

Surface Tension of Water by the Capillary Tube Method

Apparatus:

Set of three glass capillary tubes- one of 0.5 mm diameter. One of greater and one of less diameter; dilute nitric acid, dilute caustic soda solution, traveling microscope or glass scale, rubber bands, beaker, stand and clamp, thermometer.

Method:

Clean all three capillary tubes free from dirt and grease both inside and outside by washing them successively with nitric acid, with tap-water, with caustic soda solution and lastly and repeatedly with tap-water. The beaker and the glass scale (if used) must also be from dirt and grease so clean them in the same way.

Select the capillary tube of medium bore and attach bent pin to it by means of a rubber band. Hold the capillary tube in a clamp with its lower end immersed in the water. Before measuring the capillary rise push the tube a little farther down into the water and then restore it to its original position. This ensures that the tube is wet a little above the meniscus.

Adjust the position of the bent until its point touches the water surface. Focus the microscope on the meniscus of the water level in the capillary tube and adjust the microscope until the horizontal cross-wire is tangential to the bottom of the meniscus which is of course seen inverted in the eyepiece of the microscope. To facilitate preliminary focusing of the microscope on the meniscus it is useful to hold a piece of paper with printing on it behind the capillary tube and first focus on that. Record the position of the travelling microscope on its vertical scale (h_1).

Make the position of the meniscus on the capillary tube with a loop of cotton or by gummed paper and then carefully remove the beaker of water from contact with the bent pin. Lower the microscope until it can now be focused on the tip of the bent pin. Record the position of traveling microscope on its vertical scale (h_2).

With the aid of a file cut the capillary tube at the place previously occupied by the meniscus and measure the internal diameter (d) by the travelling microscope, taking the mean of two determination at right angles.

Repeat all the measurements with the other two clean capillary tubes in turn.

Record the temperature of the water.

Theory and calculation:

Look up in the tables the density of water at the particular temperature of the experiment and record it (ρ) in kgm^{-3} .

Take $g = 9.81 \text{ ms}^{-2}$

Calculate surface tension ($\hat{\sigma}$) from:

$$\hat{\sigma} = \frac{1}{4} d h g \rho$$

Remember that d (diameter) and h (height) are both measured in m.

Errors and Accuracy:

Errors arise in the measurements of the diameter d of the capillary tube and of the capillary rise h . estimate these as % errors having regard to the scale of the microscope and the fact that both are difference measurements.

Form (1) % errors in $\hat{\sigma}$ = sum of % errors in d and h .

Another assessment of the error can also be made from the greatest divergence from the mean of the three values obtained for $\hat{\sigma}$ and your result should be stated to degree of accuracy in accordance with the greater of these two assessments of error.

Medical Applications:

The alveoli are physically like millions of small interconnected bubbles. They have a natural tendency to get smaller due to the surface tension of unique fluid lining. This lining called surfactant, is necessary for the lung.

To understand the physics of alveoli we have to understand the physics of bubbles. The pressure inside bubbles is inversely proportional to radius and directly proportional to surface tension $\hat{\sigma}$.

$$P = 4 \hat{\sigma} / R \quad \text{Laplace Law .}$$

The surface tension of surfactant that lines the alveoli of healthy individuals plays a major role in lung function.

The surface tension of surfactant is not constant.

References:

1- John R. Cameron. Medical Physics.