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Viscosity of water-bearing silicate melts

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Soda lime silica glasses with different water content using wet condition of melting under ambient pressure, and 5 bar and 12 kbar external pressure are synthesized. Experimental studies of viscous flow and rheological behavior of molten glasses are conducted to determine (a) the effect of water content on viscosity, (b) the onset of non-newtonian flow in water-rich melts and (c) the "mixed cation effect" (Na^+ / H^+) in hydrous silicate glasses.

(a) The research is centered about the general effect of water on the T_{12} isokom temperature (viscosity η = 10^{12} Pa s). Therefore literature data are gathered for a broad range of total water content c_w from $3{\cdot}10^{-4}$ to 27 wt%. In terms of a reduced glass transition temperature T_g* = T_g / T_g^{GN} where T_g^{GN} is T_g of the melt containing c_wg $\approx$ 0.02 wt% total water, a uniform dependence of T_g* on total water content (c_w) is evident for silicate melts. T_g* decreases steadily with increasing water content, most strongly at the lowest water content where H_2O is dominantly dissolved as OH. For water-rich melts, the variation of T_g* is less pronounced, but it does not vanish even at the largest water contents reported ($\approx$ 27 wt%). T_g* vs. c_w is fitted by a three-component model. This approach accounts for different transition temperatures of the dry glass, hydroxyl and molecular water predicting T_g* as a weighted linear combination of these temperatures. The required but mostly unknown water speciation in the glasses is estimated using IR-spectroscopy data for hydrous sodium trisilicate and rhyolite.

(b) Cylinder compression measurements of viscosity at high strain rates are conducted to determine the relationship between structural changes, structural relaxation and inherent strength of sheared liquids. Results are presented in terms of the onset of shear thinning as function of water content.

(c) Studies involve measurement and theoretical analysis of the mixed cation effect (Na^+/ H^+) in hydrous silicate melts, which are analyzed by the depression of the T_{12} isokom temperatures.