Student's name _____

Experiment № 8

DETERMINATION OF SURFACE TENSION BY COMPARING LIQUID DROPS

Objective: to master conception of surface tension in liquid. To determine surface tension of the liquid under investigation by comparing liquid drops.

1 EQUIPMENT

1. Burette.
2. Studied liquid.
3. Distilled water.
4. Measuring glass.

2 THEORY

2.1 Molecules of water, as in any substance, are in constant motion. In distinction from gaseous media, strong interaction between molecules is inherent to liquid. Due to this interaction, molecules on the surface are in a different state from those being deep in volume (see fig. 2.1). Any molecule within the volume is surrounded by other molecules. The surrounding is symmetrical, the same molecules concentration and mean distances to them abov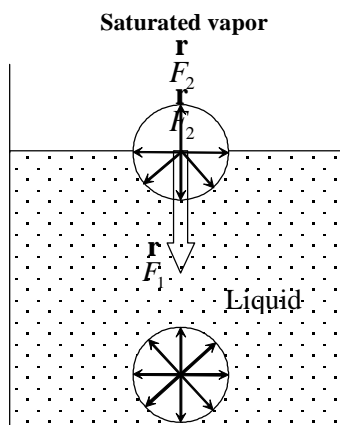e, below, to the right, to the left for the given molecule. For this reason the averaged resultant force acting on the given molecule from side of the others is equal zero. In contrast to this, for a molecule on surface forces $\vec{F_2}$ from above vapor is much smaller than the forces $\vec{F_1}$ from below liquid, because the liquid is much more dense. The resultant of these forces is directed into the liquid, in consequence of it the surface layer press onto below layers and create an additional pressure in the liquid.

Figure 2.1

Total energy of molecules on surface differs from one for molecule deep inside the liquid. The energy difference of surface and in-volume molecules is known as the surface energy.

The mumber of surface molecules is proportional to the area of the surface, so any increase in the surface area ΔS result in the work ΔA done by the external forces to move molecules from inside the volume to the surface

$$\Delta A = a\Delta S . \tag{2.1}$$

Surface tension

$$a = \frac{\Delta A}{\Delta S} . \tag{2.2}$$

is defined as a work per area unit to increase surface by area unit. 1J/m^2 is a unit of surface tension.

As liquid has no rigid form, its surface in equilibrium state tends to have minimal energy. Due to the surface tension, in free state, liquid tends to take the form of the least volume, which is a sphere. In this way forces of surface tension appear, which cause the decrease of liquid's surface.

The force of surface tension on a segment of a surface layer is always normal to the segment and tangential to the surface. Magnitude of this force is proportional to the length of the segment

$$\Delta F = a\Delta l . \tag{2.3}$$

From the above equation one can see that surface tension can also be defined as ratio of surface tension force ΔF, acting on the segment, to the length Δl of this segment

$$a = \frac{\Delta F}{\Delta l} . \tag{2.4}$$

According to such definition, 1 N/m can also be taken as the unit of surface tension in SI system.

Every liquid is characterized by its own value of surface tension, dependent on a chemical composition of the liquid. Surface tension decreases with the increase of temperature and becomes zero at critical temperature.

3 DERIVATION OF COMPUTATION FORMULA

One can determine the surface tension for a liquid by comparing its drop's volume with other, standard one. If a liquid drips out of a burette B through faucet K (fig. 3.1). Surface tension does not allow the liquid to flow out of the burette freely and it drips out drop by drop. Every drop starts falling (see fig. 3.2) at the instance when weight of the drop exceeds the surface tension force

$$mg = F. \tag{3.1}$$

Taking into account, that tension force is $F = aL$, where L is довжина контура в шийці краплі, що приблизно дорівнює довжині кола обводу кінчика бюретки:the circumference of the burette's end

$$L = 2pR, \tag{3.2}$$

here R is radius of the burette's end.

The tension force equals

$$F = 2pRa. \tag{3.3}$$

Weight of the liquid drop is

$$mg = rV_x g, \tag{3.4}$$

where V_x is volume of one drop, ρ is liquid's density. Equalizing right hand sides of equations (3.3) and (3.4), we obtain

$$2pRa = rV_x g. \tag{3.5}$$

For distilled water one has

$$2pR_1 a_1 = r_1 V_{x1} g. \tag{3.6}$$

For the studied liquid one has

$$2pR_2 a_2 = r_2 V_{x2} g. \tag{3.7}$$

Both liquids drips out of the same burette,so $R_1 = R_2$. From system of equations (3.6) and (3.7) we find

$$\frac{a_1}{a_2} = \frac{V_{x1} r_1}{V_{x2} r_2} \tag{3.8}$$

and, finally

$$a_2 = a_1 \frac{V_2 r_2}{V_1 r_1}. \tag{3.9}$$

where V_1, and V_2 are volumes of water drop and studied liquid drop, respectively. This method allows to determine the surface tension for any liquid, comparing volumes of drops of two liquids.
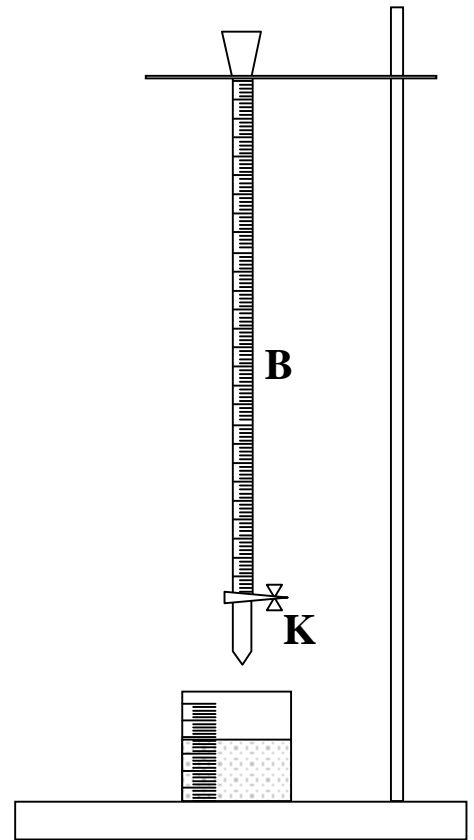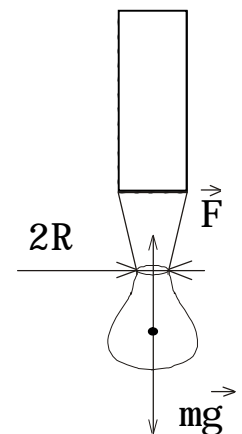

Figure 3.1

Figure 3.2