American Mineralogist, Volume 86, pages 1–13, 2001

Self diffusion of Si and O in dacitic liquid at high pressures

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ABSTRACT

Laboratory experiments have been conducted to determine simultaneously the self diffusivities of Si and O in synthetic dacite melt (NBO/T = 0.1) from 1 to 5.7 GPa and from 1355 to 1662 °C. Glasses enriched in ^{18}O and ^{28}Si were synthesized and mated to their isotopically normal counterparts to form diffusion couples used in the piston cylinder device (1 and 2 GPa) and multi-anvil apparatus (4 to 5.7 GPa). Profiles of isotope abundances were measured by secondary ion mass spectrometry. Self-diffusion coefficients for Si (D^*_{Si}) are significantly lower than self-diffusion coefficients for O (D^*_O) at all run conditions; for example, $D^*_O = 6.45 \pm 0.65 \times 10^{-14}$ m^2/s and $D^*_{Si} = 1.45 \pm 0.45 \times 10^{-14}$ m^2/s at 1 GPa and 1355 °C. The temperature dependence is similar, but not identical, for Si and O self diffusion at all pressures, yielding activation energies of 293–380 kJ/mol at 1 GPa, 264–305 kJ/mol at 2 GPa, and 155–163 kJ/mol at 4 GPa. The pressure dependence is similar for Si and O at all temperatures, giving activation volumes for Si and O that are –14.5 to –17.1 cm^3/mol at 1460 °C, –9.8 to –8.7 cm^3/mol at 1561 °C, and –8.8 to –9.3 cm^3/mol at 1662 °C. Self-diffusion coefficients for Si and O reach maximum values at roughly 5 GPa. The mode of Si and O self diffusion in dacitic liquids is constrained by the large activation volumes, $D^*_O \approx 2\, D^*_{Si}$, and predictions using the Eyring equation, which suggest that Si and O diffuse as molecular species at 1460 °C. At 1561 and 1662 °C, less negative activation volumes and predictions of the Eyring equation are consistent with diffusion of Si and O by a combination of mechanisms, including the formation of a high-coordinated intermediate species.