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Water diffusion in silica glass through pathways formed by hydroxyls

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Abstract

Water diffusion in silicate melts is a fundamental process controlling physical and chemical consequences for magmatism, but mechanisms of diffusion in silicate glasses and melts are not fully understood. In this study, water diffusion experiments in silica glass were performed at temperatures of 650–850 °C and water vapor pressure of 50 bar, with the aim of improving our understanding of the mechanism of water diffusion in a simple SiO_2-H_2O system, and to construct a general water diffusion model for multi-component silicate glasses. Hydrogen diffusion profiles in silica glass were measured by secondary ion mass spectrometry (SIMS) down to a water concentration of ~10 ppm. Water diffusion profiles indicate that water diffusion becomes slower with decreasing water concentration in silica glass, with the water concentration dependence being greater than in multi-component silicate glasses, particularly at low concentrations (e.g., Doremus 1969, 2000; Zhang and Behrens 2000). A new water diffusion model is proposed for silica glass, where the greater concentration dependence is attributed to the limited number of diffusion pathways in silica glass, formed by breaking Si–O–Si bonds through hydroxyl formation. The model was applied to multi-component silicate glasses, taking into account the effects of metal cations that act as network modifiers by providing additional diffusion pathways for water molecules. The lower water concentration dependence in multi-component silicate glasses and melts is explained by little dependence of the number of diffusion pathways on water concentration because it is controlled extrinsically by network modifier cations. It is concluded that the number of diffusion pathways is an essential controlling factor for water diffusion in silica and silicate glasses.

Keywords: Water, diffusion, silica glass, SIMS, diffusion pathway