(PM1-4) Surface Tension Using Capillary Tubes for Water at Different Temperatures

Aim of experiment

Determination of the coefficient of surface tension of water at different temperatures.

Apparatus

Capillary Tubes of Same Radii, Water in a Beaker, Ruler, Hot Plate Heater, Thermometer

Theory of experiment

Consider a liquid, such as water, is placed in a vessel as shown in *figure 1.* For a molecule inside the liquid the net force acting on it equal zero. For a molecule on the liquid surface the net force acting on it tends to pull the molecule inside the liquid, so the surface of liquid acts as elastic tension membrane. This phenomenon is known as *surface tension.*

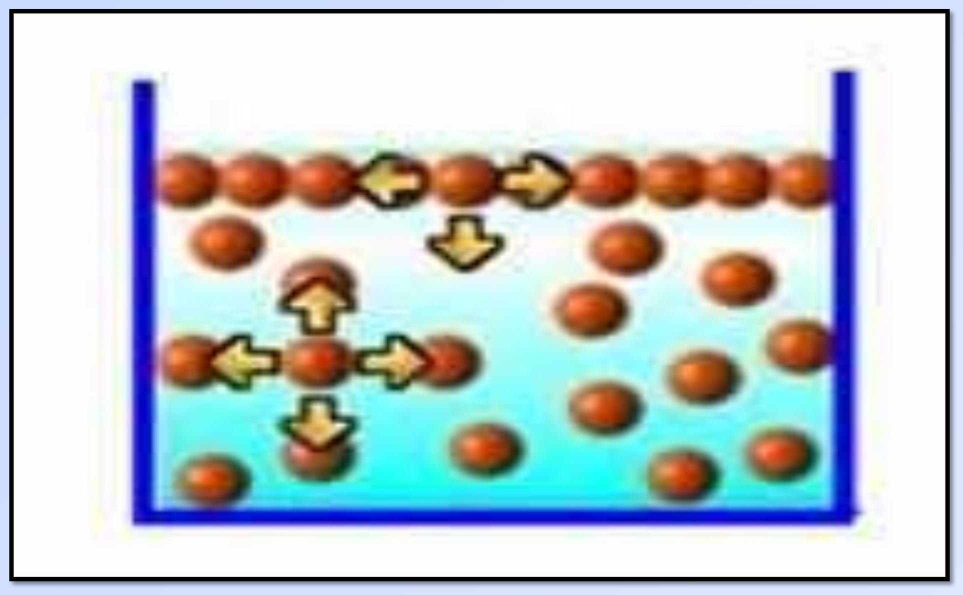

*Figure 1***.** Force acting on liquids molecules

Coefficient of surface tension is the tangent force per unit length acting on the surface of liquid.

Consider a capillary tube with inner radius $r=d/2$ is dipped vertically in a liquid with density ρ and surface tension T.

The liquid will rise up until certain height h, at which equilibrium between the following two forces takes place.

1- A force acting upward due to surface tension .

$$F = \sigma (2\pi r) \cos \theta$$

2- A force acting downward due to gravity

$$w = \pi r^2 h \rho g$$

At equilibrium

$$\sigma (2 \pi r) \cos \theta = \pi r^2 h \rho g$$

$$2 \sigma \cos \theta = r h \rho g$$

$$h = 2 \sigma \cos \theta / \rho r g \qquad (1)$$

This equation represents the relation between the height, of liquid in a capillary tube and its surface tension.

Published data for the density of water fitted, Above 8 ^{o}C, to a linear equation of the form;

$$\rho_T = (-7x10^{-5}\ T\,^oC + 0.99987)\ x1000\ \ kg/m^3 \qquad (2)$$

Also the temperature dependent surface tension is given by;

$$\sigma_T = -\ 0.000182\ T\,^oC + 0.0757\ \ N/m\ (3)$$

This means that the surface tension is a temperature dependant parameter. The surface tension of water decreases by increasing temperature above about 5 ^{o}C. From equations (1), (2) and (3) one obtains the water rise in meter, h, in a capillary tube of radius, r at temperature T as;

$$\sigma_T = h\ x\ [r\ x\ (-7\ x\ 10^{-5}\ T^oC + 0.999\ 87)\ x\ 1000]\ /2$$

where θ is taken to be zero, for water. It is obvious that the surface tension is slowly decreasing with temperature.

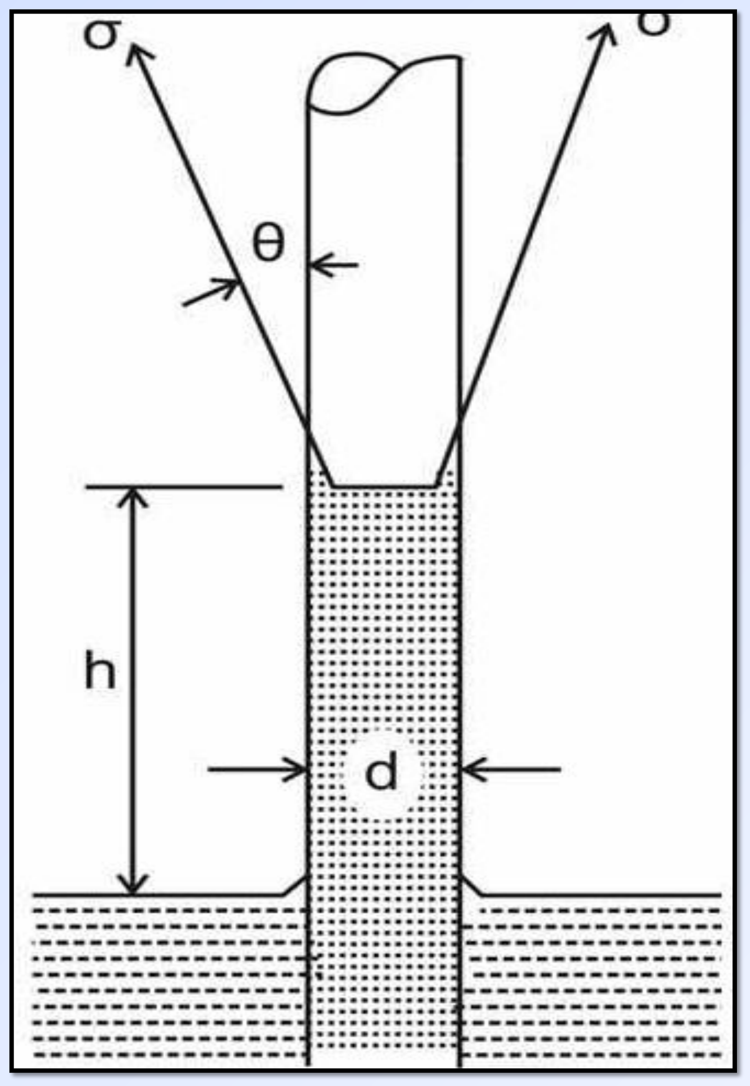

Figure 2 A capillary tube immersed in a liquid

Procedures

1. Measure the internal radii of the given capillary tubes, at least three of nearly same radius, r, using a traveling microscope.
2. Insert the three capillary tubes of radius, r, in the water tank at a low temperature.
3. Measure the height of the water in the capillary tubes at that temperature.
4. Increase the temperature, and measure the height of water at different temperatures.
5. Calculate the surface tension at different temperatures from equation (3) for each tu
6. Record the results in a table.
7. Draw a graph between the temperature of water and average surface tension.
8. Comment on the graph.

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Results

r_{av}=

r_1 (m)		r_2 (m)		r_2 (m)		r_{av}=
T (°C)	σ (N/m)	T (°C)	σ (N/m)	T (°C)	σ (N/m)	σ_{av} (N/m)