Self diffusion and chemical diffusion of iron in hydrous rhyolitic melts

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Diffusion data for iron in natural silicate melts are rare. Such data is required in order to model processes like crystal growth and dissolution in magmas, or to predict the timescales of iron isotope exchange between coexisting phases in magmas. Here we present the results of an experimental study on diffusion of iron in hydrous rhyolitic melts with peralkaline [Al/(Na+K+2*Ca)=0.76] and peraluminous [Al/(Na+K+2*Ca)=1.06] composition using the diffusion couple technique. The water content of the melts was always ca. 4 wt%. In chemical diffusion experiments an iron-bearing melt was contacted with an iron-free melt. In self diffusion experiments the chemical composition of the melt was the same in both halves of the couple but one half was isotopically enriched in ^{57}Fe. Experiments were performed in internally heated gas pressure vessels at 800 – 1100°C and a confining pressure of 2 kbar for 0.5 to 30 hours. Compositional profiles of oxides in the quenched glasses were measured by electron microprobe. The relative abundance of iron isotopes along the diffusion direction was measured in-situ using UV femtosecond laser ablation – MC-ICPMS. The iron redox state of the quenched melts was determined by colorimetric wet-chemical analysis. Typically, the Fe^{2+}/Fe_{total} ratio was smaller for the peralkaline rhyolite (0.33) than for the peraluminous rhyolite (0.66) which can be attributed to the stabilizing effect of excess alkali elements (compared to the amount needed for charge compensating Al) on ferric iron.

The self diffusion of iron was found to be systematically faster by up to 0.16 log units than chemical diffusion. Surprisingly, the diffusivity of iron in both melt compositions differs by less than 0.5 log units. This implies that variations in anhydrous melt composition have a minor effect on the transport properties of hydrous rhyolite melts. The most important compositional parameter is obviously the water content of the melt. Chemical diffusion coefficients of iron in hydrous rhyolite melt increase from log D = -13.48 at 800°C to log D = -12.28 at 1100°C (D in m^2/s) for the peralkaline melt and from log D = -13.20 at 800°C to log D = - 11.71 at 1100°C for the peraluminous melt. It is noteworthy that the iron diffusivity is 1-2 log units faster than the diffusivity calculated by the Eyring relationship using viscosity data for metaluminous rhyolite [Al/(Na+K+2*Ca)≈1.0]. This indicates that iron diffusion is partially decoupled from the diffusion of the network forming elements such as Al and Si.

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