

What is surface tension?

The most common manifestation of surface tension is the impression that any water surface appears to have an elastic “skin” over it. It is this “skin” which allows insects such as pond skaters to literally “walk on water,” and, conversely, mosquito larvae to hang upside down from the water surface. It ensures that raindrops (ideally) are spherical and that two water droplets on a window will coalesce given the chance.

What causes surface tension?

General note: while, in the following explanations, the term “surface” refers to a liquid/air interface, the same reasoning also lies behind the behavior of liquid/liquid interfaces, where “interfacial tension” is essentially the same phenomenon.

Scientifically speaking, surface tension is the force which is required to extend the area of a surface by one area unit. The area unit is usually 1 cm^2 . The unit of force is usually dynes/cm or milliNewtons/meter (mN m^{-1}) in SI units. Note: the two units are equivalent, $1 \text{ dyne/cm} = 1 \text{ mN m}^{-1}$.

Surface tension results from an imbalance of intermolecular attractions at a surface. In a bulk liquid, the forces acting on a molecule are effectively equal in all directions, the molecule “feels” no net energy vector. As shown in the diagram on the next page (Figure 1), as a molecule moves to the surface, it loses some nearest neighbors, thus leaving it with unbalanced attractive forces and “feeling” a downward energy vector.

In order for a molecule to stay in the surface region, it must gain excess energy (and entropy) over those in the bulk liquid. This excess energy (surface free energy) is the surface tension. The net result of this excess energy at a surface is that surfaces can be thought of as being “expensive.” Work is required to increase the surface area of a system. Therefore nature tries to minimize surface area leading to the effects described in the first paragraph above.

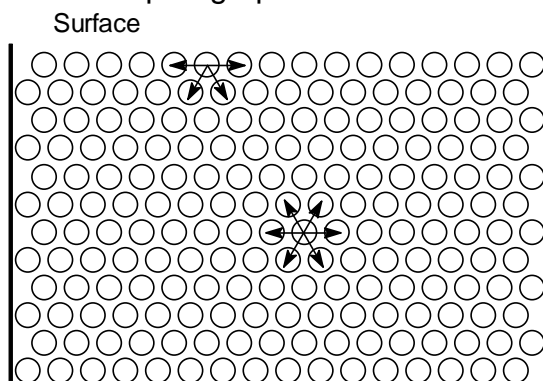


Figure 1

The surface tension of any liquid depends on the strength of intermolecular interactions within that liquid. For example; water, having strong intermolecular interactions (hydrogen bonds), has a surface tension of 73 mN m^{-1} ; heptane, on the other hand, with much weaker intermolecular interactions (van der Waal's forces), has a surface tension of only 20 mN m^{-1} .

How does a surfactant affect the surface tension?

As mentioned previously in RFF 705.10.01, a surfactant molecule consists of two portions; a hydrophobic tail and hydrophilic head. When a surfactant is dissolved in water, the presence of the hydrophobic portion in solution disrupts the balance of the intermolecular forces in the bulk liquid. This leads to a rise in the free energy of the system. This means that it is easier (requires less work) to promote a surfactant molecule than a water molecule to the surface. The surfactant molecules therefore congregate at the surface with their hydrophobic tails aligned along the surface plane minimizing contact with water molecules. This effectively makes the surface less "expensive" so the surface tension drops.

In extremely dilute solutions, the drop in surface tension is proportional to the surfactant concentration. However, at a certain concentration, the surface tension drop stops and from then on, as the concentration increases, the surface tension remains almost constant. The point at which this behavior change is observed is called the *Critical Micelle Concentration*. Physically, what is happening here is the following; surfactant molecules congregating at the surface gradually cover more and more of that surface as their concentration in the solution increases - surface tension drops proportionally. At the point where the surface becomes saturated, micellization occurs in the bulk liquid. The number of surfactant molecules at the surface reaches a maximum - the surface tension remains constant.

How do we measure surface tension?

There are a wide variety of methods for measuring surface tension, however, the two most popular are the DuNouy Ring Tensiometer and the Wilhelmy Plate Methods. Both methods measure the force required to detach an object (a thin platinum wire ring or plate) from the solution surface. Repeated measurements of this force are made as the concentration of surfactant in the solution is increased. A simple calculation allows conversion of this raw data to the surface tension of the solution.