Instruction - Exercise 1

Title: *Determining surface tension of liquids*

Theoretical topics

1. The structure of liquids and intermolecular forces.
2. Cohesion and adhesion forces. Meniscus concave and convex. Capillarity.
3. Surface tension factor. Surface energy. Pressure under curved surface.
4. Experimental methods of the determination of the surface tension.

Topics for a test.

1. Explain what the surface tension is.
2. Which processes occurring in biological systems are affected by surface tension?

The purpose of the exercise:

Familiarizing students with the description of intermolecular interactions adhesion and cohesion forces, as well as measurement methods of surface tension of liquids.

Instrument:

Torsion balance.

Technical Introduction:

To measure the surface tension a torsion balance is used. The torsion balance has a lightweight, precisely balanced lever in which the bearing has minimal friction. At the free end of the lever, the frame is suspended. The frame is immersed in the test liquid.

Before the measurement please, level the balance using the knobs at the balance feet. Next, unlock the balance with the metal knob on the right bottom side of the balance housing (the red dot should be set to the letter "**O**"). The large black knob on the right side of the balance housing is used to change the range that should be set to zero (please check it in the small window at the scale). After unlocking, the balance should be reset to zero in the air with a large black knob and a small metal knob

located on the left side of the housing (both directions must be set to zero). Next, please pour the test liquid into the dish and dip the frame into it.

Warning! Immerse the frame by lifting the dish with the liquid up. Do not pull the frame - it may damage the balance!

Remove the frame from the liquid by slowly rotating the large black knob located on the left side of the housing. The value of the pull-off force **F** from the frame can be read on the rotary scale. At the end of the measurement, set the weight knob to the position "**Z**".

Force **F**, needed to pull-off the frame from liquid surface, is equal to the sum of the frame weight **P** and the force derived from surface tension **Q**.

Measurements and the results analysis:

1. The value of surface tension γ is determined using the formula:

$$\gamma = \frac{Q}{2L}$$

where: L is a length of the longer edge of the frame, Q = F – P denotes the surface tension.

Calculate the Q value for each of the tested liquid as a mean value.

2. Determine surface tension for several liquids, for example for water, ethyl alcohol and glycerol or determine the dependence of surface tension on solution concentration, for example for aqueous solutions of alcohol at the following concentrations: 10%, 20%, 30%, 40% and 50%. For each tested liquid perform 10 measurements.

3. Determine the weight of the frame **P.**

Warning! Quantities **F** and **P** are measured in mG units and should be converted to SI units. For this purpose, it is assumed that g = 9.81 $\frac{m}{s^2}$.

4. Make a graph of surface tension coefficient versus solution concentration.

5. For each liquid determine a measurement error of the surface tension force ΔQ, a scale error of the frame length ΔL, and finally a measurement error of the surface tension $\Delta\gamma$.

Appendix Estimation (calculation) of mesurement error of surface tension

$$\Delta\gamma = \gamma \cdot (\frac{\Delta Q}{Q} + \frac{\Delta L}{L})$$

where: $\Delta\gamma$ denotes an measurement error of the surface tension, ΔL – scale error of the length of frame, $\Delta Q = t_\alpha(df) \cdot \sqrt{\frac{\sum_{i-1}^{i=n} (Q_i - Q_{AV})^2}{n \cdot (n-1)}}$ is a measurement error of the surface tension force, $t_\alpha(df)$is the coefficient taken from t-distribution table presented below, *df=n-1*, *n* is a number of measurements (put $\alpha=0.05$), Q_i - result of the i-th measurement, $Q_{AV} = \frac{\sum_{i=1}^{n} Q_i}{n}$is an average value of *Q*.