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PROTONS AND THE FLOATING WATER BRIDGE

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Abstract

The floating water bridge is a special case of an electrohydrodynamic liquid bridge and constitutes an intriguing phenomenon that occurs when a high potential difference (~kV cm^{-1}) is applied between two beakers of water. High voltage electrolysis is responsible for proton production, transport through the bridge and recombination with hydroxyl ions in the catholyte. We have measured the quasi-elastic neutron scattering (QENS) of such a liquid bridge. Two proton populations were distinguished: one consisting of protons strongly bound to oxygen atoms (immobile population, elastic component) and a second one of quasi-free protons (mobile population, inelastic component). The diffusion coefficient of the quasi-free protons was found to be $D = (26 \pm 10) \times 10^{-5}$ cm^2 s^{-1} with a jump length $l_{av} \sim 3$ Å and an average residence time of $\tau_0 = 0.55 \pm 0.08$ ps. The associated proton mobility in the proton channel of the bridge is $\sim 9.34 \times 10^{-7}$ m^2 V^{-1} s^{-1}, twice as fast as diffusion-based proton mobility in bulk water. It also matches the so-called electrohydrodynamic or “apparent” charge mobility, an experimental quantity which so far has lacked molecular interpretation. Impedance spectroscopy was used to measure excess positive and negative Bjerrum-defect like charge (protonic and ‘aterprotonic’) in anolyte and catholyte during and after the experiment. These results corroborate the proton channel model for liquid water under high voltage and give new insights into the molecular mechanisms behind electrohydrodynamic charge transport phenomena in liquid water.