Variation of surface tension with temperature

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Abstract In this experiment, we measure the variation of surface tension of a detergent solution with temperature, by observing the height of water column in a thin capillary tube, and relating it to empirical formulae.

Keywords surface tension, temperature

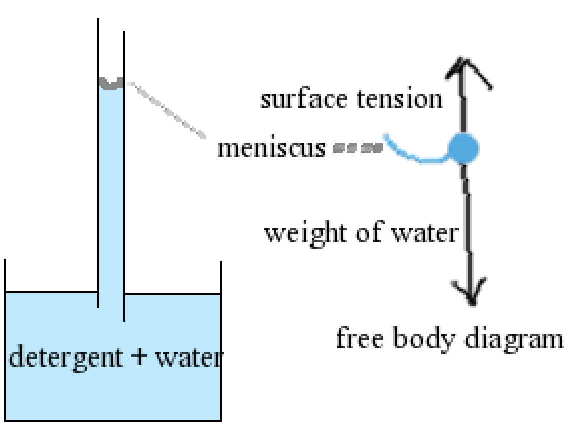
Introduction

This experiment involves the observation of variation of surface tension with temperature by seeing the rise of detergent solution in capillary tubes. Since we are examining a surface phenomenon, we must make sure that no obstructions or other irregularities are present to prevent the smooth flow of water in the tube. Earlier research in this area tells us that surface tension *decreases* with increase in temperature. We shall also try to see the dependence of the surface tension vis-a-vis empirical formulae relating to variation of surface tension with temperature.

Theory

Surface tension is a quantitative measure of the surface energy a liquid has. The force of surface tension always acts tangential to the liquid surface, its effect always being to reduce the surface energy of the liquid. It is this force of surface tension that allows insects to walk on water and allows water to rise in the capillary tube. When a liquid is in a capillary tube, due to the heightened surface tension at the edges due to attraction between the liquid and the glass, there is formation of a meniscus.

At the meniscus a component of the force caused by surface tension acts upwards, tangential to the liquid surface. This force, $T.2\pi r\cos\theta$ upwards is balanced by the downward weight of the water column which is $A\rho gh$, where A is the cross section of the liquid, here πr^2, ρ is the density of the liquid and h is the height of the water column. Since the meniscus is not moving and we *approximate* $\cos\theta$ approx 1 because the capillary tube is *very* thin, and the water meniscus is nearly hemispherical. Since the



meniscus is stationary, the forces cancel.

Thus, we get the following equation: (T is the surface tension)

$$T.2\pi r = A\rho gh$$

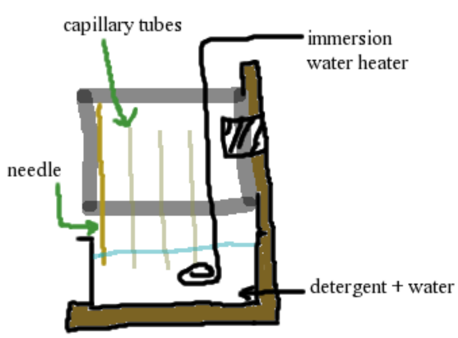
$$\Rightarrow T.2\pi r = \pi r^2 \rho gh$$

$$\Rightarrow T = \rho ghr/2$$

However, we have to do some end corrections to the height, as the height we actually measure does not take into account the water that is above the bottom of the meniscus. The actual height h' used in the experiment is $h' = h + r/3$.

Also surface tension decreases with temperature because as temperature rises, so does the kinetic energy of the molecules, and thus intermolecular attraction decreases. So, the force of surface tension also decreases. An empirical formula $S = S_0\ (1 - T/T_c)^{3/2}$, where S is the surface tension and S_0 the surface tension at 0 ℃ is often used to empirically show the trend of surface tension.

Experiment



The apparatus is set up as shown in the figure. A needle with sharp ends was used to provide a reference so that we could measure the height easily. The capillary tubes are sellotaped onto the glass plate. Care is taken so that the capillary tubes remain vertical and aligned parallel to the vertical ridges on the glass plate.

Since we are observing surface phenomena, thus we must be very careful that there are no obstructions in the glass tube to prevent the rise of water in the capillary tube. The glass tube should be dipped in water fully to moisten it and all the water in the test tube is then blown out of the test tube.

After cleaning, they are dipped in detergent solution. The detergent solution was made using Vim powder by dissolving **3g** of it in **1L** of water. The rise of the detergent solution in the test tube was seen using *travelling microscope*. At first the top of the meniscus of the microscope was noted. Then the top of the needle was noted, and the height of the liquid column is given by L-(reading at top of needle – reading at the meniscus).

Results

ρ taken to be 1 (density of water).

Table 1 Variation of surface tension with temperature

Temperature (°C)	**Height of water column (cm)**	**Radius of tube (cm)**	**Surface tension**
30	2.635	0.053	68.89
51	2.415	0.053	63.18
80	1.279	0.053	33.67

Conclusion and Discussion

Our observations generally confirm the expected behaviour of surface tension decreasing with temperature, with a greater increase at higher temperatures compared to low temperatures. A notable point here is that in the third temperature (80 ℃), the surface tension decreases *dramatically* to **34.70**, thus suggesting that molecular interactions become very pronounced at higher temperatures. This is in contrast to the very slow decrease of surface tension of pure water. So we can conclude that detergent greatly affects molecular interactions to cause such a dramatic decrease.

We can improve the experiment by taking more precautions and also taking measurements at many more temperatures, then we can then try to fit it using the empirical equation describing surface tension variance with temperature. We could also repeat the experiment using a glass-water interface instead of a air-water interface as we have done currently. It is known that surface tension is affected by the nature of the two surfaces in contact, and also on their contact angle. The surface dependence could then be observed. If it were possible to repeat the experiment with other kinds of commercial detergents, which was not possible in this experiment due to time constraint, we could determine the quality of the detergent. We could also generalise and diversify the experiment to consider the effects on surface tension that various kinds of packing and bonding in chemical compounds could have, like say benzene (aromatic system) dissolved in water, or of polymer subunits dissolved in water.

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References

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