

Determination of liquid surface voltage

by measurement of maximal pressure at blowing formation

1 Goal of experiment

Liquid surface voltage is to be investigated using the capillary method during this experiment.

2 Motivation

This experiment investigates the surface voltage, which plays an important role in the nature. It makes possible for example to live the water runner on the surface of the water and helps water birds not to become wet. Not great water pollution can drastically reduce the surface voltage. We can find water runner only in clean basins because they will sink at reduced surface voltage in the water.

3 Basics

The liquid surface voltage can be described by following model: we place some small hard balls in a vessel, which attract their d-neighbors very much and make Brownian movements in the vessel. There is a big amount of other balls on the each side of every ball inside the vessel, so they create an attractive force, which effects every ball there. But it works differently for the ball on the surface because on one side neighboring balls and so attractive forces are present. These things summarize to a resulting force, which stands vertical on the surface and shows inside. In balanced state an attractive force works as an opposite to the pressure, because every ball reserves minimum in space. If no forces influence the liquid (or its influence is weak enough to ignore it, drops in water tap), is it the most convenient to take ball form, because this ball form requires the smallest surface voltage and therefore the fewest energy remains on the surface of molecules (i.e. the potential energy is minimal). If the liquid surface needs to be increased, so the molecules would be transported from the inside on the surface. In this regard it is necessary to use attractive force

$$Work = Force \times Way l$$

The work ΔW [J], which can be made to increase the surface in ΔA [m²], is proportional to one surface. This tension is called "surface voltage" and designated the letter σ .

$$\sigma = \frac{\Delta W}{\Delta A} \quad [\text{Jm}^{-2}]. \quad (1)$$

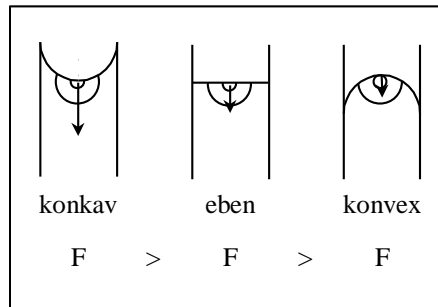
This value depends:

1. On the connected liquid, firstly on the intensity of attractive forces between the molecules. σ is a material constant too.
2. On the contiguous phase: air, gas, and steam of the material or of the vacuum. Because of very little density of the (called) material its influence is scarcely noticeable. But it becomes more noticeable, if two liquids are connected.

3. On the temperature T : with increasing temperature is the proper movement of the molecules stronger, the influence of the attractive forces becomes weaker: σ decreases with the temperature and disappears, soon before the evaporation temperature is achieved.
4. Certain materials, which are called "tenside", are concentrated on the surface. Even small additives of such substances can change σ strongly; growing concentration brings the surface voltage of the tenside together.

The measurement of the surface voltage requires constant temperature and special cleanness.

The form of the surface has an influence on surface work performing, because the resulting force on the molecule grows with the number of surrounding molecules in marked bordering field.



4 Maximal pressure at blowing formation in a liquid

If a blowing from the capillary (thin walled, sharp) enters in liquid, an overpressure p_k , which is called "capillary pressure", is necessary. As the surface can be changed by the radius of the blowing, the following differential quotient:

$$\sigma = \frac{dW}{dA} \quad (2)$$

is to be considered. In differentially form the definition for work is the following:

$$dW = F \cdot dr \quad (3)$$

From *Pressure = Force/ Surface* follows

$$p_k = F / A \Rightarrow F = p_k \cdot A \quad (4)$$

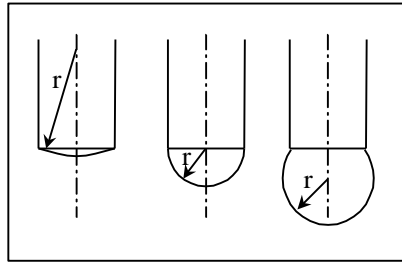
If the formulas 3 and 4 in Gl. 2 are used, the results are following:

$$\sigma = \frac{dW}{dA} = \frac{p_k \cdot A \cdot dr}{dA} \quad (5)$$

If the blowing is small enough, the hydrostatic pressure on the top and at the bottom is nearly identical, the blowing gets approximately a shape of a ball. The surface A corresponds then $A = 4 \cdot \pi \cdot r^2$, which makes the differential: $dA = 8 \cdot \pi \cdot r \cdot dr$. If we put this in eq. 5 and find p_k , we will get:

$$p_k = \frac{2 \cdot \sigma}{r} \quad (6)$$

For a definite material is σ at constant temperature T constant. If the pressure is slowly risen in the capillary, it follows that the overpressure p_k in the blowing for $r_{Kapillare} = r_{Blase}$ achieves a maximum value, because before and after that is $r_{Blase} > r_{Kapillare}$, we can see it in the figure.



By an overpressure in the capillary, which is bigger than P_k , or an appropriate underpressure in external room/space an air-blowing stream appears, which comes out from the capillary. Sinking overpressure (or underpressure) stops this air-blowing stream,

$$\frac{2 \cdot \sigma}{r_{\text{Kapillare}}} + h_E \cdot g \cdot \rho_F \quad (7)$$

and no more of it appears again. At that time hydrostatic pressure is $h_E \cdot g \cdot \rho_F$, the h_E deep in the liquid of the density ρ_F dipped capillary. It must be overcome additionally to P_k . It is in the state by which the air-blowing stream breaks away in particular:

$$\Delta h \cdot g \cdot \rho_W = \frac{2 \cdot \sigma}{r_{\text{Kapillare}}} + h_E \cdot g \cdot \rho_F, \quad (8)$$

if Δh the difference of the menisci is in a water manometer, using which the overpressure is measured in the capillary or the underpressure in external space. ρ_W is the water density at room temperature. g is the gravitational acceleration. This connection can be used to determine with a liquid of known surface tension, for example water, to determine the capillary radius $r_{\text{Kapillare}}$. It is easier to measure as the capillary inflow under the microscope.

If $r_{\text{Kapillare}}$ and ρ are known, the surface voltage of another liquid can be determined by the measurement of h and h_E .

For water is: $\sigma_{\text{Wasser}} = 72,9 - 0,155(T - 18) [\text{mJ/m}^2]$, mit T [$^{\circ}\text{C}$]

5 The performance of the experiment

1. The inner, with a scale visible pipe R is carefully cleaned and joined if it is filled with distilled water. **Attention!** The scale is checked in mL. Then it is set on the rubber plugs without T-piece in particular. One needs to make sure, that everything is dense, to make the measurements not successful.
2. A capillary is realized from a glass tube of about 5 mm Diameter AR-glass in the following way: you turn about 15 - 20 cm long element of the tube on an even basis about 1 cm above the inner cone of the colorless (hot) flame of the Bunsen burner, until it is good softened. Beyond the flame you pull then the tube quickly until a diameter of about 1/10 mm inner diameter. Too wide capillaries lead to inexact measurements, too narrow capillaries is not more sufficient the created pressure for the water manometer. The capillary is on a convenient position with a diamond etc. carefully broken and cut. The inflow must be controlled on all sides and at the front with the loupe: You need to show rounded thinwalled sharpened inflow, face grinding, if necessary. The other side of the glass tube is round melted in the flame.
3. The capillary is pushed with the thick end at first from below into the connector of the T-tube, namely, that the inflow does not dip later by the installation of the T-tube.
4. Production of the pressure in external space:
You fill the vessel, which is standing on whole highly-placed desk (at that, the flexible tube be-

tween the leveling vessels bends down, and stays like that (comes better in pairs), put the stopper again and put another vessel below (if it is not there yet). The capillary can be pushed now into the investigated liquid. If it is short before the dip, the flexible tube must be left there to prevent the liquid from getting into the capillary.

5. The platform with the leveling vessel is turned slow down until the air-blowing stream is even gone out, not longer. The level difference h in manometric tube is read, as the diving depth of the capillary h_E and the temperature T . Then you bring the air-blowing stream into action again. Generally it must be measured for a diving depth h_E about 10-fold Δh . For the counting is later the average value of Δh used. The measurement is repeated with two next sinking depth h_E .
6. The by assistant released test liquid (e.g. ethanol), from which you can find out the density, and then the measuring vessel is filled and tempered about 15 min. Then the undamaged capillary is used.
7. The measurement of σ is realized according the description above. They are measured with three different h_E values about 10 Δh -values.

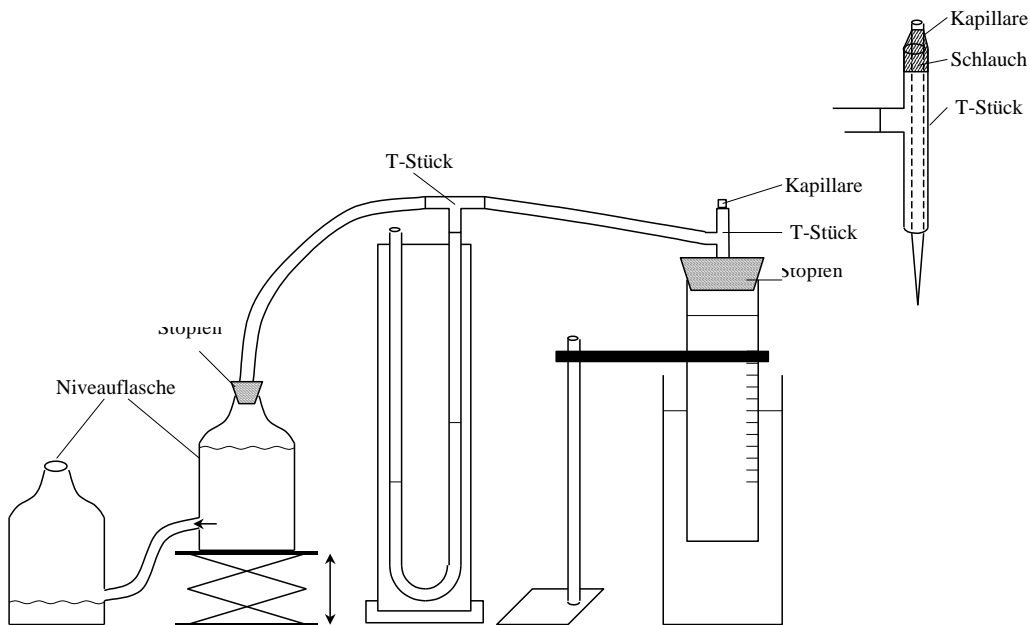
6 Usage

For the Δh -values the average values are used. The error therefore is an average error of an average value. The error of the sinking depth is esteemed. With help of the error law an error of r for a sinking depth can be calculated.

From the three r -values, which were established for the different sinking depth, it is possible to calculate the weighted average value and the appropriate error.

By the calculation of σ the given liquid are used Δh and h_E as described above. For r the average value is used.

Orientate yourself please about next methods of the determination of the surface voltage!



Test facility for the determination of surface voltage