Measuring the surface tension using the “break-away” method

Objects of the experiments

- Creating a liquid layer between the edge of a metal ring and the surface of the liquid.
- Measuring the tensile force acting on the metal ring just before the liquid layer breaks away.
- Determining the surface tension from the measured tensile force.

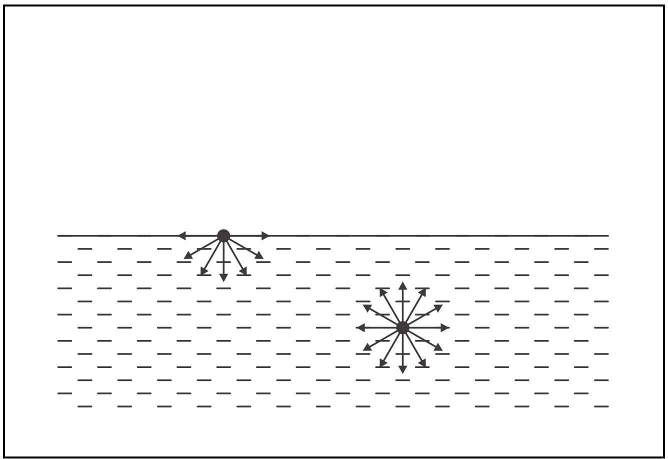


Fig. 1 Forces exerted by adjacent molecules on molecules on the surface of a liquid and inside the liquid

Principles

The surface tension is due to the fact that a molecule on the surface of a liquid is acted upon by attractive forces from adjacent molecules towards one side only (see Fig. 1). The resultant force acting on the molecule points into the liquid and is perpendicular to the surface.

In order to enlarge the surface, i.e. to take more molecules to the surface, energy has to be supplied. The ratio of the energy ΔE supplied at a constant temperature and the change of the surface ΔA is called surface energy or surface tension of the liquid:

$$\sigma = \frac{\Delta E}{\Delta A} \quad \text{(I)}.$$

The surface tension can be measured, e.g., by means of a metal ring with a sharp edge which at first is immersed in the liquid so that it is completely wetted. If the ring is slowly taken out of the liquid, a thin liquid layer is pulled up (see Fig. 2). The outside and inside surface of the liquid layer changes by

$$\Delta A = 4 \cdot \pi \cdot R \cdot \Delta x \quad \text{(II)}$$

R: radius of the metal ring

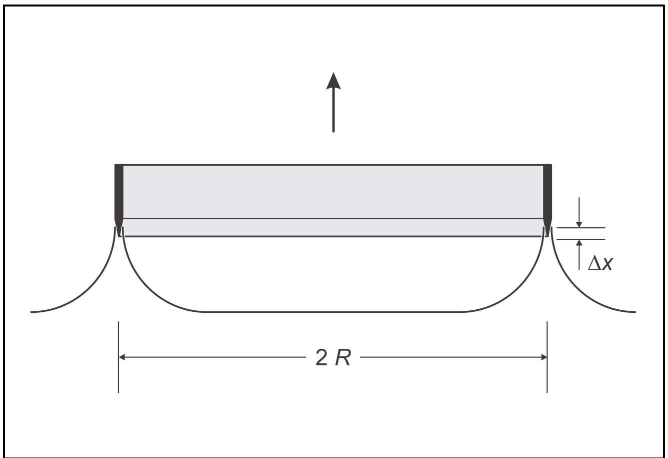
when the metal ring is lifted by Δx. Pulling up the ring requires the force

$$F = \frac{\Delta E}{\Delta x} \quad \text{(III)}$$

to be applied. If this force is exceeded, the liquid layer breaks away. Because of Eqs. (I)-(III), the surface tension is

$$\sigma = \frac{F}{4 \cdot \pi \cdot R} \quad \text{(IV)}.$$

Fig. 2 Illustration of the measuring principle



Apparatus

1 apparatus for measuring surface tension	367 46
1 precision dynamometer 0.1 N	314 111
1 vernier callipers	311 52
1 crystallization dish, 95 mm dia., 55 mm high	664 175
1 laboratory stand II	300 76
1 stand base, V-shape, 20 cm	300 02
1 stand rod, 75 cm	300 43
1 clamp with hook	301 08

additionally required:

distilled water, ethanol

Setup

The experimental setup is illustrated in Fig. 3.

– Carefully clean the crystallization dish.
– Carefully remove fat from the metal ring, e. g. with ethanol, and suspend it from the dynamometer. Suspend the dynamometer from the clamp with hook so that the ring hangs over the crystallization dish.
– Set the laboratory stand to a height of approx. 10 cm.

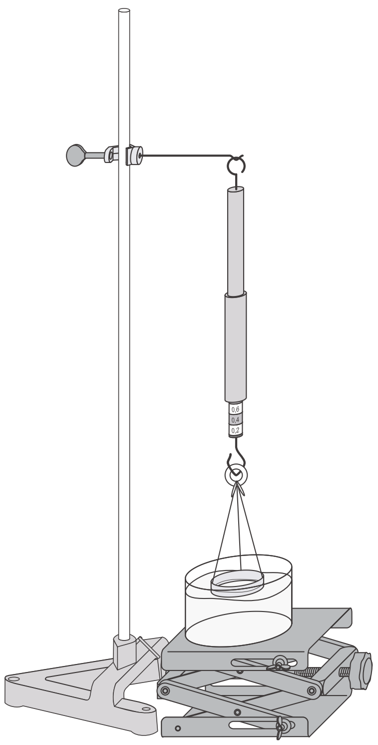
Carrying out the experiment

– Determine the diameter of the metal ring.
– Make the zero adjustment at the dynamometer using the movable tube.
– Fill distilled water into the crystallization dish.
– Lower the clamp with hook until the metal ring is completely immersed.
– Cautiously lower the laboratory stand, always observing the tensile force at the dynamometer.

  As soon as the edge of the metal ring emerges from the liquid, the liquid layer is formed. When the tensile force does no longer increase although the laboratory stand is further lowered, the layer is just before breaking away.

– Read the tensile force just before the layer breaks away, and take it down.
– Pour the distilled water out, and dry the crystallization dish and the metal ring.
– Repeat the measurement with ethanol.

Fig. 3 Experimental setup for measuring the surface tension using the “break-away” method



Measuring example

Diameter of the metal ring:	$2R = 60$ mm
Measurement with water:	$F = 28$ mN
Measurement with ethanol:	$F = 9$ mN

Evaluation

Measuring result for water:	$\sigma = 74$ mN m^{-1}
Literature value for water at 25 °C:	$\sigma = 72$ mN m^{-1}
Measuring result for ethanol:	$\sigma = 24$ mN m^{-1}
Literature value for ethanol:	$\sigma = 22$ mN m^{-1}

Result

Compared with other liquids, water distinguishes itself by a particularly high surface tension.