Water diffusion in silicate glasses: The effect of glass viscosity

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Water diffusion in silicate melts is one of the main controlling factors of degassing and magma fragmentation processes in a volcanic system. Water diffusivity in silicate melts (glasses) depends on its own concentration. However, the mechanism that is responsible for the dependences on water concentration and on glass compositions has not been fully understood yet. We conducted water diffusion experiments in silica glass [1] and proposed a new water diffusion model for silicate glasses, where the water diffusivity is controlled by the concentrations of main diffusion species (i.e. molecular water) and of diffusion pathways, which are determined by the concentrations of hydroxyl groups and network modifier cations.

The model we proposed well explains the water diffusivity in various silicate glasses from silica glass to basalt glasses. However, pre-exponential factors of diffusion coefficients of water in various glasses show seven orders of magnitude variation although the pre-exponential factor should mainly represent the jump frequency and the jump distance of molecular water and show a much smaller variation.

Water diffusivity in silicate glasses is known to depend on the viscosity of glasses [2]. In this study, we discuss the water diffusivity in various silicate glasses as the function of glass viscosity and water concentration, focusing on the variation of the pre-exponential factors. The viscosity of anhydrous silicate glasses is expressed by the Vogel-Fulcher-Tammann (VFT) equation [e.g., 3-5]. We included the effect of viscosity into the water diffusion model [1] by taking the relationship between water diffusivity and viscosity [2] into account, and found that the variation of the pre-exponential factors of diffusion coefficients of water in various silicate glasses became much smaller than the seven orders of magnitude. This indicates that the diffusion of molecular water in various silicate glasses is controlled by the same atomic process.

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