Cavitation in water: a matter of the weakest link

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Liquids can sustain surprisingly large negative pressures before cavitation bubbles occur. In water, such deeply metastable states are typically observed when the liquid is exceptionally pure and free of nucleation sites. Yet in some cases, the opposite behavior is observed: the presence of amphiphilic molecules can significantly increase the resistance of water to cavitation. Even more strikingly, plants transport water at negative pressures approaching −100 atm without cavitation, even though xylem sap is far from pure water. How is this possible?

Cavitation in such systems is governed by the interplay of surfaces, impurities, nanobubbles, and amphiphilic molecules. These molecules can adsorb onto hydrophobic surface crevices—sites that would otherwise trap gas pockets and act as nucleation sites for cavitation. Once coated by amphiphiles, these nanoscale defects become effectively passivated and can no longer stabilize nanobubbles, allowing water to remain intact even under strong tension.

These mechanisms show how molecular organization at interfaces can fundamentally alter nucleation processes and the mechanical stability of liquids under tension.