

Diffusion of F and Cl in dry rhyodacitic melt

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ABSTRACT

Chemical diffusion of F and Cl has been experimentally determined in a rhyodacitic melt obtained from remelting a sample of Hekla pumice (Iceland). Diffusion couple experiments were conducted in a vertical tube furnace over a temperature range of 750–950 °C and in air for durations of 1 to 35 days. Concentration profiles of F and Cl were obtained for the quenched samples using an electron microprobe.

Fluorine and chlorine exhibit Arrhenian behavior over the range of temperature investigated here. The pre-exponential factors of F and Cl are $D_0(\text{F}) = 4.3 \times 10^{-4}$ and $D_0(\text{Cl}) = 1.6 \times 10^{-5}$ m²/s. Fluorine diffusion coefficients vary in the order of 1×10^{-15} to 1×10^{-13} m²/s, whereas Cl diffusivity is up to two orders of magnitude slower. The activation energies for F and Cl diffusivities are equal within error at 223 ± 31 and 229 ± 52 kJ/mol, respectively.

The difference in diffusivity between F and Cl is particularly pronounced in the melt of our study, compared to results obtained for other magmatic melt compositions. This means that the potential for diffusive fractionation exists and may occur especially under conditions of magma ascent and bubble growth, as this would favor partitioning of the relatively fast-diffusing halogens into growing bubbles, due to H₂O exsolution. A dependence of diffusivity on atomic radius observed here is enhanced over that observed in more basic, less viscous melts, indicating that diffusive fractionation is more likely to be pronounced in more silicic, more viscous systems. A proper parameterization and modeling of diffusive fractionation of halogens in actively degassing volcanic systems thus holds the potential of serving as a tool for quantifying the processes responsible for volcanic unrest.

Keywords: Halogens (F, Cl), diffusion, silicate melt, diffusion couple, experimental volcanology