American Mineralogist, Volume 105, pages 244–254, 2020

Partitioning of V and 19 other trace elements between rutile and silicate melt as a function of oxygen fugacity and melt composition: Implications for subduction zones

Megan Holycross[1,]* and Elizabeth Cottrell[1]

[1]National Museum of Natural History, Smithsonian Institution, Washington, D.C.

Abstract

Vanadium is a multivalent element that can speciate as V^{2+}, V^{3+}, V^{4+}, and V^{5+} over a range of geologically relevant oxygen fugacities (f_{O_2}). The abundance of V in planetary materials can be exploited as a proxy for f_{O_2} when its partitioning behavior is known. The mineral rutile (TiO_2) is an important carrier of the high field strength elements Nb and Ta in the solid Earth, but it can also incorporate substantial quantities of vanadium (up to ~2000 ppm; e.g., Zack et al. 2002). However, little work has been done to systematically investigate how the partitioning of V in rutile-bearing systems changes as a function of both f_{O_2} and composition. We measured the partitioning of V and 19 other trace elements (Sc, Cr, Y, Zr, Nb, La, Ce, Pr, Nd, Sm, Eu, Gd, Dy, Ho, Er, Yb, Lu, Hf, and Ta) between rutile and three silicate melt compositions equilibrated at 1 atm pressure, 1300 °C and f_{O_2} values from two log units below the quartz-fayalite-magnetite oxygen buffer (QFM-2) to air (QFM+6.5). Rutile/melt partition coefficients ($D_V^{rt/melt}$) change dynamically over an eight-log unit range of f_{O_2} and are greatest at f_{O_2} = QFM-2 in all compositions. Vanadium solubility in rutile declines continuously as f_{O_2} increases from QFM-2 and approaches unity in air. Trace-element partitioning between rutile and melt is also correlated with melt composition, with the greatest values of $D^{rt/melt}$ measured in the most polymerized melt systems containing the least TiO_2. We do not find any circumstances where V becomes incompatible in rutile. Our results indicate that rutile is a considerable sink for V at terrestrial f_{O_2} values and will contribute to the retention of V in refractory slab residues in subduction zones. In agreement with previous work, we find that $D_{Ta}^{rt/melt} > D_{Nb}^{rt/melt}$ under all conditions investigated, suggesting that rutile fractionation does not lead to low Nb/Ta ratios in Earth's continental crust.

Keywords: Rutile, oxygen fugacity, vanadium, partitioning, trace element