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Trace element partitioning between olivine and melt in lunar basalts

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Abstract

Mineral/melt partition coefficients have been widely used to provide insights into magmatic processes. Olivine is one of the most abundant and important minerals in the lunar mantle and mare basalts. Yet, no systematic olivine/melt partitioning data are available for lunar conditions. We report trace element partition data between host mineral olivine and its melt inclusions in lunar basalts. Equilibrium is evaluated using the Fe-Mg exchange coefficient, leading to the choice of melt inclusion-host olivine pairs in lunar basalts 12040, 12009, 15016, 15647, and 74235. Partition coefficients of 21 elements (Li, Mg, Al, Ca, Ti, V, Cr, Mn, Fe, Co, Y, Zr, Nb, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu) were measured. Except for Li, V, and Cr, these elements show no significant difference in olivine-melt partitioning compared to the data for terrestrial samples. The partition coefficient of Li between olivine and melt in some lunar basalts with low Mg# (Mg# < 0.75 in olivine, or < ~0.5 in melt) is higher than published data for terrestrial samples, which is attributed to the dependence of D_{Li} on Mg# and the lack of literature D_{Li} data with low Mg#. The partition coefficient of V in lunar basalts is measured to be 0.17 to 0.74, significantly higher than that in terrestrial basalts (0.003 to 0.21), which can be explained by the lower oxygen fugacity in lunar basalts. The significantly higher D_{V} can explain why V is less enriched in evolved lunar basalts than terrestrial basalts. The partition coefficient of Cr between olivine and basalt melt in the Moon is 0.11 to 0.62, which is lower than those in terrestrial settings by a factor of ~2. This is surprising because previous authors showed that Cr partition coefficient is independent of $f_{\mathrm{O_2}}$. A quasi-thermodynamically based model is developed to correlate Cr partition coefficient to olivine and melt composition and $f_{\mathrm{O_2}}$. The lower Cr partition coefficient between olivine and basalt in the Moon can lead to more Cr enrichment in the lunar magma ocean, as well as more Cr enrichment in mantle-derived basalts in the Moon. Hence, even though Cr is typically a compatible element in terrestrial basalts, it is moderately incompatible in primitive lunar basalts, with a similar degree of incompatibility as V based on partition coefficients in this work, as also evidenced by the relatively constant V/Cr ratio of 0.039 ± 0.011 in lunar basalts. The confirmation of constant V/Cr ratio is important for constraining concentrations of Cr (slightly volatile and siderophile) and V (slightly siderophile) in the bulk silicate Moon.

Keywords: Partition coefficients, lunar basalts, olivine, melt inclusions, Cr/V ratio