP-MS (Universität Bonn). Additional cadmium stable isotope compositions were measured by MC-ICP-MS in Bonn (Kremser et al., this volume). The volatile element distribution at the top 10 or 20 cm (SV1 and SV2, respectively) of the condensation traps was investigated at 0.5 mm resolution using an XRF scanner (Universität zu Köln).

At low fO_2 (SV1), all alkali elements and Mn behaved refractory. Co, Ga, Cr as well as Cu and Te were increasingly depleted in that order, while In, Tl, Sn, Sb and Cd were most volatile. Some elements display complex depletion patterns with time. Cr, for example, is initially lost rapidly, but the residual ∼30% were retained in the melt. Recondensation of Cd and Te set in sharply at about 450 K, while Tl condensed more gradually with a peak at ∼425 K.

At high fO_2, volatile loss is generally slower in air compared to CO-CO_2. Li, Na, Mn, Zn and Ga behaved (almost) refractory, while Cu, Rb, Sn, Sb, Cr and Cs were increasingly depleted and Cd, Te and Tl were lost almost completely. The distribution pattern of Cd and Te at the uppermost 10 cm of the condensation plates appears more complex and both elements start to condense at lower temperatures compared to the low fO_2 experiment. The lost alkali element fraction (K, Rb, Cs) condensed at about 450 K.

The data indicate a complex volatilization and condensation behavior for the investigated elements that is strongly related to the ambient oxygen fugacity. The retention of the alkali elements and Mn bears some resemblance to the volatile element patterns in ordinary chondrites, however, the gradual depletion pattern typically observed in chondrites was not matched in our experiments.