

Ultrasonic studies of alkali-rich hydrous silicate glasses: Elasticity, density, and implications for water dissolution mechanisms

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ABSTRACT

The acoustic velocities of three series of alkali-rich hydrous silicate glasses were determined at ambient conditions using ultrasonic interferometry. The sound velocities and calculated elastic properties are nearly linear functions of dissolved water content. The water content derivatives of both compressional [$d(V_p)/d(X_{H_2O})$] and shear wave velocity [$d(V_s)/d(X_{H_2O})$] decrease with increasing Na₂O content, which suggests that increasing sodium content might weaken the effect of water on acoustic velocities. For each glass series, the shear modulus decreases with increasing water content, whereas the adiabatic bulk modulus (K_s) varies little with water content. By comparing our results of K_s to previously published data on hydrous alkalic (rhyolite, phonolite, and trachyte) glasses, we speculate that H₂O may have a negligible effect on the compressibility of alkalic glasses/melts. The measured densities of each series of glasses were converted to molar volumes and extrapolated to the hypothetical pure water component to derive the partial molar volume of water (\bar{V}_{H_2O}). The resulting \bar{V}_{H_2O} at room pressure and temperature was found to be independent of composition for the three series of glasses, with a value of 10.4 ± 0.5 cm³/mol, whereas the partial molar bulk modulus (K_s) of water is composition-dependent, suggesting that \bar{V}_{H_2O} may depend on composition at elevated pressures. Furthermore, the Poisson's ratio (ν) increases linearly with increasing water content for all three composition series. Therefore, the similar behavior of Al-free and Al-bearing glasses implies that water depolymerizes melts in both systems. The decrease of water content derivative of the Poisson's ratio [$d(\nu)/d(X_{H_2O})$] with increasing Al/(Al+Si) indicates that water interaction with Al-O bonds to produce Al-OH depolymerizes peralkaline silicate melts less effectively than with Si-O bonds to form Si-OH. Hence, we speculate that water prefers to interact with Si-O bonds rather than Al-O bonds in peralkaline silicate systems. The dissolution mechanisms of water between peraluminous and peralkaline melts might be different, which merits further research.

Keywords: Ultrasonic interferometry, hydrous silicate glasses, alkali-rich, the partial molar volume of water, elastic properties, water speciation, dissolution mechanisms