

SURFACE TENSION

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

Objective

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

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 the surface ΔA is called surface energy or surface tension of the liquid:

$$\sigma = \Delta E / \Delta A$$

The surface tension can be measured, e.g., by means of 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

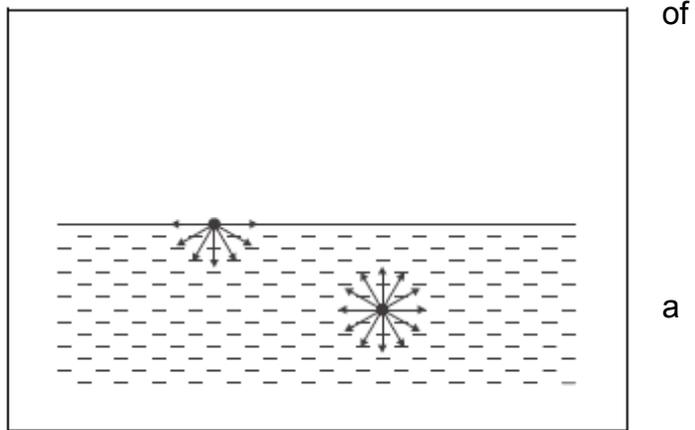


Fig. 1: Forces exerted by adjacent molecules on molecules on the surface of a liquid and inside the liquid

$$\Delta A = 4 \pi R \Delta x$$

R : radius of the metal ring

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

$$F = \Delta E / \Delta x$$

to be applied. If this force is exceeded, the liquid layer breaks away. Now the surface tension is

$$\sigma = \Delta E / \Delta A = F / 4 \pi R$$

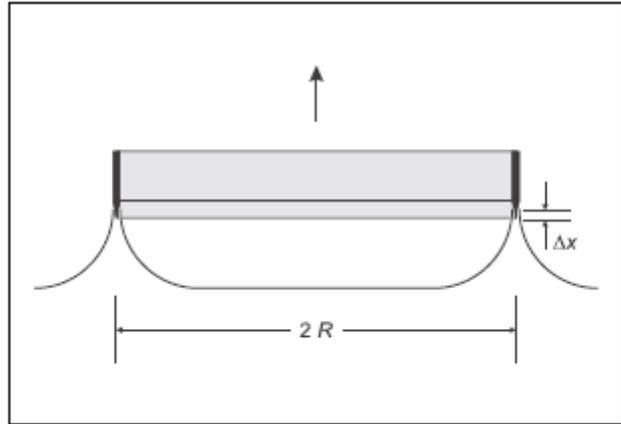


Fig. 2

Contents:

- 1) Metal ring for measuring surface tension
- 2) precision dynamometer 0.1 N
- 3) vernier callipers
- 4) crystallization dish
- 5) laboratory Jack
- 6) stand base, A-shape
- 7) stand rod, 75 cm
- 8) clamp with hook

Additionally required:

Distilled water, ethanol

Setup Procedure

The experimental setup is illustrated in Fig. 3.

- 1) Carefully clean the crystallization dish.
- 2) 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.
- 3) Set the laboratory stand to a height of approx. 10 cm.



Fig. 3 Experimental setup

Experiment Procedure

- 1) Determine the diameter of the metal ring.
- 2) Make the zero adjustment at the dynamometer using the movable tube.
- 3) Fill distilled water into the crystallization dish.
- 4) Lower the clamp with hook until the metal ring is completely immersed.
- 5) 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.
- 6) Read the tensile force just before the layer breaks away, and take it down.
- 7) Pour the distilled water out, and dry the crystallization dish and the metal ring.
- 8) Repeat the measurement with ethanol.

Measurement

Weight of the ring = 0.037N

Force when the metal ring is completely immersed $F_1 = 0.029\text{N}$

Tensile force just before the layer breaks away $F_2 = 0.057\text{N}$

Actual Tensile force with water $F = F_2 - F_1 = 0.028\text{N}$

Diameter of the metal ring: $2 R = 61.5 \text{ mm}$

$$\begin{aligned} \text{Surface Tension } (\sigma) &= F / 4 \pi R = 0.028 / (2 \times 3.14 \times 61.5 \times 10^{-3}) \\ &= 7.249 \times 10^{-2} \text{ N/m} = 72.49 \text{ mN/m} \end{aligned}$$

Evaluation

Measuring result for water: $\sigma = 72.49 \text{ mN/m}$

Literature value for water at 25°C: $\sigma = 72 \text{ mN/m}$

Literature value for ethanol: $\sigma = 22 \text{ mN/m}$

Result

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

Data table

Surface tension of various liquids in dyn/cm against air
Mixture %'s are by mass
dyne/cm is also called mN/m (milli-Newton per meter) in S.I. units

Liquid	Temperature °C	Surface tension, γ
Acetic acid	20	27.6
Acetic acid (40.1%) + Water	30	40.68
Acetic acid (10.0%) + Water	30	54.56
Acetone	20	23.7
Diethyl ether	20	17.0
Ethanol	20	22.27
Ethanol (40%) + Water	25	29.63
Ethanol (11.1%) + Water	25	46.03
Glycerol	20	63
<i>n</i> -Hexane	20	18.4
Hydrochloric acid 17.7M aqueous solution	20	65.95
Isopropanol	20	21.7
Mercury	15	487
Methanol	20	22.6
<i>n</i> -Octane	20	21.8
Sodium chloride 6.0M aqueous solution	20	82.55
Sucrose (55%) + water	20	76.45
Water	0	75.64
Water	25	71.97
Water	50	67.91
Water	100	58.85