Hygroelectricity: liquid water and vapor are electric charge carriers

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Every pure chemical substance under equilibrium has zero net electric charge, according to the electroneutrality principle. However, reports on the ability of water to store charge have been recently published, triggering strong debate.[i] This work shows that water with excess charge can be reproducibly obtained and stored and that water vapor is also an effective charge carrier.

Water dropped from a biased metal needle[ii] and kept within a Faraday cup contains net excess electric charge. Positive (negative) water is obtained from a positive (negative) needle and its charge largely exceeds the Rayleigh limit. Water drops are stretched forming water threads at V<-9.5 kV, even under field strengths well below those used in electrospray, electrowetting or electrospinning experiments described in the literature.

Water drops falling through a biased non-contacting metal ring also acquire charge but its sign is opposite to the ring potential. This is understood considering that water in the atmosphere or adsorbed on surfaces under non-zero electric potential should always have excess concentration of H^+ (under V<O) or OH^- ions (under V>0), to satisfy the thermodynamic equilibrium condition expressed by the electrochemical potential equation.

Thus, falling water drops under a potential V acquire charge but while contacting only the atmosphere. This is only possible if there is charge exchange between water and the atmosphere, which is in turn assigned to the adsorption/desorption of water molecule clustered ions with excess H^+ or OH^-.

Adsorption of water vapor also contributes charge to initially discharged solid surfaces of shielded dielectrics or isolated metals:[3] acidic surfaces acquire negative charge under increasing relative humidity, while basic surfaces become more positive, showing that H^+ and OH^- ions are partitioned between the atmosphere and the solid surface.

These findings show that the atmosphere is a charge reservoir for solids and liquids and that every interface with gas holds an electric double-layer in which H^+ and OH^- ions are potential-determining species, associated to clustered water molecules. These phenomena are collectively designated as "hygroelectricity"-electricity from humidity. Further understanding and control of hygroelectric phenomena will probably help us to understand complex charge patterns observed in any surface as well as hitherto unexplained atmospheric electricity build-up in thunderclouds and other electrostatic phenomena, in every size scale.

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