3. MEASUREMENT THE DENSITY OF THE LIQUIDS

OBJECTIVES

1. Measure the density of the liquid by the pycnometer
2. Measure the density of the liquid by the method using the Archimedes' law
3. Measure the density of liquid by Mohr's balance
4. Measure density liquid by densimetre
5. Compare your results find out by various methods and explain the accuracy of each measurement

THEORETICAL PART

Density, ρ_k is one of the materials constants which describes the mechanical properties of the matter. It is defined by the expression

$$\rho = \frac{\mathrm{d}m}{\mathrm{d}\tau}$$

where $\mathrm{d}\tau$ is the volume element of a substance, dm is the mass element of a substance. If a substance is homogeneous it means that the every element has the same mass then the density is given by the relation

$$\rho = \frac{m}{\tau}$$

Unit of the density is in SI units kg/m^3. We must remember that the density depends on the temperature. This effect is connected by the fact that the volume is changed with the change of the temperature.

THE METHOD-PRACTICAL PART

There are several methods for measurement the density of liquids. We shall take an interest in the measurement the density of the liquids by the method of pycnometer, the method using the Archimedes' principle, about the method of Mohr's balance and the method using the densimeter.

1.MEASUREMENT THE DENSITY OF UNKNOWN LIQUID BY THE METHOD USING PYCNOMETER

This method is based on the measurement of the density of unknown liquid by the help of the density of known liquid with the same volumes. This volume is realized by the pycnometer.

Pycnometer is the bottle, which is closed with the plug containing the capillary tube. This one is needed to flow the superfluous liquid out of the pycnometer. If is density of known liquid, ρ_k, mass m_k and volume τ then the density of known liquid is by the definition given by

$$\rho_k = \frac{m_k}{\tau_k} \qquad (1)$$

From this equation immediately follows

$$\tau = \frac{m_k}{\rho_k} \qquad (2)$$

Similarly the density of an unknown liquid at the same volume is given by

$$\rho_u = \frac{m_u}{\tau} \qquad (3)$$

where m_u is the mass of the unknown liquid. Inserting eq.2 into eq.3 gives

$$\rho_u = \rho_k \frac{m_u}{m_k} \qquad (4)$$

MEASUREMENT

APPARATUS: pycnometer, balance, weights, distillate water, unknown liquid, thermometer

Measure the mass m_p of dry pycnometer. Fill this pycnometer with the distillate water (know liquid) and measure its mass m_k'. Then fill the pycnometer with the unknown liquid and determine its mass. Calculate the mass of the distillate water from equation

$m_k = m_k' - m_p$

and the mass of the unknown liquid as

$m_u = m_u' - m_p$.

Measure the temperature of distillate water and find out the value of its density from the table. This value is needed to correction of your result.

CALCULATION

Calculate the density of unknown from eq.4. Calculate the percentage error of the density given by the formula

$$u_\rho = \rho \sqrt{\left(\frac{u_k}{m_u}\right)^2 + \left(\frac{u_u}{m_u}\right)^2} * 100\,\%_0 \qquad (5)$$

where u_k and u_u are the errors of the using balance. These quantities can be calculated from expression

$$u_k = u_u = \sqrt{\frac{2}{3} z_{\max}} \qquad (6)$$

where z_{max} is the smallest value of the weights.

2. MEASUREMENT OF THE DENSITY OF UNKNOWN LIQUID BY THE METHOD USING ARCHIMEDES' LAW

The Archimedes law states that the body submerged into a liquid is buoyed up by the force equals to the weight the liquid displaced its submerged volume. We shall use this principle to determinetion the density of unknown liquid.

If we submerge the body (in our case is the body realize by the cylinder) with volume τ into liquid of the density ρ then the buoyant force acting on this body equals

$$F_b = \rho \tau g \qquad (7)$$

where : g is the acceleration of gravity

$\rho\tau = m$ is the mass of displaced liquid

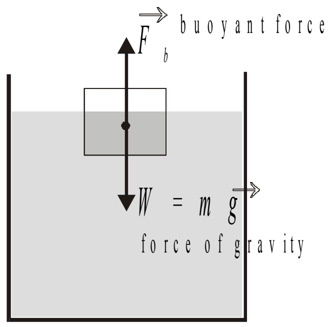

Fig.1

If we can see from the figure 1 the resultant force acting on the submerge body in liquid is given by the vector's expression

$$F = W + F_b$$

or

$$F = W - F_b \qquad (8)$$

The mines sign in this equation means that the directions of these forces are opposite to each other.

If we submerge the cylinder into distillate water then the resultant force acting on it is given by the expression

$$F_k = mg - \rho_k \tau g \qquad (9)$$

and similarly the resultant force acting on the same cylinder in unknown liquid is

$$F_u = mg - \rho_u \tau g \qquad (10)$$

where $mg=W$ is the weight of the cylinder in the air. Combining eq.9 and 10 gives

$$\rho_u = \rho_k \frac{m - m_u}{m - m_k} \qquad (11)$$

where: m is the mass of the cylinder in the air
m_u is the mass of the cylinder submerged into unknown liquid
m_k is the mass of the cylinder submerged into distillate water

MEASUREMENT

APPARATUS: submersible cylinder, balance, weights, distillate water, unknown liquid, thermometer

Hang the cylinder on a little hook on the balance a measure its mass m. Plunge the cylinder into distillate water and measure its mass m_k . Repeat this procedure for unknown liquid and determine the mass m_u. Measure the temperature of both liquids.

CALCULATION

Calculate the density of the unknown liquid from eq.11 and calculate the percentage error from eq.5.

3. MEASUREMENT OF THE DENSITY OF UNKNOWN LIQUID BY THE MOHR BALANCE.

Mohr balance is one, which is based on the Archimedes principle. The steelyard of this balance consists of a gradual metal bar with the fulcrum near one end. The using body (cylinder) will be hanged on the on the arm of the balance and a sliding weights is moved along the arm until equilibrium is attained. The arm is graduated to read directly value of the body.

The cylinder is balanced by the weights on the air. If the balance is in equilibrium then the momentum to the axis of rotation of the balance equals the momentum of the using

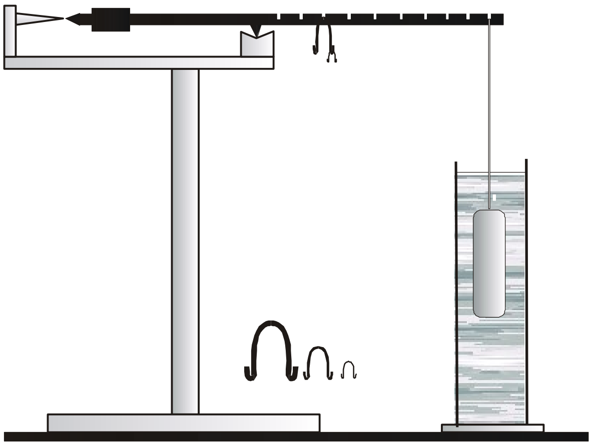

Fig. 2

weights as is shown in Fig.2

In this case is valid this equation

$$M = mg * 10d \quad (12)$$

where: mg is the weight of the cylinder

d is the magnitude of one section on the scale of the arm. If we submerge the cylinder into test liquid then the equilibrium is broken due to Archimedes principle. Weights must be hanged on arm of the balance so that the balance is in equilibrium. It means that

$$\sum_{i=1}^{n} \vec{M_i} = o \quad (13)$$

The largest weight is calibrated so that its value balances the buoyed force acting on the cylinder in distillate water at the temperature 4^0C. In this case the distillate water has the density of 10^3kg/m^3. Values of the other weights are $0.1.10^3$ kg/m^3 and $0.01.10^3$kg/m^3.

Then the balance condition is in the form

$$\rho_u g \tau \times 10d = mgx_1 \times d + 0.1mgx_2 \times d + 0.01mgx_3 \times d$$

(14)

where: ρ_u is the density of the measured liquid

τ is the volume of submergible cylinder

x_1 is the position of the most large weight on the arm of the scale

x_2 is the position of the middle weight on the arm

x_3 is the position of the smallest weight on the scale

Using the definition of the density $\rho = \frac{m}{\tau}$ gives

$$\rho_u = (1 \times x_1 + 0.1 \times x_2 + 0.01 \times x_3) \times 10^3 kg/m^3 \quad (15)$$

Because the density depends on the temperature of the matter we must control the accuracy of the Mohr balance. The help of distillate water provides this control. Correction of the density is given by expression

$$\rho_{u_{corr}} = \rho_u \frac{\rho_{k_{tab}}}{\rho_{k_{meas}}} \quad (16)$$

MEASUREMENT

APPARATUS: Mohr balance, weighs, distillate water, unknown liquid, thermometer

Balance the cylinder in the air. Measure the density of the distillate water. Measure the density of the unknown liquid. Measure the temperature of the distillate water and determine its density from the table.

CALCULATION

Calculate the correct value of the density of unknown liquid from eq.16. Calculate the percentage error from eq. 5.

4. MEASUREMENT THE DENSITY OF THE UNKNOWN LIQUID BY THE

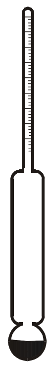

Fig.3

DENSIMETER.

The densimeter is a glass tube lowered into liquid heavier the matter, it will not sink as deep since it will displaced its own weight of the heavier liquid with a lesser volume displaced. If used the liquid higher than water it will sink deeper than it does in water, since greater volume of the higher liquid will be required to weigh the same as the floating densimeter. The scale of this device is calibrated using liquid of known density, usually, in order to attain a longer scale and therefore more precise readings; the same densimeter is not used for both heavy and light liquids. Densimeter is shown in Fig.3.

MEASUREMENT

APPARATUS: densimeter, distillate water, unknown liquid, thermometer

Pour the two liquids into separate tall jars, and determine their density with the densimeter. Measure the temperature of the liquids.

5. Analyze and discuss the possible sources of errors in these experiments.