

One atmosphere experimental study on the partitioning of the HFSE between olivine, pyroxene and lunar basaltic melts in the CMAS + Fe + Ti system

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Titanium is generally regarded as a minor element in the Bulk Silicate Earth (1265 $\mu\text{g/g}$), with average and maximum TiO_2 contents of 1.06 and 5.57 wt. %, respectively. In the Moon, however, TiO_2 can be found in concentrations as high as 17 wt. %. In order to better explain this enrichment, petrogenetic models require precise knowledge of major and trace elements fractionation under conditions similar to the ones that may have prevailed on the lunar mantle. Previous studies show that Fe-Ti-O melt species may affect the fractionation of the high-field strength elements (HFSE) between Fe-Ti oxides and silicate melt. However, there is a scarcity of data on the behaviour of these elements between silicates and lunar mare basalts with different TiO_2 contents. To address this issue, we present results from an experimental campaign on a HFSE-doped basalt in the CMAS system with different amounts of Cr_2O_3 (0.1 – 1.5 wt.%), P_2O_5 (0.1 – 0.5 wt.%), FeO (0 -17 wt.%) and TiO_2 (1 – 21 wt.%). Experiments were carried out in a vertical tube gas-mixing furnace with temperatures ranging from 1100 to 1300 °C and ΔFMQ from -5.2 to +6.6. Major and trace elements were acquired with the EMP and LA-ICP-MS, respectively.

Our results for $D_{\text{HFSE}}^{\text{silicate/melt}}$ are in agreement with the literature for glasses with ca. 1.0 wt.% TiO_2 . Nevertheless, $D_{\text{HFSE}}^{\text{olv/melt}}$ for 4+ and 5+ cations have a negative correlation until ca. 4.8 wt. % TiO_2 in the silicate glass and after that values are constant until ca. 20 wt. % TiO_2 . This may be used to indicate that a melt complex may be present, since $D_{\text{Ti}}^{\text{olv/melt}} < 0.01$. Regarding the $D_{\text{U}}^{\text{olv/melt}}$, values change by almost one order of magnitude from more incompatible at the more oxidizing experiments, where the main species present is U^{6+} to relatively more compatible at the more reducing experiments, where there is a greater contribution of U^{4+} . Results for $D_{\text{HFSE}}^{\text{cpx/melt}}$ do not show any change over the range of TiO_2 in the glass in this study, apart from the same behaviour observed in olivine for $D_{\text{U}}^{\text{cpx/melt}}$. The most striking feature is the $D_{\text{HFSE}}^{\text{cpx/melt}}$ which varies by almost one order of magnitude from low-Ti to high-Ti glasses. This behaviour is observed for $D_{\text{Zr}}^{\text{cpx/melt}}$, $D_{\text{Hf}}^{\text{cpx/melt}}$, $D_{\text{Ta}}^{\text{cpx/melt}}$ and $D_{\text{Th}}^{\text{cpx/melt}}$ and is surprisingly less pronounced for $D_{\text{Nb}}^{\text{cpx/melt}}$. For the $D_{\text{U}}^{\text{cpx/melt}}$, this trend is much more pronounced on the experiments where U^{4+} predominates than U^{6+} . The TiO_2 in the silicate glass is proportional to the TiO_2 in the cpx, which reaches concentrations up to 3.1 wt.% and substitutes both into the M1 and the T site. The $^{\text{IV}}\text{Al}$ on the experiments is in agreement with lunar pyroxene data, with values lower than 0.07 apfu, indicating that Ca-Tschermak component was seldom present. Charge balance mechanism is defined by the substitution of $\text{Ti}^{4+} - 2\text{Al}^{3+}$. Our data represent an improvement on the understanding of the fractionation of the HFSE in conditions similar to the ones that may have prevailed during generation of high-Ti lunar mare basalts.