Instruction for exercise 2

Title: *Study of the dependence of glycerine viscosity on temperature. Determining the activation energy.*

Theoretical topics

1. Internal friction forces. Newton equation for fluids.
2. Viscosity of liquids and their types (relative viscosity, specific viscosity).
3. Viscosity of water, viscosity of blood.
4. Newtonian and non-Newtonian liquids. Thixotropy phenomenon. Methods of measuring surface tension.
5. Fluid flow: laminar and turbulent.
6. Construction and operation principle of the rotary viscometer.

Topics for a test.

1. Explain what viscosity of liquid is.
2. Which processes occurring in biological systems are affected by viscosity of liquid?

The purpose of the exercise:

Investigating temperature dependence of glycerol viscosity. Determining the value of viscous fluid activation energy.

Instruments:

Rotary viscometer RN-211, thermostat

Theoretical Introduction:

Comparing the moment of friction viscosity between the walls of two coaxial rollers (movable and fixed) with the torque of the spring connected to the synchronous motor, i.e.:

$$\eta \cdot 2\Pi \cdot L \cdot r^{3} \cdot \frac{d}{dr} = c \cdot$$

We set the value of the dynamic viscosity coefficient according to the expression given below:

$$\eta = K \cdot N \cdot \alpha$$

where: r, L - roller parameters, c - factor, - inclination angle of the pointer on the scale,

N - speed ranges (1 - 2 - 4 - 10),

K - factor, depending on the properties of the cylinder and roller.

For thermo-stabilization of the test liquid, the measuring cylinder is located in the vessel through which the water flows from the thermostat

The dependency of the dynamic viscosity coefficient on temperature is expressed as:

$$\eta (T) = A \cdot \exp(W / kT)$$

where: A - proportional coefficient, k - Boltzmann constant, T - temperature in the Kelvin scale, W - activation energy of viscous flow.

Measurements and reporting:

1. Set the temperature in the thermostat. Turn on the pump and the thermostat heater. Measure water temperature – read it from the control thermometer in the thermostatic vessel.
2. Turn on the viscometer and set the speed switch to N = 10.
3. Measure the viscosity coefficient using the following formula: $\eta = K \cdot N \cdot \alpha$

   For cylinder N and roller N1 **K= 0.97 [cP/Skt]**, **(1cP = 10^{-3}Nsm^{-2})**.
4. At the given temperature, perform at least 5 measurements of (for N = 10).
5. By changing the temperature in the thermostat every 5^{o}C (in the range from 20^{o}C to 65^{o}C),

   carry out measurements for each temperature. Measure for 3 - 5 min. after the temperature has been established on the control thermometer.

6. For each temperature, determine the average value of the viscosity coefficient **η**.

7. Put the results in the table below:

No.	**t** [ºC]	**T** [ºK]	**α[Skt]**					Average value **α** **[Skt]**	**N**	**η** **[Nsm⁻²]**
			α_1	α_2	α_3	α_4	α_5			

8. Based on the obtained results, plot the dependence of viscosity on temperature in the coordinate system: 1. (**T**, **η**) and 2. ($\mathbf{T^{-1}}$,**ln η**).

9. By linear regression, determine the parameters **a** and **b** of the straight line: **Y = a X + b** and their standard deviations σ_a and σ_b

$$\ln = \frac{W}{k} \cdot \frac{1}{T} + \ln A$$

10. Using the found regression coefficients, calculate activation energy W.

Appendix – Obtaining a,b,σ_a, σ_b parameters in EXCEL

Parameters of the line y = ax + b, such as:

- directional factor a,
- height factor b,
- correlation coefficient R^2,
- deviation of the directional factor σ_a,

- deviation of thev height factor σ_b,

can be obtained by using the REGLINP table function. In the result array, they will be set as follows:

	1	2
1	a	b
2	σ_a	σ_b
3	R^2	

Parameter values can be obtained by using the INDEKS function, giving the row and column number successively. For example, the following function gives the value of σ_a for the line y = ax + b:

=INDEKS(REGLINP(A1:A10;B1:B10;1;1);2;1)