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

Recording and evaluating with CASSY

### 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.

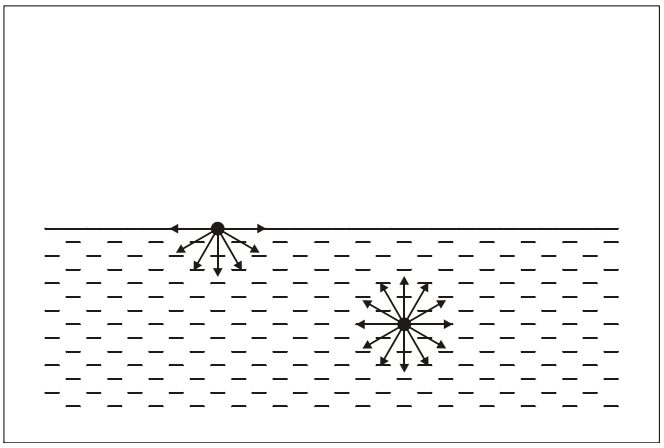

Fig. 1 Forces exerted by adjacent molecules on molecules on the surface of a liquid and inside the liquid

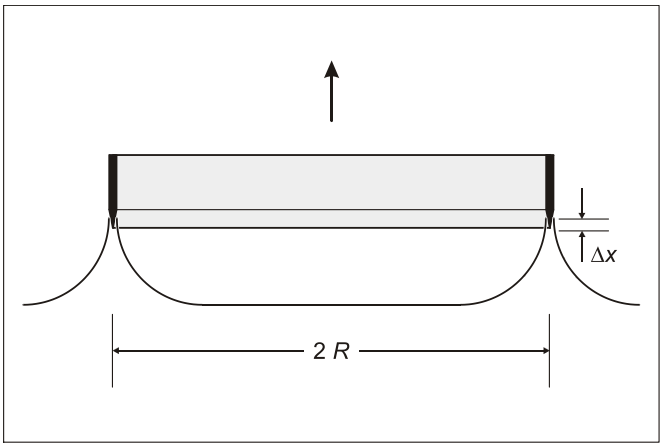


Fig. 2 Illustration of the measuring principle

### 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 $\Delta E$ supplied at a constant temperature and the change of the surface $\Delta A$ is called surface energy or surface tension of the liquid:

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

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

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

$R$: radius of the metal ring

when the metal ring is lifted by $\Delta x$. Pulling up the ring requires the force

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

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

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


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## Apparatus

| | | |
|---|---|---|
| 1 | Surface tension, determination device | 367 46 |
| 1 | Crystallization dish, 95 mm Ø, 55 mm high | 664 175 |
| 1 | Sensor-CASSY 2 | 524 013 |
| 1 | CASSY Lab 2 | 524 220 |
| 1 | Force sensor S, 50 N | 524 060 |
| 1 | Vernier callipers | 311 53 |
| 1 | Laboratory stand II | 300 76 |
| 1 | Stand base V-shape, small | 300 02 |
| 1 | Stativ rod 47 cm, 12 mm Ø | 300 42 |
| 1 | Leybold multiclamp | 301 01 |
| 1 | Ethanol, denaturated, 250 ml | 671 9740 |
| 1 | Water, pure, 1 l | 675 3400 |
| 1 | PC with Windows XP/Vista/7/8 | |

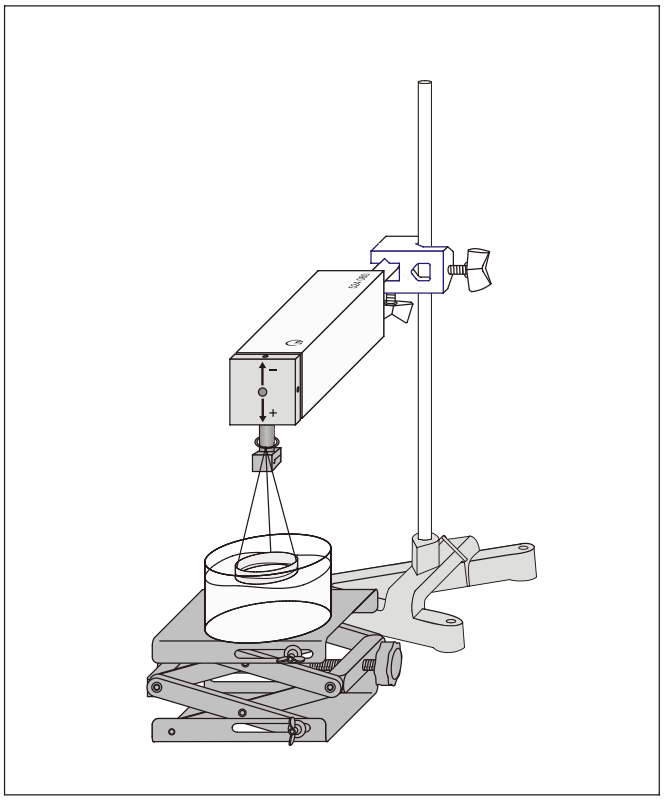

Fig. 3 Experimental setup for measuring the surface tension using the “break-away” method

## 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.
- Set the laboratory stand to a height of approx. 10 cm.

## Carrying out the experiment

For the measurement of the force sensor is operated in the 30 mN range.

- Load the settings in CASSY Lab 2.
- Determine the diameter of the metal ring.
- Make the zero adjustment in the settings FA1 with → **0** ←.
- Fill distilled water into the crystallization dish.
- Lower the Leybold multiclamp until the metal ring is completely immersed.
- Start the measurement with ⏱.
- 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.
- Stop the measurement with ⏱ again after the layer breaks away.
- Pour the distilled water out, and dry the crystallization dish and the metal ring.
- Repeat the measurement with ethanol.

## Measuring example

| | |
|---|---|
| Diameter of the metal ring: | $2R = 60$ mm |
| Measurement with water: | $F = 24.4$ mN |
| Measurement with ethanol: | $F = 8.5$ mN |

## Evaluation

| | |
|---|---|
| Measuring result for water: | $\sigma = 65$ mN m$^{-1}$ |
| Literature value for water at 25°C: | $\sigma = 72$ mN m$^{-1}$ |
| Measuring result for ethanol: | $\sigma = 23$ 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.

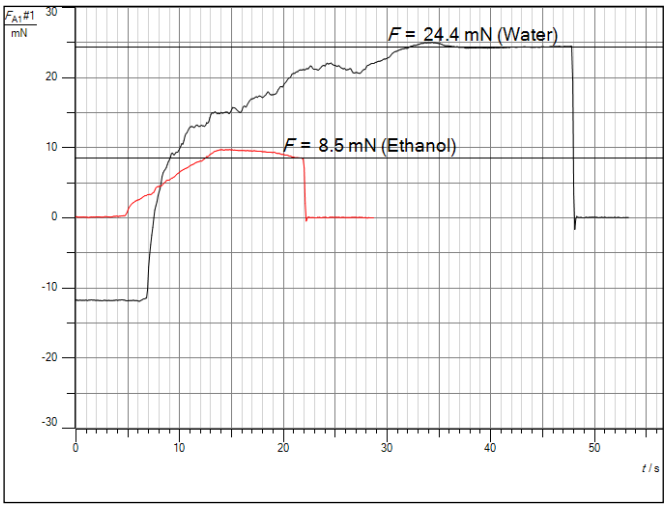


Fig. 4 Measurement for water and ethanol.

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