

The diffusion coefficients of noble gases (He-Ar) in a synthetic basaltic liquid: one-dimensional diffusion experiments.

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Diffusion coefficients of noble gases in silicate liquids are poorly known, and, as a result, it is difficult to quantify the importance of kinetic fractionation of noble gas abundances and isotopic compositions during magmatic processes. Nevertheless, diffusive fractionation has been invoked to explain noble gas signatures in MORBs and OIBs, with important implications for magma degassing and noble gas mantle geochemistry. In order to investigate the diffusion of noble gases in magmas, we developed an experimental protocol based on uniaxial diffusion of He and Ar through a column of synthetic basaltic liquid in a Pt tube. At the end of the experiment, the column of silicate liquid was rapidly quenched to a glass recording the diffusion profile. The glass cylinder was cut into a series of slices, which were analyzed for noble gases by traditional noble gas mass spectrometry following total gas extraction by fusion.

Using this protocol, we measured He and Ar diffusivities in CMAS glass G1 (50 mol % SiO₂, 9 mol % Al₂O₃, 16 mol % MgO, 25 mol % CaO) at temperatures of 1673 K and 1823 K: $D_{\text{He}} = 2.75 \pm 0.25 \times 10^{-6} \text{ cm}^2 \cdot \text{s}^{-1}$ ($T = 1673 \text{ K}$); $D_{\text{He}} = 4.77 \pm 0.42 \times 10^{-6} \text{ cm}^2 \cdot \text{s}^{-1}$ ($T = 1823 \text{ K}$); and $D_{\text{Ar}} = 9.3 \pm 1.3 \times 10^{-7} \text{ cm}^2 \cdot \text{s}^{-1}$ ($T = 1673 \text{ K}$). Combining these new high temperature data with diffusion coefficients measured on the same composition just above the glass transition temperature [1], we determined the activation energy E_a and the pre-exponential factor D_0 for He and Ar diffusion in silicate liquids: $D_0 = 1.72 \pm 0.9 \times 10^{-2} \text{ cm}^2 \cdot \text{s}^{-1}$ and $E_a = 59.3 \pm 2 \text{ kJ/mol}$ for Ar; $D_0 = 1.8 \pm 0.5 \times 10^{-4} \text{ cm}^2 \cdot \text{s}^{-1}$ and $E_a = 24.7 \pm 0.9 \text{ kJ/mol}$ for He. Because He and Ar have very different activation energies for diffusion in the liquid state, the ratio $D_{\text{He}}/D_{\text{Ar}}$ is strongly sensitive to temperature, decreasing from 145 at the glass transition temperature (1005 K) to 2 at 1823 K. The implication is that the kinetic fractionation of He relative to Ar in magmas is likely to be more important during the cooling stages than during the earlier, high temperature stages of magmatic history.

[1] Amalberti, et al., (2016). *Geochimica et Cosmochimica Acta*, 172, 107-126.