GAZI UNIVERSITY
ENGINEERING FACULTY
CHEMICAL ENGINEERING DEPARTMENT

CHE392
CHEMICAL ENGINEERING LABORATORY - I

1A. VISCOSITY MEASUREMENTS

Prof. Dr. METİN GÜRÜ
Prof. Dr. AYLA ALTINTEN
Res. Asst. Dr. BİRCE KARAMAN

PURPOSE

- The purpose of this experiment is to determine the viscosities (viscous flow coefficients) of the liquids at the desired temperature by kinematically and dynamically.

VISCOSITY

- In our daily life, it is possible to observe that the fluids such as honey, hard flowing liquid oil etc. flow more slowly than the others.

- **The movement of a fluid can be thought as a slip between adjacent fluid layers. Here, the internal friction between neighboring liquid strata with different velocities, which are interactions with each other, is called viscous flow.**

- **In other words, it is a measure of the internal resistance against the flow of liquid.**

- Let us consider two parallel planar layers with a surface area S of a very small (molecular order) distance apart in a real fluid (Figure 1).

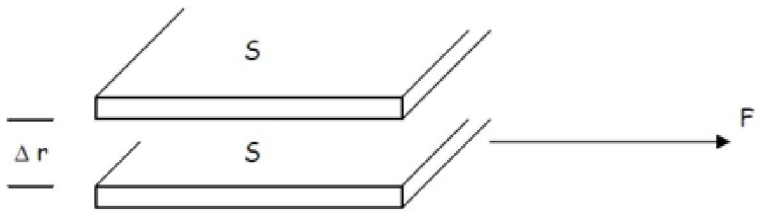


Figure 1

- Experiments have shown that the resistance force of a liquid layer to the unit surface is proportional to the rate of change between the layers. So;

$$F / S = \eta \, \Delta v / \Delta r \qquad (1)$$

where η is the viscous flow coefficient and its value is dependent on the type of liquid.

UNIT OF VISCOSITY

- In SCI unit, unit of viscosity is Pa.s
- Pa.s (pascal.second); $kg.m^{-1}s^{-1}$ or $N.s.m^{-2}$
- In CGS units, unit of viscosity is poise (g cm s)
  - **1 poise = 0,1 Pa.s**

    1cP (centi poise) =1mPa s(mili Pa s)

    1 poise = 100 centipoise = 1 g/(cm·s) = 0.1 Pa·s.
- Viscosity of water at 20 ^{o}C is 1.0020 cP, approximetrly 1 cP.
- When temperature increase from 0 ^{o}C to 100 ^{o}C, the viscosity of water decrease from 1.79 cP to 0.28 cP

TYPE of VISCOSITY

- **Absolute (Dinamic Viskozite):** It is the distance in cm traveled by a mass of 1 gram of flowing liquid in 1 second. The mathematical expression of absolute viscosity is 1 g / (cm.s) according to CGS system. The unit of absolute viscosity is “Poise”. Generally, centipoise (cP), which is equal to 1/100 of Poise, is used.

- **Kinematic Viscosity:** It is obtained by dividing absolute viscosity by specific gravity. Kinematic viscosity of a fluid having an absolute viscosity of 1 g / (cm.s) and a specific weight of 1 g / cm^3;

$$\gamma = \frac{\frac{1g}{cm.s}}{\frac{1\,g}{cm^3}} = \frac{cm^2}{s}$$

The unit of kinematic viscosity is “Stokes”.

Effects of Temperature and Pressure on the Viscosity of Liquids

- **The viscosity of liquids decreases with increasing temperature.** According to the Hole theory, there are voids in a fluid and molecules constantly move into the voids. This event allows flow, but transporting a molecule into a void requires energy which is an activation energy. At higher temperatures, as the activation energy is more easily available, the liquid flows easier as the temperature rises.

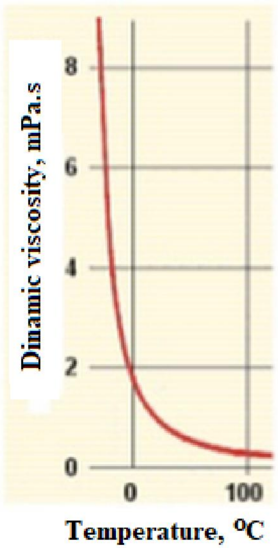
- On the other hand, **with the increasing pressure, the viscosity of a liquid decreases** because increasing the pressure decreases the number of voids in the liquid, and consequently the movement of the molecules becomes difficult.

Effect of Temperature on the Viscosity of Liquids

- Kinematic viscosity values of water measured at different temperatures can be given as an example of the effect of temperature on the viscosity of liquids.

- As seen in the table below, the kinematic viscosity of water at 0 °C is 1.31 cSt, while the kinematic viscosity of water at 50 °C is 0.661 cSt. As a result, viscosity is decreased with increasing temperature.

Temperature, °C	Kinematic Viscosity, cSt
0	1.79
10	1.31
20	1.01
30	0.804
40	0.661
50	0.556
60	0.477



Effects of Temperature and Pressure on the Viscosity of Gases

- The viscosity expression of the gases is given below..

$$\eta = \frac{(m\,k\,T)^{1/2}}{\pi^{3/2}\,d^2} \qquad (2)$$

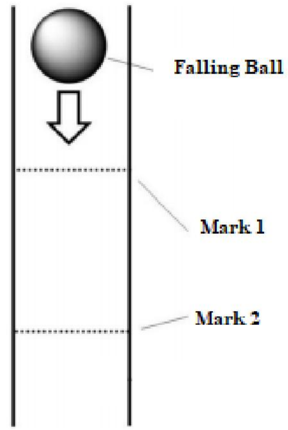
- According to this statement, the viscosity of a gas depends on the molecular diameter (d), the molar mass (m) and the temperature (T). **Viscosity is not affected by gas density and pressure. However, viscosity increases under very high pressure.**

- It is seen from the equation that the viscosity increases with the square root of the temperature. Therefore, the **viscosity increases as the temperature increases.** As the temperature rises, more molecules pass from one layer to the neighboring layer, thereby increasing friction and viscosity between layers.

EXPERIMENTAL PROCEDURE

Viscosity Evaluation with Terminal Velocity Method

- 3 identical steel or lead balls are taken for each diameter (at least 3 different diameter) and their diameter is measured with micrometer.
- Glycerol is filled into the glass cylinder. The height between top and bottom points is measured.
- A ball is taken and released slowly to the liquid surface. When it reaches to top point (Mark 1), chronometer is started and when it reaches to bottom point (Mark 2), chronometer is stopped.
- The elapsed time is recorded.
- This step is repeated for each balls. All elapsed time data is recorded.
- Using the t value and V = h / t equation, the limit speed (V) value is determined.
- The viscous flow coefficient of the glycerol is calculated.



Terminal Velocity Method
(Falling ball method)

Viscosity Evaluation with Terminal Velocity Method

$$\eta = 2gr^2(d' - d)/9v \qquad (3)$$

η: viscosity, g: gravity, r: radius of ball, d': density of balls, d: density of liquid, v: speed

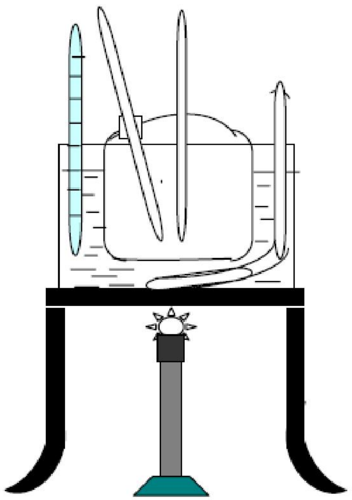
The force that occurs on the surfaces during the movement of the solid ball in the liquid and prevents the movement of the liquid is called the resistance force. This force depends on the following factors.

- Dimensions of ball
- Shape of ball
- Speed of ball in liquid
- Density of liquid
- Viscosity of liquid

EXPERIMENTAL PROCEDURE

Viscosity Evaluation with Engler Viscosimetry

- The container is filled with that water to the marked points.
- The collecting container is placed below the flow hole so that the liquid can not penetrate the edges.
- The plug is pulled and the elapsed time for the flow of 50 ml water is measured by pressing the chronometer.
- Then, water is removed, and the container is filled with oil.
- Previous steps are repeated at 3 different temperatures (25°C, 37°C, 52°C) and 3 times for each temperature.
- All elapsed time data are recorded.



Engler Viscosity

$$\text{Viscosity at T (°C)} = \frac{\text{The flow time (sec) of the liquid at T (°C)}}{\text{The flow time (sec) of the water at 20 °C}} \quad (4)$$

DATA SHEET

Table 1. Viscosity Determination Data of Engler Viscosity Method

Type of liquid	Temperature (°C)	1st Measurement (s)	2nd Measurement (s)	3rd Measurement (s)
WATER	20	10.69	10.57	10.32
OIL	25	96.54	96.13	96.50
	37	54.91	52.84	54.44
	52	33.96	32.91	32.16

Table 2. Viscosity Determination Data of Terminal Velocity Method

Diameter (m)	Height (m)	Time (s)	Density (kg/m^3)	Velocity (m/s)	Viscosity (kg/m.s)
0.0051	0.113	1.87			
0.0056	0.113	1.55			
0.0060	0.113	1.35			

CALCULATIONS

- Calculate the viscosity of the glycerin using the experimental data of terminal velocity method.

- Calculate the viscosity of the oil using the experimental data of Engler viscosity method.

Also give detail information about results.

- Explain both of viscosity data (terminal velocity method and Engler viscosity method) comparing with literature.