**C02: To determine the viscosity average molecular weight of a polymer(VLab)**

**Batch: C4-1 Date: 9/11/23**

**Roll no: 16010123217**

**Name: Om Thanage**

**Experiment No.**

**Title: Viscosity Average Molecular Weight of Polymer**

**Aim:** To determine Viscosity Average Molecular Weight of Polymer

**Theory:**

Viscosity is an internal property of a fluid that offers resistance to flow. It is due to the internal friction of molecules and mainly depends on the nature & temperature of the liquid.

Many methods are available for measuring viscosity of polymer solution. The Ostwald method is a simple method for the measurement of viscosity, in which viscosity of liquid is measured by comparing the viscosity of an unknown liquid with that of liquid whose viscosity is known. In this method viscosity of liquid is measured by comparing the flow times of two liquids of equal volumes using same viscometer.

Consider two liquids are passing through a capillary of same viscometer. Then the coefficient of viscosity of liquid (η2) is given by equation

https://vlab.amrita.edu/userfiles/1/image002%286%29.png

Here*t1* and*t2* are the time of flow of the liquids and*ρ1* and *ρ2* are the respective densities. And *η1* is the coefficient of viscosity of water.

For a given liquid *η* has a specific value at the same temperature.

Various mixtures of two non-interacting liquids viscosities will lie among the viscosities of those pure components.

The time of flow of liquid depends on the viscosity and composition. In this method the flow times are measured for different known compositions and a graph is plot for time of flow and compositions. The unknown composition can be determined by plotting a graph for the time of flow and compositions.

The molecular weight of the polymer is measured by using viscometer and the molecular weight obtained by this technique is called viscosity average molecular weight. The molecular weight of the polymer solution is very high so the viscosity of polymer solution is very high compared to that of pure solvent.

From the Mark-Houwink equation the relationship among the molecular weight and viscosity are given below

«math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«mfenced close=¨]¨ open=¨[¨»«mi»§#951;«/mi»«/mfenced»«mo»=«/mo»«mi»K«/mi»«msup»«mi»M«/mi»«mi»§#945;«/mi»«/msup»«/math»

Where«math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«mfenced close=¨]¨ open=¨[¨»«mi»§#951;«/mi»«/mfenced»«/math» is the intrinsic viscosity , «math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«mi»M«/mi»«/math» is Molecular weight, *«math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«mi»K«/mi»«/math»* and «math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«mi»§#945;«/mi»«/math» are constants for a particular polymer solvent  system.

If we know the *«math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«mi»K«/mi»«/math»*and «math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«mi»§#945;«/mi»«/math»values for a given polymer solution the intrinsic viscosity and molecular weight can be calculate using the above equation.

| **Polymer-solvent system** | **K x 103mL/g** | **«math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«mi»§#945;«/mi»«/math»** |
| --- | --- | --- |
| PMMA-Acetone | 7.70 | 0.70 |
| PMMA-Benzene | 5.20 | 0.76 |
| PMMA-Toluene | 7.0 | 0.71 |
| Poly vinyl acetate-Acetone | 10.2 | 0.72 |
| Poly vinyl acetate-Benzene | 56.3 | 0.62 |
| Poly vinyl acetate-Acetonitrile | 41.5 | 0.62 |
| Poly vinyl alcohol-Water | 45.3 | 0.64 |
| Poly styrene-Benzene | 10.6 | 0.735 |
| Poly styrene-Toluene | 11.0 | 0.725 |

**Terms Related to Viscosity Measurements:-**

Relative Viscosity**= «math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«mfrac»«mi»§#951;«/mi»«msub»«mi»§#951;«/mi»«mn»0«/mn»«/msub»«/mfrac»«mo»=«/mo»«mfrac»«mi»t«/mi»«msub»«mi»t«/mi»«mn»0«/mn»«/msub»«/mfrac»«mo»=«/mo»«msub»«mi»§#951;«/mi»«mi»r«/mi»«/msub»«/math»**

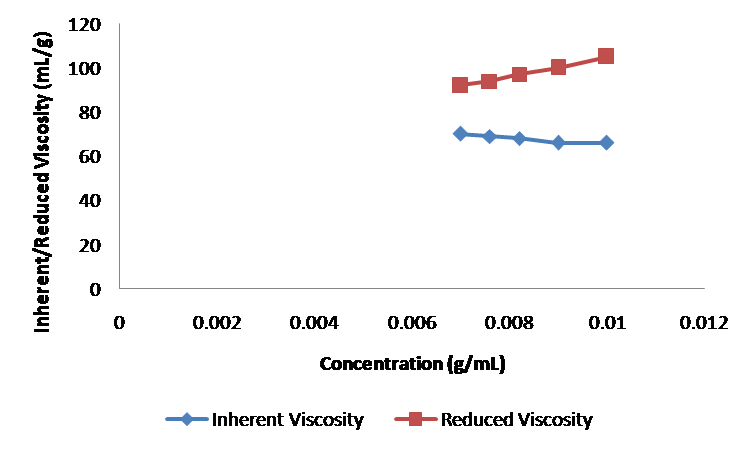
Specific Viscosity **=«math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«mfrac»«mrow»«mi»§#951;«/mi»«mo»-«/mo»«msub»«mi»§#951;«/mi»«mn»0«/mn»«/msub»«/mrow»«msub»«mi»§#951;«/mi»«mn»0«/mn»«/msub»«/mfrac»«mo»=«/mo»«mfrac»«mrow»«mi»t«/mi»«mo»-«/mo»«msub»«mi»t«/mi»«mn»0«/mn»«/msub»«/mrow»«msub»«mi»t«/mi»«mn»0«/mn»«/msub»«/mfrac»«mo»=«/mo»«msub»«mi»§#951;«/mi»«mi»r«/mi»«/msub»«mo»-«/mo»«mn»1«/mn»«mo»=«/mo»«msub»«mi»§#951;«/mi»«mrow»«mi»s«/mi»«mi»p«/mi»«/mrow»«/msub»«/math»**

Reduced Viscosity =**«math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«mfrac»«msub»«mi»§#951;«/mi»«mrow»«mi»s«/mi»«mi»p«/mi»«/mrow»«/msub»«mi»C«/mi»«/mfrac»«mo»=«/mo»«msub»«mi»§#951;«/mi»«mrow»«mi»r«/mi»«mi»e«/mi»«mi»d«/mi»«/mrow»«/msub»«/math»**

Inherent Viscosity =**«math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«mfrac»«mrow»«mi mathvariant=¨normal¨»ln«/mi»«mo»§nbsp;«/mo»«msub»«mi»§#951;«/mi»«mi»r«/mi»«/msub»«/mrow»«mi»C«/mi»«/mfrac»«mo»=«/mo»«msub»«mi»§#951;«/mi»«mrow»«mi»i«/mi»«mi»n«/mi»«mi»h«/mi»«/mrow»«/msub»«/math»**

Intrinsic Viscosity**= «math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«msub»«mfenced»«mfrac»«msub»«mi»§#951;«/mi»«mrow»«mi»s«/mi»«mi»p«/mi»«/mrow»«/msub»«mi»C«/mi»«/mfrac»«/mfenced»«mrow»«mi»C«/mi»«mo»§#8594;«/mo»«mn»0«/mn»«/mrow»«/msub»«mo»=«/mo»«msub»«mfenced»«mfrac»«mrow»«mi mathvariant=¨normal¨»ln«/mi»«mo»§nbsp;«/mo»«msub»«mi»§#951;«/mi»«mi»r«/mi»«/msub»«/mrow»«mi»C«/mi»«/mfrac»«/mfenced»«mrow»«mi»C«/mi»«mo»§#8594;«/mo»«mn»0«/mn»«/mrow»«/msub»«mo»=«/mo»«mfenced close=¨]¨ open=¨[¨»«mi»§#951;«/mi»«/mfenced»«/math»**

 For measuring intrinsic viscosity of polymer sample, solutions of known concentrations are prepared, the flow times of solvent («math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«msub»«mi»t«/mi»«mn»0«/mn»«/msub»«/math») and the solutions («math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«mi»t«/mi»«/math») are measured using viscometer. Double extrapolation plots of reduced viscosity against concentration and inherent viscosity against concentration is plotted by calculating the corresponding reduced viscosity and inherent viscosity. The intrinsic viscosity is given by the common ordinate intercept of these graphs.





**Procedure:**

## Materials Required:

1. Ostwald Viscometer
2. Stop Watch
3. Sucker
4. Pipette

## 

## Reagents:

#### 

#### Solvents:

1. Acetonitrile
2. Acetone
3. Water
4. Toluene
5. Benzene

#### Polymer:

1. Polyvinyl acetate
2. PMMA
3. Polymer Alcohol
4. Polystyrene

## 

### Determining the Intrinsic Viscosity of the Polymer- solvent system:

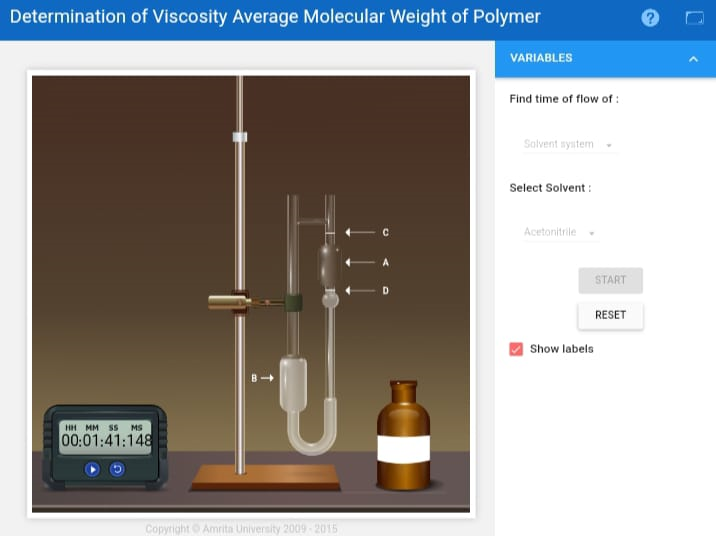
1. Select the Polymer.
2. Select the Solvent.
3. Determine the Time of flow of the solvent (t0).
4. Determine the time of flow of polymer-solvent system at different concentrations.
5. From the concentration and time of flow, the inherent viscosity and reduced viscosity are calculated using the equations;                                  Inherent Viscosity = «math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«mfrac»«mrow»«mi mathvariant=¨normal¨»ln«/mi»«mo»§nbsp;«/mo»«msub»«mi»§#951;«/mi»«mi»r«/mi»«/msub»«/mrow»«mi»C«/mi»«/mfrac»«mo»=«/mo»«msub»«mi»§#951;«/mi»«mrow»«mi»i«/mi»«mi»n«/mi»«mi»h«/mi»«/mrow»«/msub»«/math»    ,        Reduced Viscosity = «math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«mfrac»«msub»«mi»§#951;«/mi»«mrow»«mi»s«/mi»«mi»p«/mi»«/mrow»«/msub»«mi»C«/mi»«/mfrac»«mo»=«/mo»«msub»«mi»§#951;«/mi»«mrow»«mi»r«/mi»«mi»e«/mi»«mi»d«/mi»«/mrow»«/msub»«/math»
6. A graph is drawn by plotting reduced viscosity against concentration and inherent viscosity against concentration.
7. Intrinsic viscosity can be obtained by extrapolating the graph to zero concentration.
8. From the value of intrinsic viscosity, the viscosity average molecular weight of the polymer can be calculated by using the equation.

«math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«mfenced close=¨]¨ open=¨[¨»«mi»§#951;«/mi»«/mfenced»«mo»=«/mo»«mi»K«/mi»«msup»«mi»M«/mi»«mi»§#945;«/mi»«/msup»«/math»

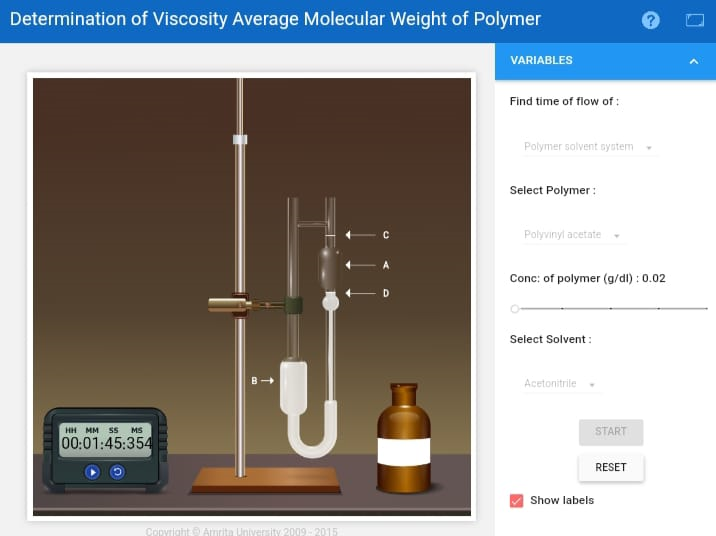
**Observation:**

**(Include screenshot/s for solvent and different concentration reading/s)**

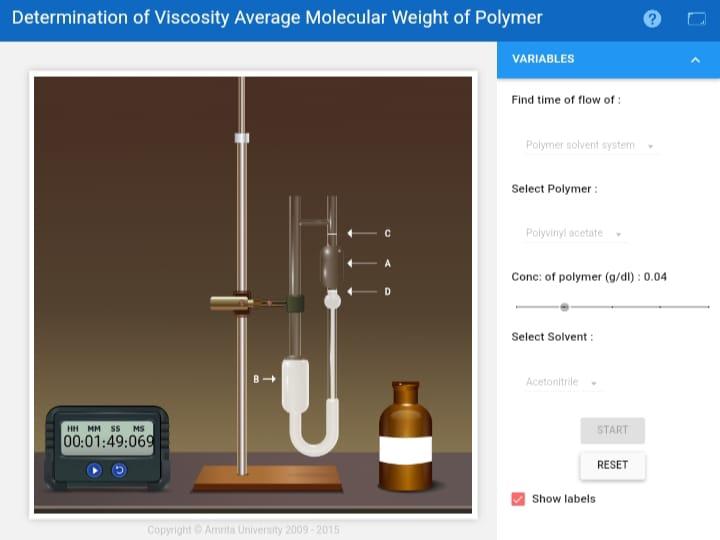
**1) Solvent**



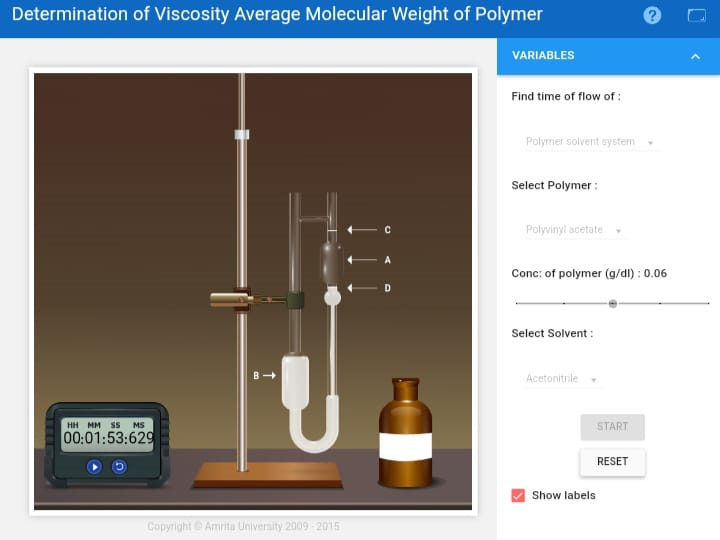
**2) Polymer at 0.02 concentration**



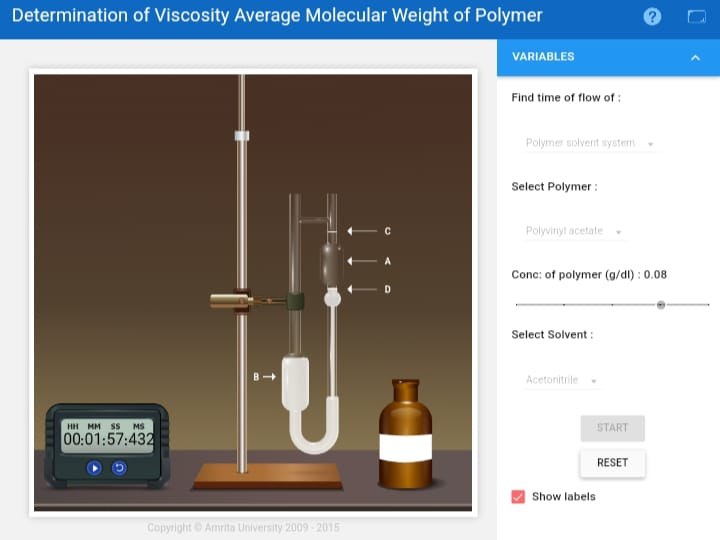
**3) Polymer at 0.04 concentration**



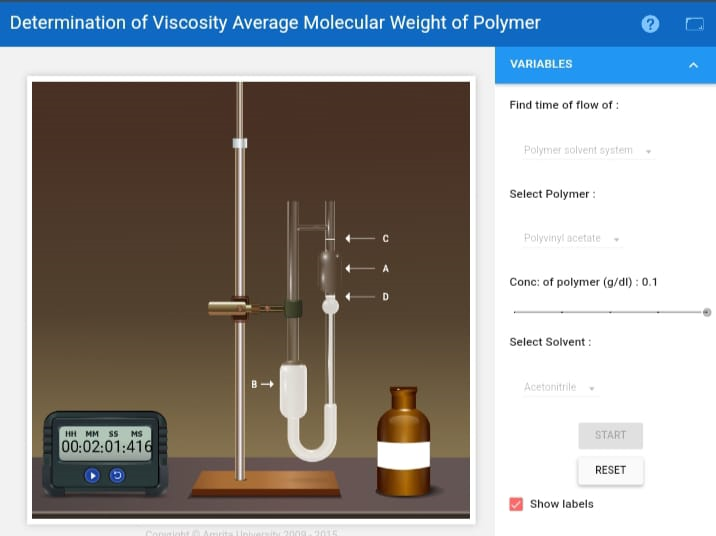
**4) Polymer at 0.06 concentration**



**5) Polymer at 0.08 concentration**



**6) Polymer at 0.1 concentration**



|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Conc:**  **(g/dl)** | **Flow Time of Polymer-Solvent system**  **(t) sec** | **Flow Time of Solvent**  **(t0) sec** | **«math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«msub»«mi»§#951;«/mi»«mi»r«/mi»«/msub»«mo»=«/mo»«mfrac»«mi»t«/mi»«msub»«mi»t«/mi»«mn»0«/mn»«/msub»«/mfrac»«/math»** | **«math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«msub»«mi»§#951;«/mi»«mrow»«mi»s«/mi»«mi»p«/mi»«/mrow»«/msub»«mo»=«/mo»«msub»«mi»§#951;«/mi»«mi»r«/mi»«/msub»«mo»-«/mo»«mn»1«/mn»«/math»** | **Reduced Viscosity,**  **«math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«msub»«mi»§#951;«/mi»«mrow»«mi»r«/mi»«mi»e«/mi»«mi»d«/mi»«/mrow»«/msub»«mo»=«/mo»«mfrac»«msub»«mi»§#951;«/mi»«mrow»«mi»s«/mi»«mi»p«/mi»«/mrow»«/msub»«mi»C«/mi»«/mfrac»«mo»§nbsp;«/mo»«mo»(«/mo»«mi»d«/mi»«mi»l«/mi»«mo»/«/mo»«mi»g«/mi»«mo»)«/mo»«/math»** | **«math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«mi mathvariant=¨normal¨»ln«/mi»«mo»§nbsp;«/mo»«msub»«mi»§#951;«/mi»«mi»r«/mi»«/msub»«/math»** | **Inherent Viscosity,** |
| 0.02 | 105.354 | 101.148 | 1.041583 | 0.041582631 | 2.07913157 | 0.04074132 | 2.03706587 |
| 0.04 | 109.469 | 101.148 | 1.082266 | 0.082265591 | 2.056639775 | 0.07905661 | 1.976415334 |
| 0.06 | 113.529 | 101.148 | 1.122405 | 0.122404793 | 2.040079883 | 0.11547352 | 1.924558668 |
| 0.08 | 117.432 | 101.148 | 1.160992 | 0.160991814 | 2.012397675 | 0.14927465 | 1.865933148 |
| 0.1 | 121.376 | 101.148 | 1.199984 | 0.199984182 | 1.999841816 | 0.18230837 | 1.823083747 |

**Calculation:**

**(Include formula)**

Formula:

[η] = KMα

Relative Viscosity**= «math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«mfrac»«mi»§#951;«/mi»«msub»«mi»§#951;«/mi»«mn»0«/mn»«/msub»«/mfrac»«mo»=«/mo»«mfrac»«mi»t«/mi»«msub»«mi»t«/mi»«mn»0«/mn»«/msub»«/mfrac»«mo»=«/mo»«msub»«mi»§#951;«/mi»«mi»r«/mi»«/msub»«/math»**

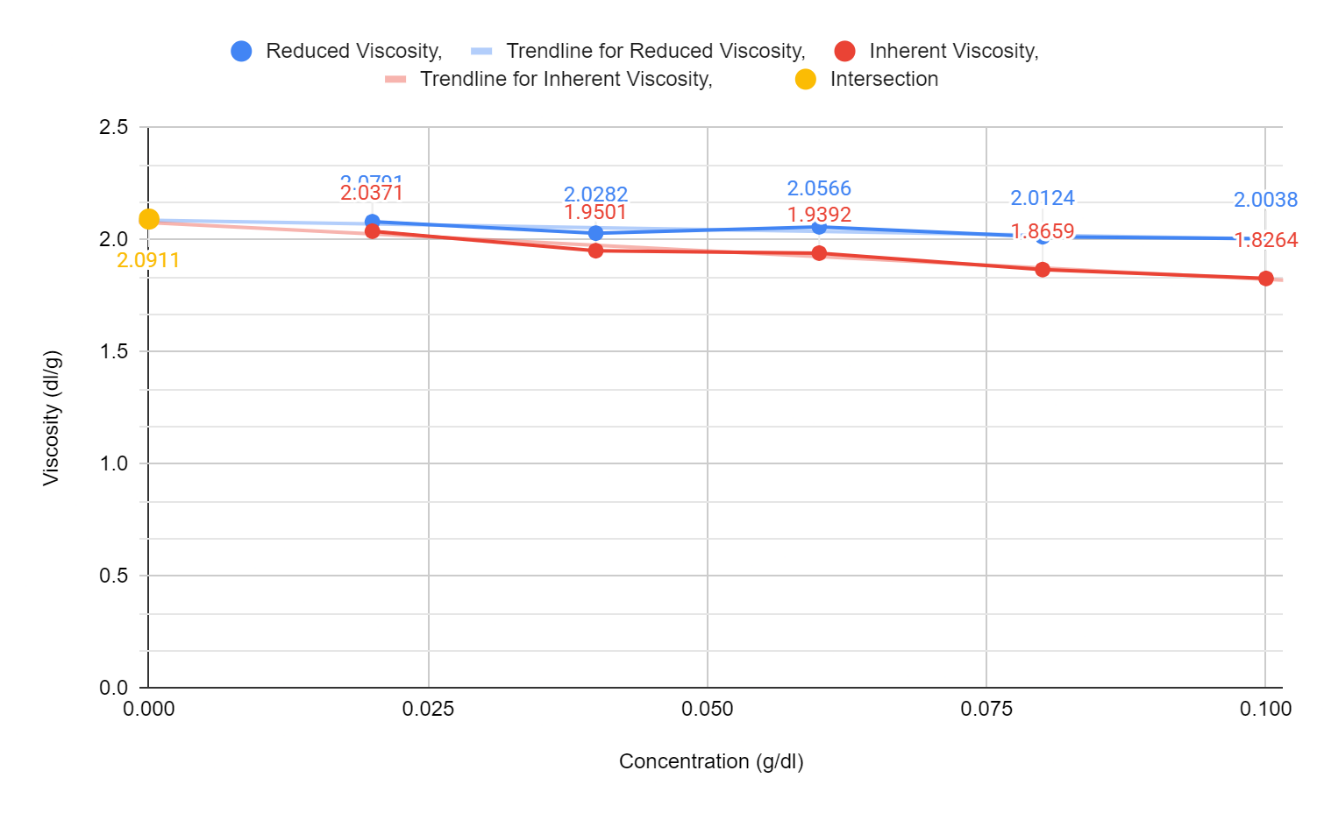
Specific Viscosity **=«math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«mfrac»«mrow»«mi»§#951;«/mi»«mo»-«/mo»«msub»«mi»§#951;«/mi»«mn»0«/mn»«/msub»«/mrow»«msub»«mi»§#951;«/mi»«mn»0«/mn»«/msub»«/mfrac»«mo»=«/mo»«mfrac»«mrow»«mi»t«/mi»«mo»-«/mo»«msub»«mi»t«/mi»«mn»0«/mn»«/msub»«/mrow»«msub»«mi»t«/mi»«mn»0«/mn»«/msub»«/mfrac»«mo»=«/mo»«msub»«mi»§#951;«/mi»«mi»r«/mi»«/msub»«mo»-«/mo»«mn»1«/mn»«mo»=«/mo»«msub»«mi»§#951;«/mi»«mrow»«mi»s«/mi»«mi»p«/mi»«/mrow»«/msub»«/math»**

Reduced Viscosity =**«math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«mfrac»«msub»«mi»§#951;«/mi»«mrow»«mi»s«/mi»«mi»p«/mi»«/mrow»«/msub»«mi»C«/mi»«/mfrac»«mo»=«/mo»«msub»«mi»§#951;«/mi»«mrow»«mi»r«/mi»«mi»e«/mi»«mi»d«/mi»«/mrow»«/msub»«/math»**

Inherent Viscosity =**«math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«mfrac»«mrow»«mi mathvariant=¨normal¨»ln«/mi»«mo»§nbsp;«/mo»«msub»«mi»§#951;«/mi»«mi»r«/mi»«/msub»«/mrow»«mi»C«/mi»«/mfrac»«mo»=«/mo»«msub»«mi»§#951;«/mi»«mrow»«mi»i«/mi»«mi»n«/mi»«mi»h«/mi»«/mrow»«/msub»«/math»**

Intrinsic Viscosity**= «math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«msub»«mfenced»«mfrac»«msub»«mi»§#951;«/mi»«mrow»«mi»s«/mi»«mi»p«/mi»«/mrow»«/msub»«mi»C«/mi»«/mfrac»«/mfenced»«mrow»«mi»C«/mi»«mo»§#8594;«/mo»«mn»0«/mn»«/mrow»«/msub»«mo»=«/mo»«msub»«mfenced»«mfrac»«mrow»«mi mathvariant=¨normal¨»ln«/mi»«mo»§nbsp;«/mo»«msub»«mi»§#951;«/mi»«mi»r«/mi»«/msub»«/mrow»«mi»C«/mi»«/mfrac»«/mfenced»«mrow»«mi»C«/mi»«mo»§#8594;«/mo»«mn»0«/mn»«/mrow»«/msub»«mo»=«/mo»«mfenced close=¨]¨ open=¨[¨»«mi»§#951;«/mi»«/mfenced»«/math»**

**Graph**



From the above graph, [η] = 2.09 dl/g

For (polymer- solvent system) Poly vinyl acetate-Acetonitrile , K = 4.15 × 10 -3 ml/g α = 0.62

Substituting these values in the formula, [η] = KMα

We get,

M = antilog [(1/α).(log η – log K)]

M = antilog [(1/0.62).(log(2.0911)-log( )]

M = antilog [(1/0.62).((0.3204) – ( ))]

M = antilog [(1/0.62).( )]

M = antilog( )

M = g/mol

M = g/mol­

**Assignment:**

* 1. Name any 5 compounding agents with an example and their functions in polymers.

Ans. Compounding agents are additives used in polymer processing to improve various properties

of the final polymer product. Five compounding agents in polymers are:

1. Fillers:

 Example: Calcium carbonate, talc, glass fibers

 Function: Fillers are used to enhance the mechanical properties of polymers,

such as tensile strength, stiffness, and impact resistance. They can also reduce

the cost of the polymer by extending it.

2. Plasticizers:

 Example: Diethyl phthalate, dioctyl adipate.

 Function: Plasticizers are used to increase the flexibility and workability of

polymers, making them more pliable and less brittle. They are commonly used

in PVC and other flexible plastics.

3. Stabilizers:

 Example: Hindered amine light stabilizers (HALS), UV absorbers.

 Function: Stabilizers are added to polymers to protect them from the harmful

effects of heat, light, and oxygen. They help prevent degradation and extend

the polymer&#39;s lifespan.

4. Flame Retardants:

 Example: Brominated flame retardants, aluminum trihydrate.

Function: Flame retardants are incorporated into polymers to reduce their

flammability and improve their fire resistance. They help prevent the spread of

flames and smoke generation.

5. Colorants:

 Example: Titanium oxide- white colour, iron oxide-red colour,

 Function: Colorants are used to add colour to polymers for aesthetic purposes.

They are widely used in the production of various plastic products, from toys

to packaging materials.

* 1. List important characteristics of an ideal polymer.

Ans . Characteristics of Ideal Polymer are:

1. They should be inert and compatible with the environment.

2. They should be non-toxic.

3. They should be easily administered

4. They should be easy and inexpensive to fabricate.

5. They should have good mechanical strength.

* 1. Write a note on doped conducting polymers.

Ans. (DCP) – Doped Conducting Polymer

Doping is the addition of a donor or an acceptor molecule to the polymer. The reaction that

take place is redox reaction.

As synthesized conductive polymers exhibit very low conductivity. To make a polymer highly

conductive doping is conducted i.e. an electron is removed from the valence band(p-doping)

or added to the conduction band(n-doping).

Doping generated charge carriers which move in an electric field. Positive charges(holes) and

negative charges(electrons) move to opposite electrodes. The movement of these charges is

what is responsible for electrical conductivity.

1.Oxidation Process or P-Doping

(C 2 H 2 )n + FeCl 3  (C 2 H 2 + )n.FeCl 4 + FeCl 2

Polyacetylene Lewis Acid positively charged

backbone

2.Reduction Process or N-Doping

(C 2 H 2 )n + C 10 H 7 NH 2  [(C 2 H 2 - )n. NH + ] + C 10 H 8

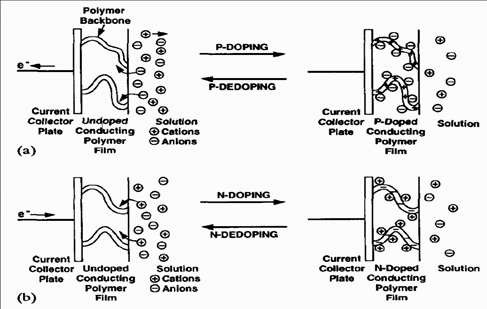
Polyacetylene Naphthylamine negatively charged Naphthalene

backbone

The above reactions are most likely to occur saturated polym electrons, as they can be

very easily removed from the polymeric chains to form polyion therefore, these are the

types of polymers, which assume high conductivity on doping.

Schematic representation of Doping of Conducting Polymers: 

**Result/ Conclusion:**

**The viscosity average molecular weight of the (polymer)** Poly vinyl acetate**\_,**

**‘M’ = \_\_\_\_\_\_\_\_\_\_\_ g/mol**