PRACTICAL 5.10

SURFACE TENSION COEFFICIENT OF A LIQUID

Objective: experimental determination of the surface tension coefficient of a liquid and its temperature dependence.

Experimental equipment: Rebinder device for determining the surface tension coefficient, thermometer, electric hot plate, water tank.

INTRODUCTION

The energy states of molecules in the surface layer and inside the liquid are different. The surface layer of liquid has an additional potential energy E, which is proportional to the surface area:

$$E = \alpha S \qquad (1)$$

The proportionality coefficient α is called the surface tension coefficient. Its value depends on the type of liquid and temperature. Due to the presence of surface energy, the liquid tends to reduce its surface.

The value of the surface tension coefficient depends on the medium with which the fluid is bordered. The tables usually give the values of the surface tension of the liquid at the boundary with its saturated steam.

The surface tension force is tangential to the surface of the liquid and perpendicular to the line bounding the surface of the liquid. The magnitude of the surface tension force is proportional to the length of the border *L*:

$$F = \alpha L \, . \qquad (2)$$

If the surface of the liquid is not flat, then the desire to reduce the area leads to the appearance of additional pressure Δp (it is usually called Laplace). For spherical surface,

$$\Delta p = \frac{2\alpha}{R} \, , \qquad (3)$$

where R – radius of curvature of a spherical surface.

In this work, we consider spherical air bubbles formed in the liquid. In equilibrium, the air pressure inside the bubble is greater than the external pressure by an amount Δp. A smaller radius of the bubble leads to a greater pressure difference. The bubbles are blown out of the capillary, the tip of which is lowered into the liquid. As can be seen in Fig. 1, the minimum bubble radius is equal to the radius of the capillary opening. By measuring the Laplace pressure (3), you can determine the surface tension coefficient.

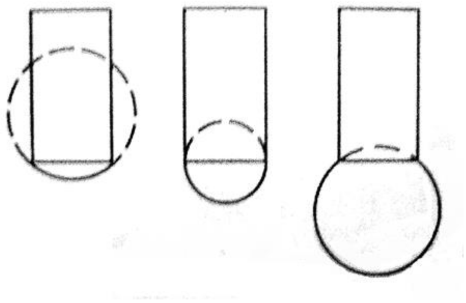

Figure 1. Schematic representation of the air bubble

DESCRIPTION OF THE EXPERIMENTAL SETUP

A schematic of the Rebinder device which is used to determine the coefficient of surface tension of liquids is shown in Fig. 2. The tube *1* with an elongated tip ***C*** (capillary) is inserted into the stopper closing the water tank *2* with the liquid being investigated. Capillary ***C*** must be in contact with the surface of the test liquid. Tee *3* connects the air space of the water tank *2* with the aspirator *4* and the pressure gauge *5*. The pressure difference between the atmospheric pressure and the air pressure in the water tank *2* is measured with a pressure gauge. The water tank *2* can be placed in a water bath *6* equipped with a heater *7* (electric hot plate) and a thermometer *8*. During the experiment, the valve of the aspirator *4* is opened, as a result the water from the aspirator is poured into the glass *10*, and a vacuum is created in the vessel *2*. The pressure difference inside and outside the vessel *2* leads to the appearance of an air bubble at the end of the capillary ***C***.

As this difference increases, the bubble is blown out of the capillary, and its radius, as can be seen in Fig. 1, decreases and the increasing pressure difference is balanced by the Laplace pressure Δp. Soon the radius of the bubble reaches the minimum possible value determined by the radius of the capillary opening. A further increase in rarefaction leads to an imbalance and tearing of the bubble. At the moment of bubble separation, the pressure difference Δp recorded by the pressure gauge is equal to the Laplace pressure $\frac{2\alpha}{R}$.

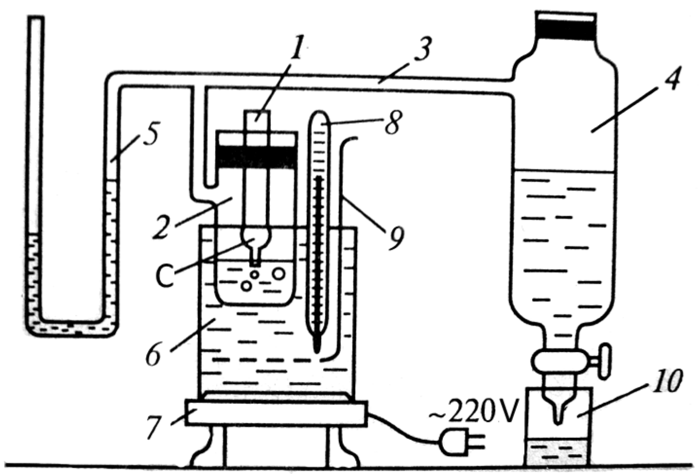

Figure 2. Experimental setup

The bubble radius in this formula cannot be determined by directly measuring the capillary radius, primarily because the capillary is not completely round. Therefore, it is best to write the relation (3) in the form

$$\Delta p = K\alpha , \qquad (4)$$

determining the coefficient K from experiment. To determine *K*, it is necessary to experiment with a liquid for which the value α is known, for example, with distilled water.

MEASUREMENT AND DATA PROCESSING

When preparing the device for operation, pour water into the aspirator. Place the tube *1* in the vessel *2* with the test liquid so that the capillary of the tube touches the surface of the liquid. The water tank *2* and the aspirator 4 are tightly closed with rubber stoppers. If you open the valve of the aspirator, air bubbles should be blown out of the capillary into the test liquid (if this does not occur, check the tightness of the fit of the plugs). Select the speed of formation of bubbles convenient for measurements by opening and closing the valve of the aspirator.

Task 1. Determination of the device constant

Measure Δp_0 while blowing bubbles through distilled water at room temperature. Measure at least 10–12 times. Calculate K using formula (4). The value α is taken from the tables. We note that the units of the coefficient K does not necessarily have to be translated into SI. Since Δp_0 is measured in millimeters of the alcohol column and all subsequent measurements of Δp are in the same units, the K coefficient can be measured in units (mm Alcohol) / (mN /m).

Task 2. Determination of the temperature dependence of the surface tension of water α

Turning on the heater, heat the water in water tank 2 to 80–90 ° C. During heating the water tank 2 must be opened so that the pressure in it does not increase. When water is cooled measure Δp every 10 degrees and determine α at appropriate temperatures.

In the Reference table at the end of the description of this work values of the coefficient of surface tension of water at different temperatures are tabulated. Using this data, plot the dependence of α on temperature. Put the α values obtained in the experiment on the same graph.

Task 3. Determination of the coefficient of the surface tension of alcohol

Using the above method, determine α for alcohol at room temperature, after placing the capillary in a vessel with alcohol.

In all cases, determine the accuracy of the measurements.

QUESTIONS AND EXERCISES

1. Give the power and energy definition of the surface tension coefficient α. How does α depend on temperature? What is the value of α at a critical temperature?

2. Tell about the experimental methods for determining α.

3. How will the coefficient of water surface tension change if soap is added to water? How can this change be illustrated through experiment?

4. Derive the formula for the height of the wetting fluid in the round capillary.

5. Water droplets of various sizes are in a closed vessel. What happens to them after a long time and why?

6. How high a layer of water can be poured into a sieve with a diameter of 1 mm?

7. What force must be applied to tear off two round glass plates from each other if there is a layer of water between them 1.9 microns thick? Radius of plate is 5 cm.

REFERENCE TABLE
COEFFICIENT OF SURFACE TENSION OF WATER AT DIFFERENT TEMPERATURES

t, °C	α, mN/m
0	75.5
10	74.0
20	72.5
30	71.0
40	69.5
50	67.8
60	66.0
70	64.2
80	62.3
90	59.0
100	56.0