Nano-Confined Water

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Water is a peculiar liquid with many abnormal properties, maximum density at 4 ^{o}C is a famous example. A 40-year-old puzzle is about supercooled water. In 1976 C.A. Angell, then at Purdue University, experimented to see how far they could supercool water, and how the liquid would behave at extremely low temperatures. What they saw surprised everybody: As water dipped below −20 °C, its isothermal compressibility began to soar, a sign that its density was fluctuating wildly at the molecular scale. The liquid seemed on the verge of some dramatic transformation. But whatever that transformation was, Angell couldn't actually see it; it occurred at temperatures below the homogeneous nucleation temperature, where the liquid state was too short-lived for the researchers to measure. In the early 1990s, Gene Stanley came up with a compelling explanation. Stanley's theory hinged on the concept of critical points, special points in a phase diagram where two thermodynamic phases of matter—say, liquid and gas—meld into one. Water has a well-known critical point at about 374 °C and 218 atm, above which liquid water and water vapor become indistinguishable. Stanley proposed that water has a second critical point, hidden deep in the supercooled regime. At temperatures below that point, there exist two distinct liquid phases of different densities; above that point, the liquid phases merge. In Stanley's interpretation, the density fluctuations in Angell's experiment represented a kind of fluctuation between the two phases of water. However, this created a big controversy among theoreticians, two schools fighting each other, David Chandler(Berkeley) was much against the 2nd critical point concept. Then in 2003, Sow-hsin Chen(MIT) and I started a decade-long experimental program(mainly by neutron scattering) to study the supercooled water under nanoconfinement. We can supercool nano-confined water down to 180 K, still maintaining the liquid state. This is because in nanoscale, water cannot freeze. In this talk, I will tell this story of resolving the water controversy, mainly from our own data.

Also, an important question of water is to understanding solubility of a hydrophobic molecule under nanoconfinement which impact on several related problems, (a) solubility of methane in water within nanopores of rock under fracking condition, (b) understanding how hydrophobic effect would be changed in confined water, (c) catalysis of gaseous molecule under confinement.

Finally, I will speculate on some implications of confined water in several fields: (a) Its role in origin of life, (b) Geological Shale Gas by Fracking, (c) Pulling water out of thin air in desert. (d) Gas hydrate as energy source.

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