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Viscosity and chemical diffusion of halogens in silicate melts: implications for volcanic degassing

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The degassing processes in subduction zone volcanism may be affected by the magmato-hydrothermal geochemistry of halogens. Moreover halogens can act as potential monitors of degassing efficiency and provide answers to the question of the role of disequilibrium during partitioning.

However still little is known quantitatively about the transport properties of halogens in silicate melts. An accurate study of the transport properties of halogens could make possible to model the information contained in halogens concentrations of eruptive products and volcanic gasses. For these reasons the chemical diffusivities of the halogens (fluorine, bromine, chlorine and iodine) have been measured in the synthetic Fe-bearing sodium disilicate melts, within a wide range of temperature (650–1400˚). The experiments were performed using diffusion couple technique. Halogens were added to the starting material in the form of FeF_3, $FeBr_3$, $FeCl_3$ and FeI_2 and stirred in concentric cylinder viscometer. The temperature was restricted to 1000-1100˚C to avoid volatilization of halogens. After synthesis the samples were drilled, cut into 2mm disks and then doubly polished. Prepared disks were putted into platinum tubes (5mm diameter) and sealed by welding. The halogen rich sample was located at the bottom. During the experiments the temperature was monitored with a thermocouple located at the vicinity of the capsule. Run durations were between 30 minutes and 3 hours. The recovered samples were analyzed using an electron microprobe in order to determine the diffusion profiles of the halogens. The results were obtained by using Boltzmann-Matano method and they suggest at least 3 orders of magnitude range at 1000˚C between the diffusion coefficients for F, Br, Cl and I. The fastest diffusing species was found to be fluorine, the slowest – iodine.

In addition viscosity measurements were performed in order to place the diffusivity measurements in the context of their extrinsic versus intrinsic nature. The viscosity measurements on halogen-bearing samples were analysed using micropenetration method at low temp. (390-520˚C) and at 1 atm. The results confirm apparently little or no influence on viscosity of chlorine and bromine, whereas the samples rich with fluorine show a greater viscosity decreasing effect. Estimated Si diffusivities for these melts lead us to infer that the diffusivities investigated are fundamentally intrinsic with the consequence that their magnitude varies greatly. The high differential viscosities imply that disequilibrium degassing should be able to be monitored using the records of the relative concentrations of the halogens in eruptive products.