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Amorphous Materials: Properties, structure, and durability

Effects of chemical composition and temperature on transport properties of silica-rich glasses and melts‡

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Abstract

Combining new measurements of thermal diffusivity (D) and viscosity (η) of 13 silica-rich glasses and their melts with previous data reveals specific effects of Al, Ca, and Fe cations on heat and mass transport for diverse glasses and melts. We investigated rhyolites, tektites, leucogranite, haplogranite, and chemically complex commercial glasses. Highly polymerized samples, with high-Al but low-Ca contents, yield high values for η, D, and glass transition temperatures ($T_{g,12}$), whereas less polymerized samples with high-Ca but low-Al contents, have low η, D, and $T_{g,12}$. Upon crossing the glass transition, D decreases substantially, to ~0.35 mm^2/s for Ca-rich melts, but D decreases only weakly, to ~0.52 mm^2/s for Al-rich melts. The magnitude of the decrease in D at $T_{g,12}$ correlates with the melt fragility, and also to the configurational heat capacity. High-Ca contents result in low D for glasses and melts, whether or not Al is present. At high T, $\partial D/\partial T$ is positive for glasses and melts containing Fe^{2+}, which we attribute to diffusive radiative transfer involving electronic-vibronic coupling. Thermal conductivity of all glasses increases with T, flattening out as the transition is approached. For melts with >1 wt% FeO_{total}, $\partial k/\partial T$ is positive. We predict that upon melting, I-type arc granite liquids should have lower thermal diffusivity than calcium-poor A- or S-types, and calc-alkaline basalts will have lower D than tholeiitic basalts, such that D of granitic melts is ~0.2 mm^2s^{-2} higher than basaltic. Ferrous iron enhancing heat transport could alter the predicted order at higher temperatures.

Keywords: Laser-flash analysis, high-temperature, thermal diffusivity, viscosity, hydration, impurities, glass, melt