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Amorphous materials: Properties, structure, and durability†

Water and the compressibility of silicate glasses: A Brillouin spectroscopic study

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Abstract

The compressional and shear wave velocities of seven series of hydrous aluminosilicate glasses were measured by Brillouin scattering at room temperature and pressure as a function of water content. The glasses were quenched from high temperature and 0.2 or 0.3 GPa pressure. The dry end-members range from highly polymerized albitic and granitic compositions, to depolymerized synthetic analogues of mantle-derived melts. For each set of glasses, the adiabatic shear and bulk moduli have been calculated from the measured sound velocities and densities. These moduli are linear functions of water content up to 5 wt% H_2O, the highest concentration investigated, indicating that both are independent of water speciation in all series. For anhydrous glasses, $(\partial V/\partial P)_S$ changes from about -0.3 to -0.7×10^{-15} m^3/(Pa·mol) with increasing degree of polymerization. For the same compositions, the partial molar $(\partial V/\partial P)_S$ of the water component changes from near zero to -0.8×10^{-15} m^3/(Pa·mol) with increasing degree of polymerization, such that dissolved water amplifies the differences in rigidity between the anhydrous glasses. This strong variation indicates that the solubility mechanisms of water depend strongly on silicate composition. A simple linear model reproduces $(\partial V/\partial P)_S$ to within measurement uncertainty, with glasses becoming more compressible as NBO/T decreases and as alkalinity increases. The dissolved water component also becomes more compressible as NBO/T decreases, but less compressible as alkalinity increases. In strongly depolymerized structures, water causes an increase in sound velocities even though it induces a decrease in density. The general rule according to which sound velocities correlate with density is, therefore, violated, for in these cases water dissolution results in a decrease of compressibility. Barring any strongly anomalous effect of water on configurational compressibility, the trends observed for glasses should be still more divergent for melts. Consequently, hydrous mafic and ultramafic liquids are predicted to have a very low compressibility. The shear modulus of hydrous glasses varies little with bulk composition or water content, supporting the use of a single composition-independent pre-exponential factor in models of melt viscosity.

Keywords: Compressibility, density, hydrous glass, bulk modulus, shear modulus, water