Alkaline Earth Element Partitioning in Simplified Magmatic Systems

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Nothing is written.

-Lawrence of Arabia (1962)

Abstract

Trace element distributions between mineral and melt phases have proven to be important recorders of igneous differentiation histories, but this utility depends on thorough understanding of their partitioning behavior. We propose a theory for crystal-melt trace element partitioning that considers the energetic consequences of crystal-lattice strain, of multi component major-element silicate liquid mixing, and of trace element activity coefficients in melts. We demonstrate application of the theory using newly determined partition coefficients for Ca, Mg, Sr, and Ba between pure anorthite and seven CMAS liquid compositions at 1330 °C and 1 atm. By selecting a range of melt compositions in equilibrium with a common crystal composition at equal liquidus temperature and pressure, we have isolated the contribution of melt composition to divalent trace element partitioning in this simple system. The partitioning data are fit to Onuma curves with parameterizations that can be thermodynamically rationalized in terms of the melt major element activity product $(a_{Al2O3})(a_{SiO2}^{2})$ and lattice strain theory modeling. Residuals between observed partition coefficients and the lattice strain plus major oxide melt activity model are then attributed to non-ideality of trace constituents in the liquids. The activity coefficients of the trace species in the melt are found to vary systematically with composition. Accounting for the major and trace element thermodynamics in the melt allows a good fit in which the parameters of the crystal lattice strain model are independent of melt composition.

We also present the first experimental measurements of mineral-melt radium partitioning. Ion probe analyses of coexisting anorthite and CMAS glass phases produce a molar D_{Ra} = 0.040 ± 0.006 and D_{Ra}/D_{Ba} = 0.23 at 1400 °C and 1 atm. Our results indicate that lattice strain partitioning models fit the divalent (Ca, Sr, Ba, Ra) partition coefficient data of this study well, supporting previous work on crustal melting and magma chamber dynamics that has relied on such models to approximate radium partitioning behavior in the absence of experimentally determined values.

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