

Hydrogen in diopside: Diffusion profiles

SUSAN CARPENTER WOODS,^{1,*} STEPHEN MACKWELL,^{1,†} AND DARBY DYAR^{2,‡}

¹Department of Geosciences, Pennsylvania State University, University Park, Pennsylvania 16802, U.S.A.

²Department of Geology and Astronomy, West Chester University, West Chester, Pennsylvania 19383, U.S.A.

ABSTRACT

The kinetics of diffusion for hydrogen in diopside single crystals from Jaipur, India, were determined by performing room pressure dehydration experiments at temperatures from 700–850 °C and an oxygen fugacity of 10^{-14} bar. The hydrogen diffusivities were determined for the [100], [010], and [001]* directions either from concentration profiles for hydroxyl in samples after annealing or from bulk hydroxyl concentrations as a function of anneal time for sequential dehydration experiments. The rate of diffusion is anisotropic, with fastest transport along the [100] and [001]* axes and slowest along the [010] axis. Fits of the data to an Arrhenius law yield activation energies and pre-exponential terms of 181 ± 38 kJ/mol and $10^{-2.1 \pm 1.9}$ m²/s for diffusion parallel to [100], and 153 ± 32 kJ/mol and $10^{-3.4 \pm 1.6}$ m²/s for diffusion parallel to [001]*. For diffusion parallel to [010], the data were measured over an insufficient temperature range to calculate the activation energy for diffusion. However, these diffusivities were approximately an order of magnitude slower than those for diffusion parallel to [100] or [001]*. The measured rates and anisotropy for self-diffusion of hydrogen in diopside are consistent with those determined from hydrogen-deuterium exchange in Russian diopside (Hercule and Ingrin 1999). The hydrogen diffusivities are also similar in magnitude to those for olivine (Mackwell and Kohlstedt 1990) and are large enough that the hydrogen content of millimeter-size diopside grains with compositions near Jaipur diopside will adjust to changing environmental conditions in time scales of hours at temperatures as low as 800 °C. As xenoliths ascending from the mantle remain at high temperatures (i.e., >1000 °C) but experience a rapid decrease in pressure, diopside grains may dehydrate during ascent. Thus, low water contents for diopside crystals from xenoliths cannot be taken as indicative of low water contents in the mantle.