Viscosity

1 Objective

- Measure the viscosity of a Newtonian fluid at room temperature and compare it with the theoretical value.
- Determine the effect of temperature on viscosity.

2 Prelab Questions

1. Define the following terms: drag, viscous force, terminal velocity, Newtonian fluid and Reynolds number.
2. Explain Stokes' Law and find the viscous force on a sphere with a small Reynolds number.
3. Explain Arrhenius' Equation, and describe how it applies to viscous systems.
4. Draw a free body diagram for a ball falling vertically in a viscous fluid.
5. Derive the following $\eta = \frac{2(\rho_2 - \rho_1)gr^2}{9v_T}$, where ρ_2 and ρ_1 are the density of sphere and water respectively, g is acceleration due to gravity, r is the radius of the sphere and v_T is the terminal velocity.

3 Principles

- The viscosity of a liquid or a gas is an indication of its internal resistance.
- The viscosity of pure water could be found using Stokes' Law.
- A sphere is allowed to travel in a cylindrical chamber filled with the fluid under study, the temperature is changed and motion of sphere is observed indicating a change in viscosity of fluid.

4 Apparatus

- Water tank.
- Viscometer with thermometer.
- Connecting rubber tubes.
- Stopwatch.
- Immersion thermostat and heat bath.

5 Precautions

1. Distilled water in the tank has to cover the heating coil attached to temperature controller.
2. Check that there are no gas bubbles in the inner chamber.

6 Experimental Steps

1. Rotate the viscometer until it clicks into the correct position, which is 10° to the vertical axis. Watch the ball as it falls and practise recording the time the ball takes to fall between any of the two white lines. Note that sphere should be moving with its terminal velocity when time is recorded.

2. Record the room temperature T_{lab} and the temperature T_{visc} of the thermometer inside the viscometer. Note that the heat bath and immersion thermostat are switched off in this step.

3. Rotate the viscometer and record the time t, repeating the step three times recording t_1, t_2 and t_3, then take the average t_{avg} of the three readings.

4. Switch on the temperature controller by pressing the switch on the lower left corner.

5. To change the temperature of the the water, press the yellow ring in the middle of temperature controller. The display will show *set*, press it again and the display will show flashing numbers indicating the temperature. To raise the temperature press the red circle repeatedly until you reach the desired temperature. The number will flash for four seconds before it is accepted. Note that the blue circle lowers the temperature.

6. Set the temperature to $25°$ on the controller and wait for 10 minutes.

7. Rotate the viscometer and record the time t the ball takes to travel between any of the two white lines.

8. Repeat the previous step three times, recording t_1, t_2 and t_3. Take the average t_{avg} of the three readings.

9. Record the temperature T_{visc} of the thermometer inside the viscometer.

10. Repeat this process, increasing the temperature by $5°$ increments, until you reach a temperature of $50°$.

7 Evaluation

1. Use a micrometer to calculate the diameter of the other borosilicate glass sphere. Knowing that, use the manual to determine the radius r of the sphere inside the chamber.

2. Using the radius r, calculate the density ρ_2 of the borosilicate glass sphere inside the chamber.

3. Find the viscosity η at room temperature T_{lab} and compare with the standard value.

4. Calculate the viscosity η at different temperatures using the given equation. Note that the density of water ρ_1 changes with respect to temperature change.

5. Plot $ln(\eta)$ vs. $\frac{1}{T}$ where T is in K.

6. Using Arrhenius's Equation, calculate the molar energy required to overcome internal friction and compare it with the real value of the energy barrier $E = 15.9\frac{kJ}{mol}$.

8 Postlab Questions

1. Do you expect the viscosity to change with temperature? Explain in a few sentences.
2. Use dimensional analysis to find the units of η, and define a poiseuille.
3. Calculate the Reynolds number for the sphere and find if it satisfies the conditions of Stokes' Law.
4. What would the difference be if we worked with the smaller sphere of the same material? Explain briefly.

9 Helpful Sites (clickable links)

- Viscosity measurement with the falling ball viscometer.