Lab 5
Viscosity

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Introduction

Viscosity: is an expression of the resistance to flow of a system under an applied stress. The more viscous a liquid ,the greater the applied force is required to make it flow at a particular rate.

This lab is concerned with the flow properties of dilute colloidal systems and the manner in which viscosity data can be used to obtain the molecular weight of materials comprising the disperse phase. Viscosity studies also provide information regarding the shape of the particles in solution.

Materials classify according to the type of flow and deformation into:

1. **Newtonian.**
   - Examples of Newtonian system: water or any simple liquid (gelatin solution, olive oil, glycerin, castor oil, chloroform and ethyl alcohol).

2. **Non Newtonian**
   - Examples of Non Newtonian system: complex liquid or systems which contain polymers (colloidal solution, emulsion, liquid suspension and ointments).

The classification depends on whether or not their flow properties are according to the Newton's law of flow.

Einstein equation

$$\boldsymbol{\eta = \eta_0(1 + 2.5\,\phi)} \ldots\ldots\ldots\ldots\ldots (\mathbf{1})$$

η :is the viscosity of the dispersion.

η_0 :is the viscosity of the dispersed medium

ϕ :is the volume fraction of colloidal particles.

The volume fraction is defined as the volume of the particles divided by the total volume of the dispersion. It is therefore equivalent to concentration term.

$$\boldsymbol{\phi = \frac{volume\ of\ particles}{total\ volume\ of\ dispersion}}$$

Several viscosity coefficients may be defined with respect to this equation. These include relative viscosity($\boldsymbol{\eta_{rel}}$), specific viscosity($\boldsymbol{\eta_{sp}}$), intrinsic viscosity($\boldsymbol{\eta_{int}}$) and reduced viscosity($\boldsymbol{\eta_{red}}$)

$$\boldsymbol{\eta = \eta_0(1 + 2.5\,\phi)} \dots\dots\dots\dots\dots(1)$$

divided by $\boldsymbol{\eta_0}$

$$\boldsymbol{\frac{\eta}{\eta_0} = 1 + 2.5\,\phi} \dots\dots\dots\dots\dots(2)$$

$$\boldsymbol{\eta_{rel} = \frac{\eta}{\eta_0}}$$

$$\boldsymbol{\frac{\eta}{\eta_0} - 1 = 2.5\,\phi} \dots\dots\dots\dots\dots(3)$$

And $\boldsymbol{\eta_{sp} = \frac{\eta}{\eta_0} - 1}$

$$\boldsymbol{\frac{\eta_{sp}}{\phi} = 2.5} \dots\dots\dots\dots\dots(4)$$

Since the volume fraction is directly related to concentration.

$$\boldsymbol{\eta_{red} = \frac{\eta_{sp}}{c}} \dots\dots\dots\dots\dots(5)$$

$\eta_{red} = reduced\ viscosity$

Where C the concentration is expressed in gram of colloidal particles per 100ml of total dispersion

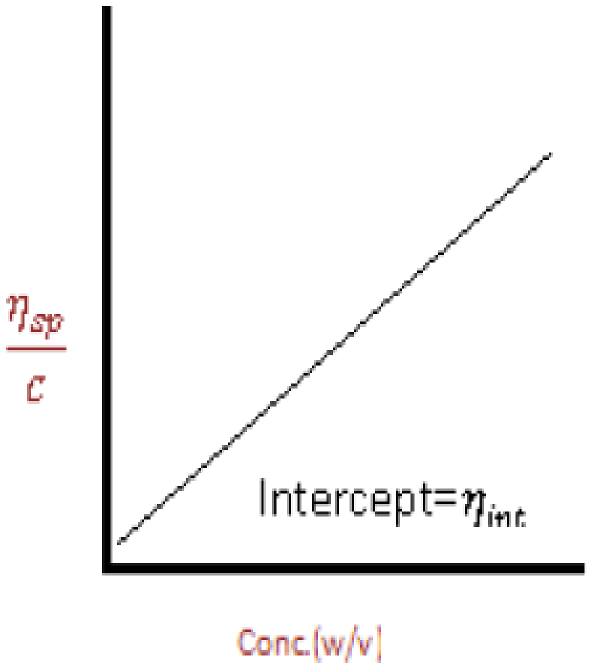
If $\frac{\eta_{sp}}{c}$ is plotted against conc. and take the line extrapolated to infinite dilution, the intercept is known as the intrinsic viscosity(η_{int}) is used to calculate the approximate molecular weights of polymers. According to Kuhn-Houwink equation:

$$\boldsymbol{\eta_{int} = K\, M^{\alpha}}$$

Where K and α are constant of the particular polymer- solvent system.

M = molecular weight.

$K=1.7 * 10^{-5}$ $\alpha=1$



$$\eta_{rel} = \frac{\eta}{\eta_0}$$

we have to divide by η_w (viscosity of water)whatever the medium

η_w viscosity of water is equal to **1 cp.**

$$\text{relative viscosity}(\eta_{rel}) = \frac{\eta}{\eta_w}$$

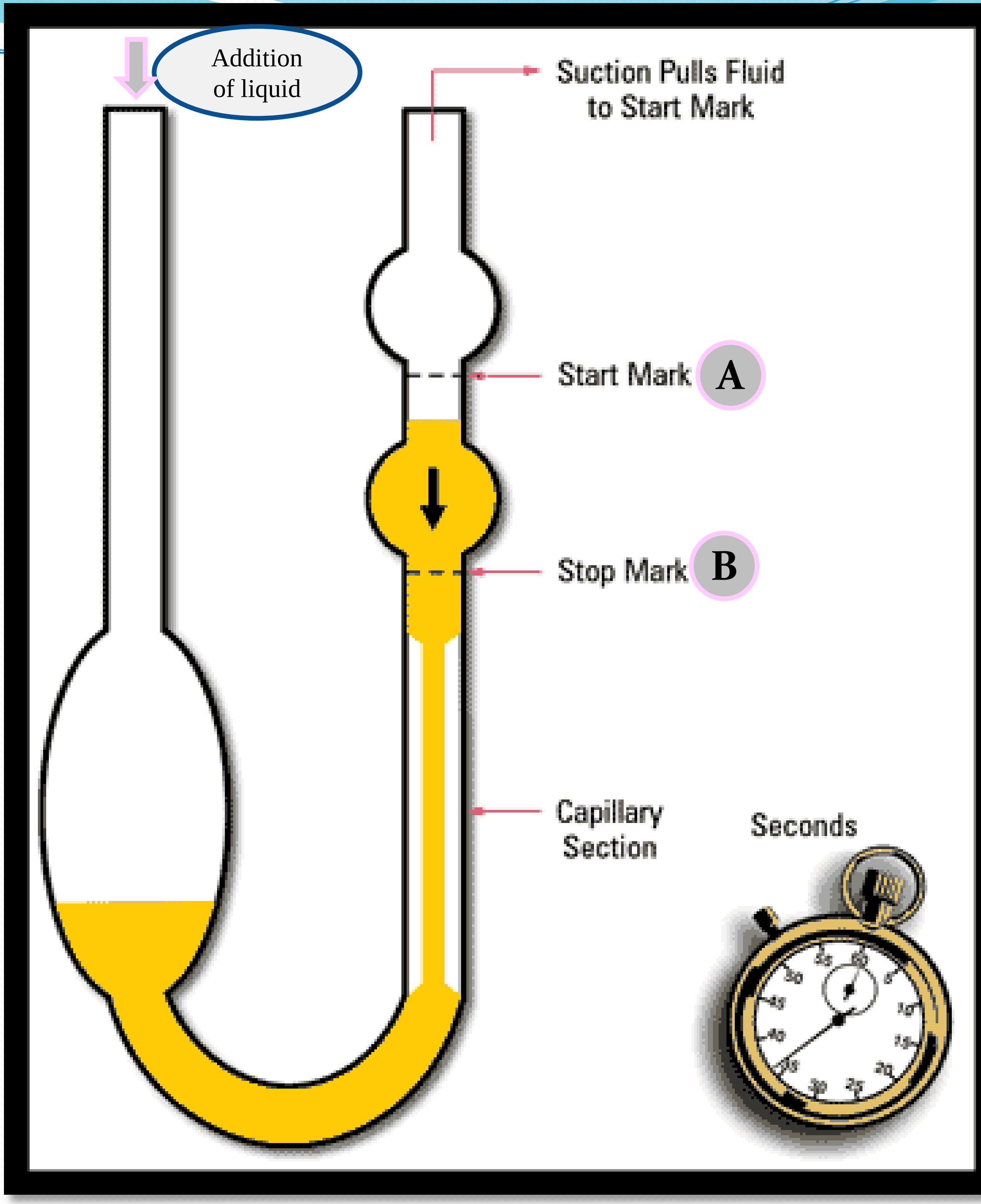
$$\text{specific viscosity}(\eta_{sp}) = \eta_{rel} - 1$$

$$\text{reduced viscosity}(\eta_{red}) = \frac{\eta_{sp}}{c}$$

* C mean concentration in g/100ml

$$\text{intrinsic viscosity}(\eta_{int}) = K\ M^{\alpha}$$

Capillary viscometer: Both $\eta_0 and\, \eta$ may determine using a capillary viscometer. The viscosity of a Newtonian liquid may be determined by measuring the time required for the liquid to pass between two marks as it flows by gravity through a vertical capillary tube, known as Ostawald viscometer. The time of flow of the liquid under test is compared with the time for a liquid of known viscosity (usually water) to pass between the two marks (A---B).



the absolute viscosity of the unknown liquid, η_1 is determined by substituting the experimental values in the equation:

$$\frac{\eta_1}{\eta_2} = \frac{p_1}{p_2}\frac{t_1}{t_2}$$

η_1 = viscosity of the unknown liquid (cp)

η_2 = viscosity of water =1cp

$p_{1=}$ density of the unknown liquid

p_2 =density of water =1

$t_{1=}$ flow time in seconds for unknown liquid

$t_{2=}$ flow time in seconds for water

Units of viscosity

Poise and centipoise

1 cp= 0.01 poise

Experimental work

Part I: bring water, glycerin, 1% gelatin solution and prepare volumetric flask (50cc), pipette, capillary viscometer (suspended level viscometer).

Part ll:

: To determine the concentration of unknown.

Procedure:

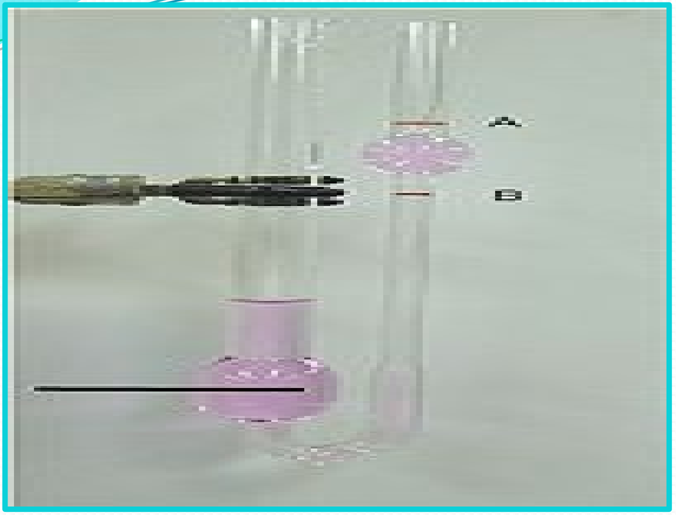
1) *Prepare different concentrations w/w of glycerin in water 2%, 5%, 10%, 15%, 20% and 25% (50 ml of each one).*

2) Measure the η of these solutions by the viscometer knowing the density of each solution 1.003, 1.005, 1.018, 1.03, 1.037, 1.044 respectively. Then find ηrel and draw curve by plotting ηrel against conc. (w/w).

3) Find out the concentration of unknown from the curve by measuring its ηrel of unknown.

4) The line started from 1 since the viscosity of water is equal to 1 cp. The density of glycerine is 1.26 and water = 1.

Calculation



Conc	Density of sol.	$\eta 1$	η_{rel}
2%	*1.003*		
5%	*1.005*		
10%	*1.018*		
15%	*1.03*		
20%	*1.037*		
25%	*1.044*		

viscosity of water is equal to 1cp
The density of and water = 1.

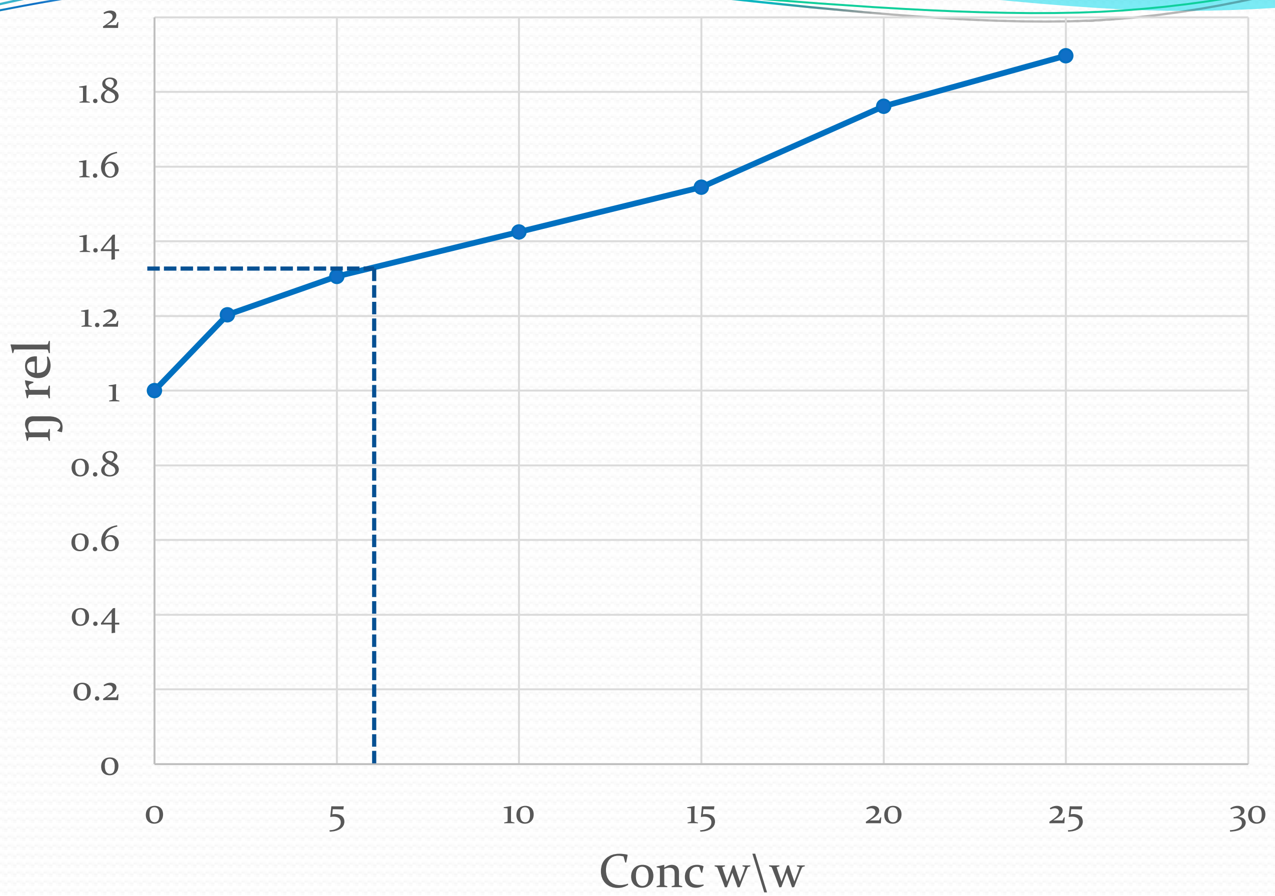
for conc 2% , if the time required for the solution was 6 seconds (t 1) and the time required for the weter was 5 seconds (t 2) ,the calculation will be :

$$\frac{\eta_1}{\eta_2} = \frac{p_1}{p_2}\frac{t_1}{t_2}$$

η_1 , P1 , t1 for the solution
η_2, P2 , t2 for water

$$\frac{\eta_1}{1} = \frac{1.003*6}{1*5}$$

η_1 =1.203 cp
$\boldsymbol{\eta_{rel}}$=η_1 \ $\boldsymbol{\eta_w}$= 1.203/1 = 1.203
* the same calculation for other concentration



Calculate the unknown concentration for solution if you know the relative viscosity of unknown conc was 1.35 ?

Part ll:

: To find the molecular weight of gelatine

Procedure:

1. *Prepare 50ml different concentration of gelatine (w/v) 0.2%, 0.4%, 0.6%, 0.8% from 1% (w/v) gelatine stock solution.*

2. *Find the η and ηrel of each solution by using capillary viscometer knowing that the density of each solution are 1.05, 1.08, 1.11, 1.2 respectively. Then find ηsp which is equal to (ηrel -1)*

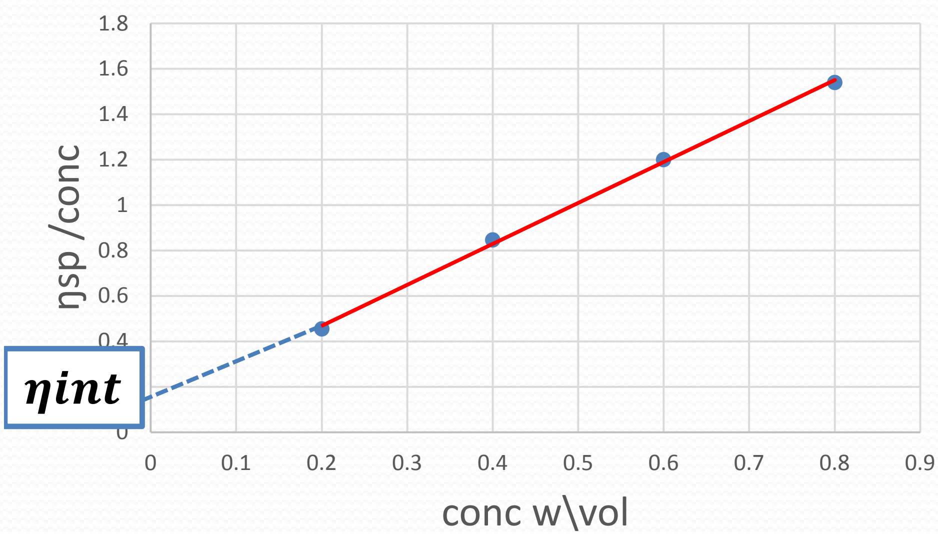
3. *Plot $\boldsymbol{\eta_{red}}$ (ηsp / concentration) versus concentration (w/v) the resulted line is then extrapolated to infinite dilution to find the intrinsic viscosity which is equal to intercept of line with y axis.*

4. *Find the molecular weight of gelatine from the equation*

$(\boldsymbol{\eta_{int}}) = \boldsymbol{K\ M^{\alpha}}$, K=1.7 *10-5 α =1.

Calculation

Conc	p1	t1(sec)	t2(sec) water	$\eta 1$	ηrel	ηsp (ηrel -1)	ηsp /conc
0.2	1.05		5				
0.4	1.08		5				
0.6	1.11		5				
0.8	1.2		5				



For 0.2% t1=5.5 seconds

$$\frac{\eta_1}{1} = \frac{1.05*5.5}{1*5}$$

η_1 =1.071 cp

$\boldsymbol{\eta_{rel}} = \eta_1 \backslash \boldsymbol{\eta_w}$

=1.071\1 =1.071

ηsp = (ηrel -1)

= (1.071-1)=0.071

$\boldsymbol{\eta_{red}} = \eta sp$ /conc

= 0.071\0.2 = 0.355

Intercept = $(\boldsymbol{\eta_{int}}) = \boldsymbol{K\ M^{\alpha}}$

Thank you for listening