Lodz University of Technology
Institute of Materials Science and Engineering

Laboratory 7

Viscosity assay

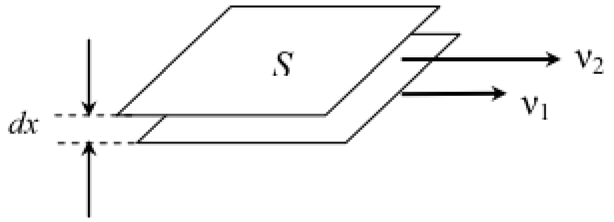
Instruction for the Laboratory of Biophysics

Institute of Materials Science and Engineering
90-924 Łódź, 1/15 Stefanowskiego Street, building A18
phone: 42 631 30 30, office: IV floor room 440,
e-mail: inzynieria.materialowa@info.p.lodz.pl, www.mechaniczny.p.lodz.pl

I. THEORETICAL INTRODUCTION

Both gases and liquids are characterized by a viscosity. This property is connected with intermolecular interactions. Viscosity is a measure of the resistance of a fluid which is being deformed by either shear stress or extensional stress. In general terms it is the resistance of a liquid to flow. In any flow, layers move at different velocities and the fluid's viscosity arises from the shear stress between the layers that opposes any applied force.

Isaac Newton postulated that, during the straight, parallel and uniform flow, the shear stress, *F*, between layers *S* is proportional to the velocity gradient, $\partial v/\partial x$, in the direction perpendicular to the layers (Fig. 1).



$$\eta = \frac{F}{S\frac{dv}{dx}}.$$

Figure 1. Illustration of viscosity.

Here, the constant η is known as the *coefficient of viscosity*, the *viscosity*, the *dynamic viscosity*, or the *Newtonian viscosity*. In liquids:

- Viscosity is pressure independent (except at very high pressure);
- Viscosity tends to fall while the temperature increases

Unit of *coefficient of viscosity* in SI system is $Nsm^{-2} = kgm^{-1}s^{-1}$.

There are few kinds of methods determining liquid's viscosity. The most commonly used there are methods which are based on measurement of the rate of flow through the capillary tube and on the measurement of the sedimentation's velocity of ball in the liquid

Operation of capillary viscometers is based on the Poiseuille's equation, according to which the flowing liquid volume *V* at the time *t* through the capillary of radius *R* and length *l* under the influence of the pressure difference *p* is

$$V = \frac{\Pi R^4 \Delta p\, t}{8\eta l}$$

The most common design of gravity type viscometer is the U-tube type and best known as the Ostwald viscometer. It consists of two reservoir bulbs and a capillary tube as shown in figure 2:

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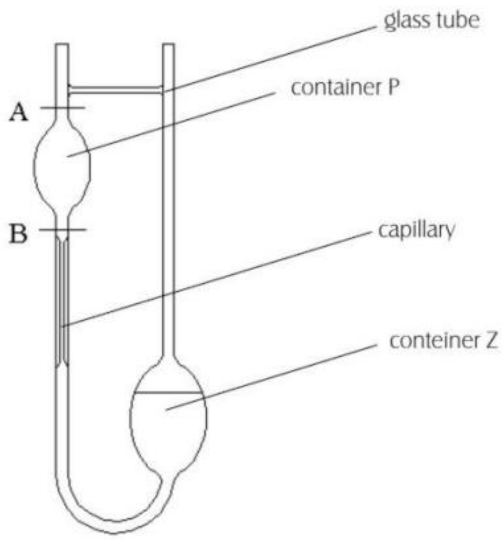

Figure 2. Ostwald viscometer.

The efflux time *t* of a fixed volume of liquid under an exactly reproducible mean hydrostatic head is measured. The viscometer is filled with the liquid until the liquid level reaches the mark Z. The viscometer is then placed inside a constant temperature bath to equilibrate the temperature of the test liquid with the bath temperature. The flow is timed between marks A and B. The viscosity is calculated using Poisseuille's low:

$$\frac{V}{t} = \frac{\pi r^4 \Delta p}{8 l \eta}. \quad (1)$$

where Δp means differential pressure between the ends of capillary.

To describe the viscosity dependence on temperature for tested liquid Arrheniusa-Guzman equation is used. In a Arrhenius's system logarithm of the viscosity is a linear function of the inverse absolute temperature:

$$\ln \eta = \ln A + \frac{E}{R} \cdot \frac{1}{T} \quad (2)$$

where

A - constant, characterized for given liquid, E - activation energy.

II. EXPERIMENTAL PART

1. Workplace

The workplace should include:

- viscometer
- pipettes
- glass beaker
- timer
- glucose
- magnetic stirrer

The exercise must be performed in a lab coat and protective gloves.

2. Laboratory

A. Viscosity measurement of a model liquid - sequence of operation

1. Check what volume is needed to fill the viscometer
2. Fill the viscometer till the level of water achieve line in container Z
3. Put viscometer into a beaker with water, making sure that it is placed vertically
4. Put also the thermometer into the water, and start heating viscometer in a beaker on a magnetic stirrer
5. Measurements are to make for temperatures 20 - 60 degrees, in every 10 degrees
6. For each of these temperatures measurements are to make. For this purpose, using a rubber bulb and the cable attached to the arm above the container P, pump the liquid till the level of water will be above line A. After removing the rubber bulb, begin observing the upper meniscus of the liquid. At a time when the meniscus is aligned with the line "A" begin to measure time. Measurement finishes when the water surface is aligned with the line "B". All the time note in table 1
7. Repeat the measurement 3 times for each temperature
8. Calculate the average time t_0 for a model liquid
9. Note the results in Table 1

B) Viscosity measurement of a tested liquid.

1. Prepare solution of glycerin (the concentration will be given by the instructor)
2. Fill the P Container of the same volume of tested liquid as water.
3. Put viscometer into a beaker with water, making sure that it is placed vertically
4. Put also the thermometer into the water, and start heating viscometer in a beaker on a magnetic stirrer
5. Make all measurements for temperatures 20 - 60 degrees, in every 10 degrees
6. Repeat measurement 3 times
7. Note all data in tables
8. Calculate the average time t for each tested liquid.

III. REPORT

1. Make graph of the temperature dependence on the viscosity for model liquid
2. Calculate the relative coefficient of viscosity by using the dependence:

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$$\frac{\eta}{\eta_o} = \frac{t\rho}{t_o\rho_o}$$

ρ- density of tested liquid;

ρ_o - density of model liquid.

3. Calculate the absolute coefficient of viscosity using the above dependence, where:
   η – absolute coefficient of viscosity;
   ηo – coefficient of viscosity for model liquid - water. This value should be found in The Physical Tables
4. Check the applicability of the Arrhenius-Guzman equation in this experiment.Plot graphs the viscosity dependence on temperature for model and tested liquids in the Arrhenius's system.
   Using least squares method determine the value of coefficient *A* and activation energy *E* and their average square relative errors.
5. Make graph of the viscosity dependence on the concentration for tested liquid in each temperature
6. Analyze achieved results
7. Discuss your results

IV. ISSUES TO STUDY

1. definition of the *viscosity, u*nit of *viscosity's coefficient* and influence different factors on liquid's viscosity
2. Newton's law, Poiseuille equation
3. laminar, turbulent flow, Reynolds number
4. methods determining liquid's viscosity.

V. REFERENCES

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