The dynamic surface tension of water

April 3 2017

The release of a water droplet. Credit: I.M. Hauner et al.

The surface tension of a liquid is a measure of the cohesive forces that hold the molecules together. It is responsible for a water drop assuming a spherical shape and for the effects of surfactants to produce bubbles and foams. The value of the surface tension of water at room temperature is known accurately to four significant figures and is recommended as a standard for the calibration of other devices. New research in which Ines Hauner and Daniel Bonn (Institute of Physics) are involved now shows that this value is not as universal as previously believed.

The recent experiments show, astonishingly, that a newly created, pristine air/water interface has a surface tension that is approximately 25 % higher than the equilibrium value, which is known to be 72.75 mN/m. Researchers from Amsterdam, Bordeaux and Sydney show that a fresh unequilibrated air/water interface has a surface tension of around 90 mN/m. They used a high-speed video camera to observe the release of a water droplet resulting from the breakup of the liquid neck that connects the drop to the orifice - see image. Their analysis of the breakup dynamics on a millisecond time scale gives a surface tension of around 90 mN/m.

In the past, similar higher-than-equilibrium surface tension values for water had in fact been reported on such short time scales. However, they have all remained highly controversial due to methodological shortcomings. In contrast, Professor Bonn states that "the method of studying droplet breakup dispenses with the previous difficulties: the experimental procedure is very robust, and the associated pinch-off dynamics well understood."

Why has such a large discrepancy been overlooked for so long? The reason is that the lifetime of the pristine state is less than a millisecond. Older technologies have slower response times; only modern methods probe microsecond regimes. Another remarkable aspect of this discovery is the magnitude of the effect. When sodium chloride or sodium hydroxide is added to water in a concentration of one mole per liter, the equilibrium surface tension changes by only about 2 mN/m. In contrast, the effect reported in the new experiments produces a 17 mN/m change. This is much larger than the consequence of any electrolyte effect and must involve the structure of the interfacial water.

There are profound consequences of this discovery for all processes involving water in sub-millisecond times. For example, the entire sequence of events in inkjet printing occurs in this time range and

involves aqueous inks forming droplets at MHz frequencies. Many spraying applications in which water is used should also be affected: a high value of the tension should make it more difficult to produce small droplets. In addition, there is a vast literature that attempts to explain the value of the surface tension of water of 73 mN/m, but so far nobody considered that the pristine surface has an even higher value.

More information: Ines M. Hauner et al. The Dynamic Surface Tension of Water, *The Journal of Physical Chemistry Letters* (2017). DOI: 10.1021/acs.jpclett.7b00267

Provided by University of Amsterdam