American Mineralogist, Volume 101, pages 1438–1450, 2016

Trace element thermometry of garnet-clinopyroxene pairs

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Abstract

We present major and trace element data on coexisting garnet and clinopyroxene from experiments carried out between 1.3 and 10 GPa and 970 and 1400 °C. We demonstrate that the lattice strain model, which was developed for applications to mineral-melt partitioning, can be adapted to garnet-clinopyroxene partitioning. Using new and published experimental data we develop a geothermometer for coexisting garnet and clinopyroxene using the concentration of rare earth elements (REE). The thermometer, which is based on an extension of the lattice strain model, exploits the tendency of minerals at elevated temperatures to be less discriminating against cations that are too large or too small for lattice sites. The extent of discrimination against misfit cations is also related to the apparent elasticity of the lattice site on which substitution occurs, in this case the greater stiffness of the dodecahedral X-site in garnet compared with the eightfold M2-site in clinopyroxene. We demonstrate that the ratio of REE in clinopyroxene to that in coexisting garnet is particularly sensitive to temperature. We present a method whereby knowledge of the major and REE chemistry of garnet and clinopyroxene can be used to solve for the equilibrium temperature. The method is applicable to any scenario in which the two minerals are in equilibrium, both above and below the solidus, and where the mole fraction of grossular in garnet is less than 0.4. Our method, which can be widely applied to both peridotitic and eclogitic paragenesis with particular potential for diamond exploration studies, has the advantage over commonly used Fe-Mg exchange thermometers in having a higher closure temperature because of slow interdiffusion of REE. The uncertainty in the calculated temperatures, based on the experimental data set, is less than ±80 °C.

Keywords: Lattice strain model, geothermometer, garnet, clinopyroxene, eclogite, experimental petrology, REE