Capillary viscometer method for Determination of liquid viscosity.

PRACTICAL PART

The purposes of the work:

1. Determine liquid viscosity coefficient using Ostwald capillary viscometer
2. Investigate dependence of solutions viscosity coefficient vs it's concentration

Equipment:

capillary viscometer, stopwatch, thermometer, investigated solutions (liquids)

The viscosity of biological fluids (blood, lymph, liquor, etc.) depends on the physiological state of the body and changes with pathology. Thus, an increase in blood viscosity occurs in ischemic heart disease, myocardial infarction, hypertension, diabetes and other diseases. Knowing the blood viscosity allows you to assess the degree of stress on the patient's cardiovascular system. The determination of viscosity is important and is widely used in medicine:

- in clinical diagnostics: measurement of blood viscosity using viscometers, assessment of erythrocyte sedimentation rate (ESR) (also take into account the aggregation of red blood cells);
- in forensic medicine (use the dependence of blood viscosity on age and gender);
- in medical research: the viscosity (microviscosity) of the cell's cytoplasm is determined. It depends on the structure of its constituent biopolymers and subcellular formations, on the period of the cell cycle, on the temperature, and on the intensity of various external influences (for example, radiation exposure).

The viscosity of liquids is determined using an Ostwald capillary viscometer.

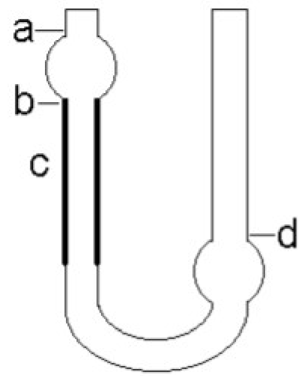

Figure 1. Ostwald capillary viscometer.

Ostwald capillary viscometer shown at the figure 1. It has control marks (a, b, d are the marks limiting the liquid level) and capillary (C).

The viscosity of the test liquid is determined by the formula:

$$\eta_x = \eta_0 \frac{\rho_x t_x}{\rho_0 t_0} \qquad (1)$$

In order to determine the viscosity coefficient of the investigated liquid, you need to know:

η_0 is the viscosity coefficient of water,

t_0 is the time of water flow between marks a and b,

t_x is the time of flow of the test liquid between marks a and b,

ρ_0 is the water density,

ρ_x is the density of the test liquid.

Task 1. Determine the viscosity coefficient of solutions with different concentrations.

1. Pour water into the knee of the viscometer that does not have a capillary up to the d mark.

2. Use a pear to suck the liquid through the capillary to mark a. After removing the pear, determine t_0 - the time of water flow between marks a and b.
3. Repeat the measurement 5 times with the same liquid.
4. Follow steps 1 to 3 for all the liquids to be tested.
5. Enter the Data in table 1.
6. Calculate average value of time for each liquid using next formula

$$t_{aver} = \frac{t_1 + t_2 + \cdots + t_5}{5}$$

7. Determine the classroom temperature. Then take the value of water density from Table 2 and write it down in the table 1. Take the data of solutions density from Table 4 and write down values in table 1.
8. The value of water viscosity coefficient take from Table 3 for classroom temperature.
9. Calculate the viscosity coefficients of the studied liquids using the formula (1).
10. Fill in all columns of the table 1.

Table 1

№	Concentration, %	t_1, s	t_2, s	t_3, s	t_4, s	t_5, s	$t_{average}$, s	ρ, 10^3 kg/m^3	η, Pa·s
1									
2									
3									
4									
5									

Table 2. The density of water at different temperatures

ρ, 10^3 kg/m³	t, ^{0}C	ρ, 10^3 kg/m³	t, ^{0}C
0,99913	15	0,99802	21
0,99897	16	0,99780	22
0,99880	17	0,99757	23
0,99843	19	0,99732	24
0,99823	20	0,99707	25

Table 3. The viscosity of water at different temperatures

η, Pa s	t, ^{0}C	η, Pa s	t, ^{0}C
0,00114	15	0,00098	21
0,00111	16	0,00096	22
0,00108	17	0,00093	23
0,00103	19	0,00091	24
0,00100	20	0,00089	25

Table 4. Density of glycerol solutions of various concentrations

C, %	ρ, 10^3 kg/m³	C, %	ρ, 10^3 kg/m³
5	1,0125	45	1,1125
10	1,0250	50	1,1250
15	1,0375	55	1,1375
20	1,0425	60	1,1500
25	1,0525	65	1,1625
30	1,0750	70	1,1750
35	1,0875	75	1,1875
40	1,1000	80	1,2000

Task 2. Determine the concentration of an unknown solution.

1. Plot the dependence of the viscosity coefficient on the concentration of the solution.

2. Knowing the viscosity coefficient of an unknown solution, use the graph to determine its concentration.

Control questions on the topic of the lesson (to prepare to these questions use file "Lesson 5-visc-theory.pdf" and any another sources):

1. What is the viscosity of a liquid?
2. What is laminar fluid flow? What is turbulent fluid flow?
3. What characterizes the Reynolds formula?
4. Write Newton's formula and explain the physical meaning of the quantities included in it? Newtonian and non-Newtonian fluids.
5. What is the dynamic viscosity coefficient? In what units is it measured?
6. What kind of fluid is called a Newtonian? What does their viscosity coefficient depend on?
7. What liquids are called non-Newtonian? What does their viscosity coefficient depend on?
8. Write the Poiseuille formula and explain the physical meaning of the values included in it.
9. Draw an analogy between Ohm's law for a section of a chain and Poiseuille's law. Write down the formula for hydraulic resistance.
10. What methods are used to determine the viscosity of a liquid?
11. Describe the device and the principle of operation of the Ostwald viscometer.
12. Describe the device and the principle of operation of the Hess viscometer.
13. Describe the device and the principle of operation of the rotary viscometer.
14. Blood as a non-Newtonian fluid.
15. Influence of physical properties of erythrocytes on blood viscosity.
16. Tell us about the rheological properties of blood and other biological fluids, and the use of rheological tests in medicine.
17. Models of blood circulation.

Situational tasks on a topic:

1. Calculate the force acting on 2 m^2 of the bed bottom if a stream of water with a height of 2m moves along it. The speed of the upper water layer is 30 cm/s, the speed of the lower layers gradually decreases and is zero at the bottom.
2. In which vessels of the circulatory system –large or small - is there a high probability of the transition of laminar flow to turbulent?
3. The diameters ratio of two needles of the same length is 1:2. In what relation will there be volumes of liquid ejected from syringes per unit of time if the pistons of syringes are affected with the same force?
4. Determine the speed at which the transition of laminar flow to turbulent flow is possible in a vessel with a diameter of 1.25 mm, if the critical Reynolds number is 1160, blood density is 1050 kg/m^3, blood viscosity is 5000 mkPa·s.

5. When a medical drug is administered, the needle diameter, needle length, or pressure can be doubled. In which case will the procedure be faster? Why?

6. Is the movement of blood in the aorta laminar or turbulent if the speed of blood movement is 0.3 m/s, the vessel diameter is 4 mm (ρ= 1050 kg/m^3, η=5000mkPa·s, Re=1160)?

7. Determine the maximum amount of blood that can pass through the aorta per unit of time, so that the flow remains laminar. (The diameter of the aorta is 0.3 cm, the blood viscosity of 5 MPa·s, Re=1000).

8. Compare the hydraulic resistance of the aorta (d= 7 mm), artery (d= 1.3 mm), arteriole (d= 0.05 mm) and capillary (d= 0.007 mm) in a section of a vessel 40 cm long, if the blood viscosity is 0.004 PA·s.

9. A wide vessel branches into two parallel small ones with hydraulic resistance X_1= 5 PA·s/m^3 and x_2= 10 PA·s/m^3. Find the hydraulic resistance of the system.

10. Laminar or turbulent will be the movement of blood in the aorta, if the blood velocity is 0.5 m/s, the diameter of the vessel is 8 mm (ρ= 1050 kg/m^3, η= 5000mkPa, Re = 1160)?

11. Determine the maximum amount of blood that can pass through the aorta per unit of time so that the flow remains laminar. (Aortic diameter 0.2 cm, blood viscosity 5 mPa×C, Re = 1000).

12. Find the hydraulic resistance of a system of small pipes connected in series with a hydraulic resistance X_1 = 5 Pa×s/m^3 and X2 = 10 Pa×s/m^3.

13. Determine blood plasma ESR (erythrocyte sedimentation rate) in mm/h, based on next information: erythrocytes are shaped like balls with size of 7 microns in diameter and are not glued together (erythrocyte density 1090 kg/m^3).