**Experiment 5: Determination of Viscosity Average Molecular Weight of Polymer**

**NAME: Hiral Patel**

**BRANCH: IT**

**BATCH: G3**

**ROLL NO.: 16010421071**

**Objectives:**

Determine the viscosity average molecular weight of a 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 10-3mL/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»**

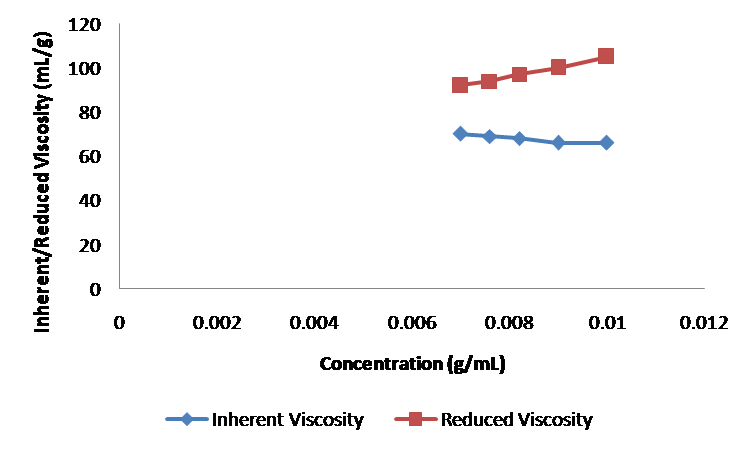
Specific Viscosity **=«math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«mfrac»«mrow»«mi»§#951;«/mi»«mo»-«/mo»«msub»«mi»§#951;«/mi»«mn»0«/mn»«/msub»«/mrow»«msub»«mi»§#951;«/mi»«mn»0«/mn»«/msub»«/mfrac»«mo»=«/mo»«mfrac»«mrow»«mi»t«/mi»«mo»-«/mo»«msub»«mi»t«/mi»«mn»0«/mn»«/msub»«/mrow»«msub»«mi»t«/mi»«mn»0«/mn»«/msub»«/mfrac»«mo»=«/mo»«msub»«mi»§#951;«/mi»«mi»r«/mi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

**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;
6. 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»
7. A graph is drawn by plotting reduced viscosity against concentration and inherent viscosity against concentration.
8. Intrinsic viscosity can be obtained by extrapolating the graph to zero concentration.
9. From the value of intrinsic viscosity, the viscosity average molecular weight of the polymer can be calculated by using the equation.

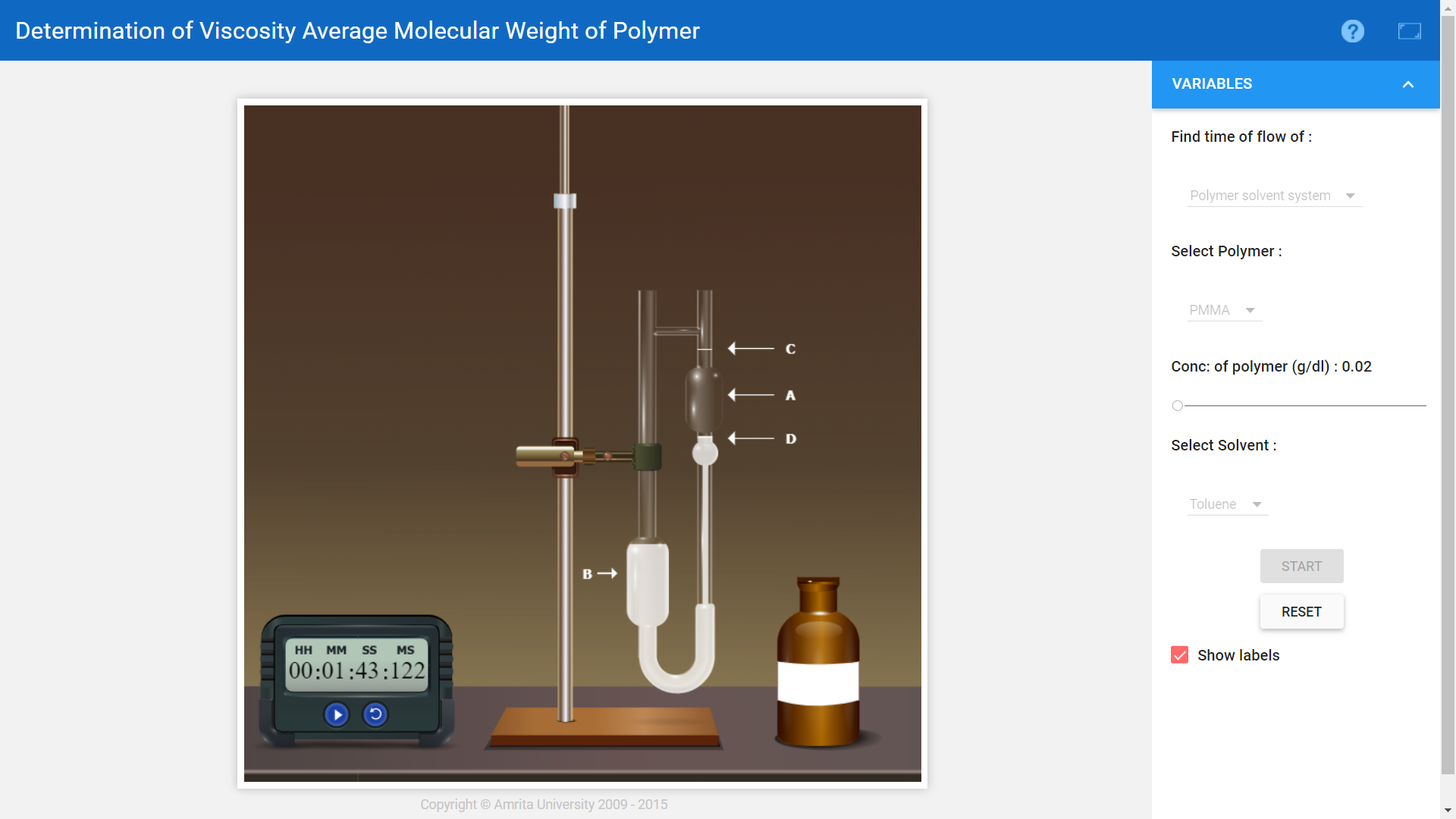
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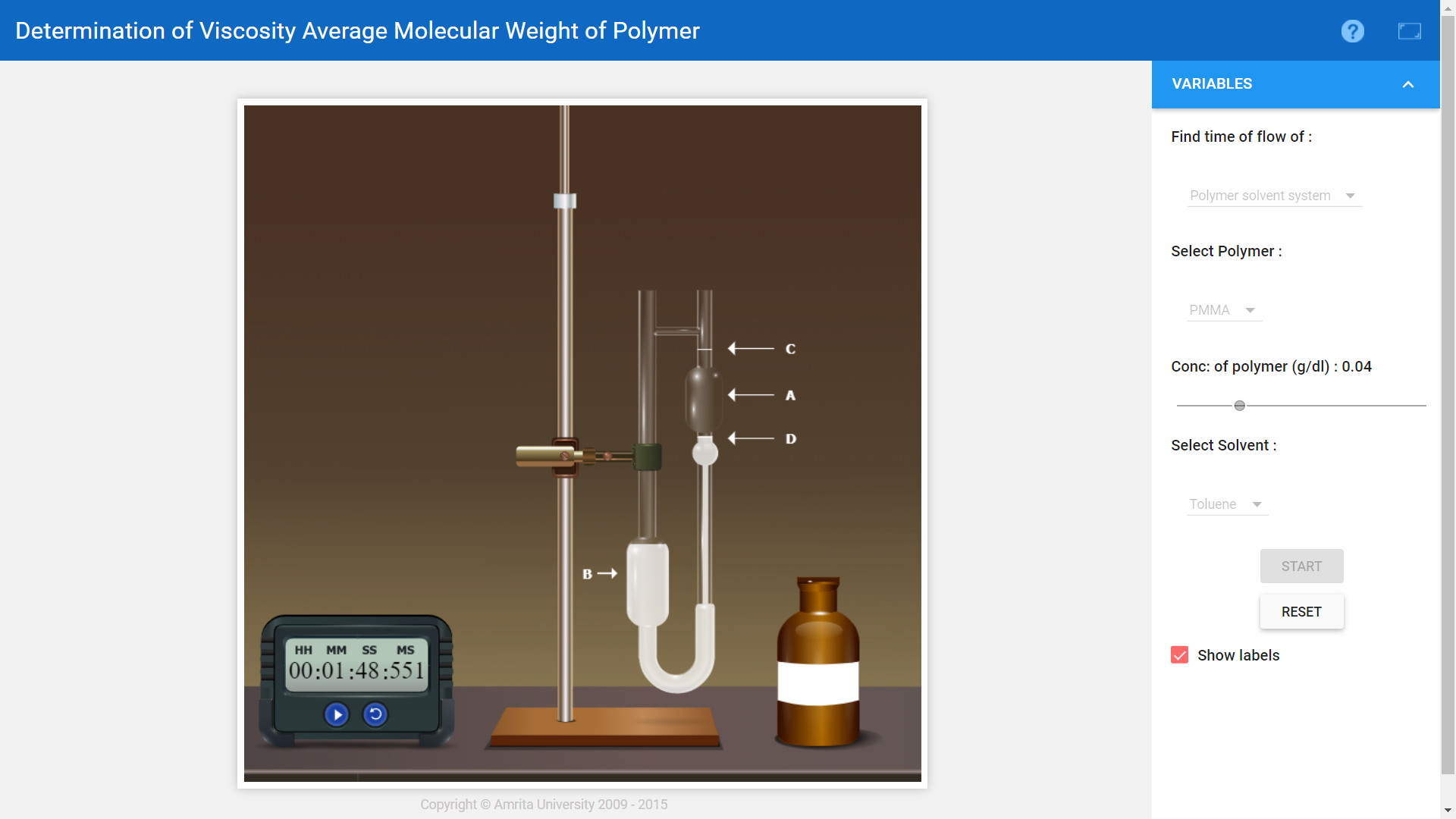
**Observations and Calculations:**

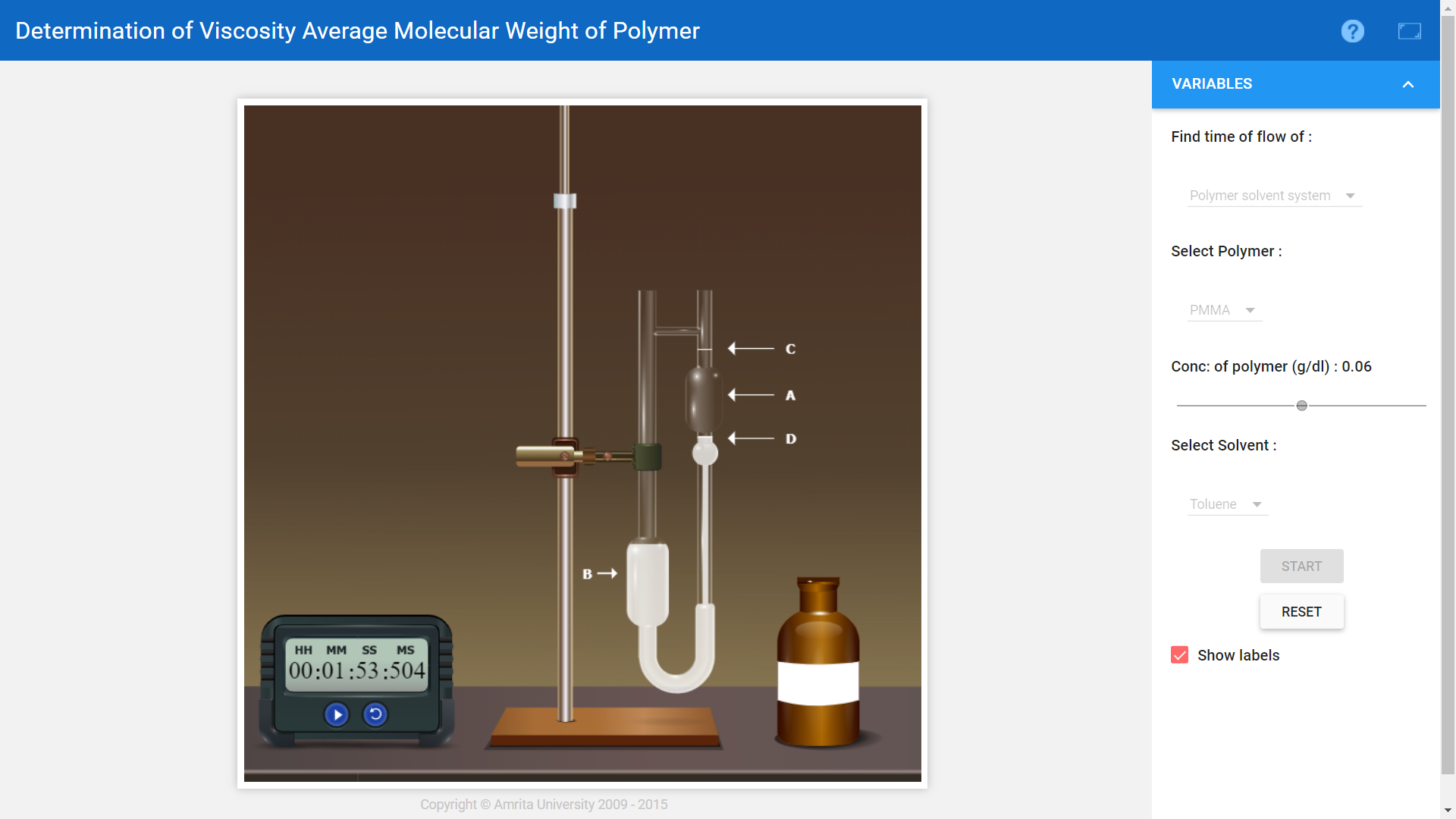
Polymer: PMMA

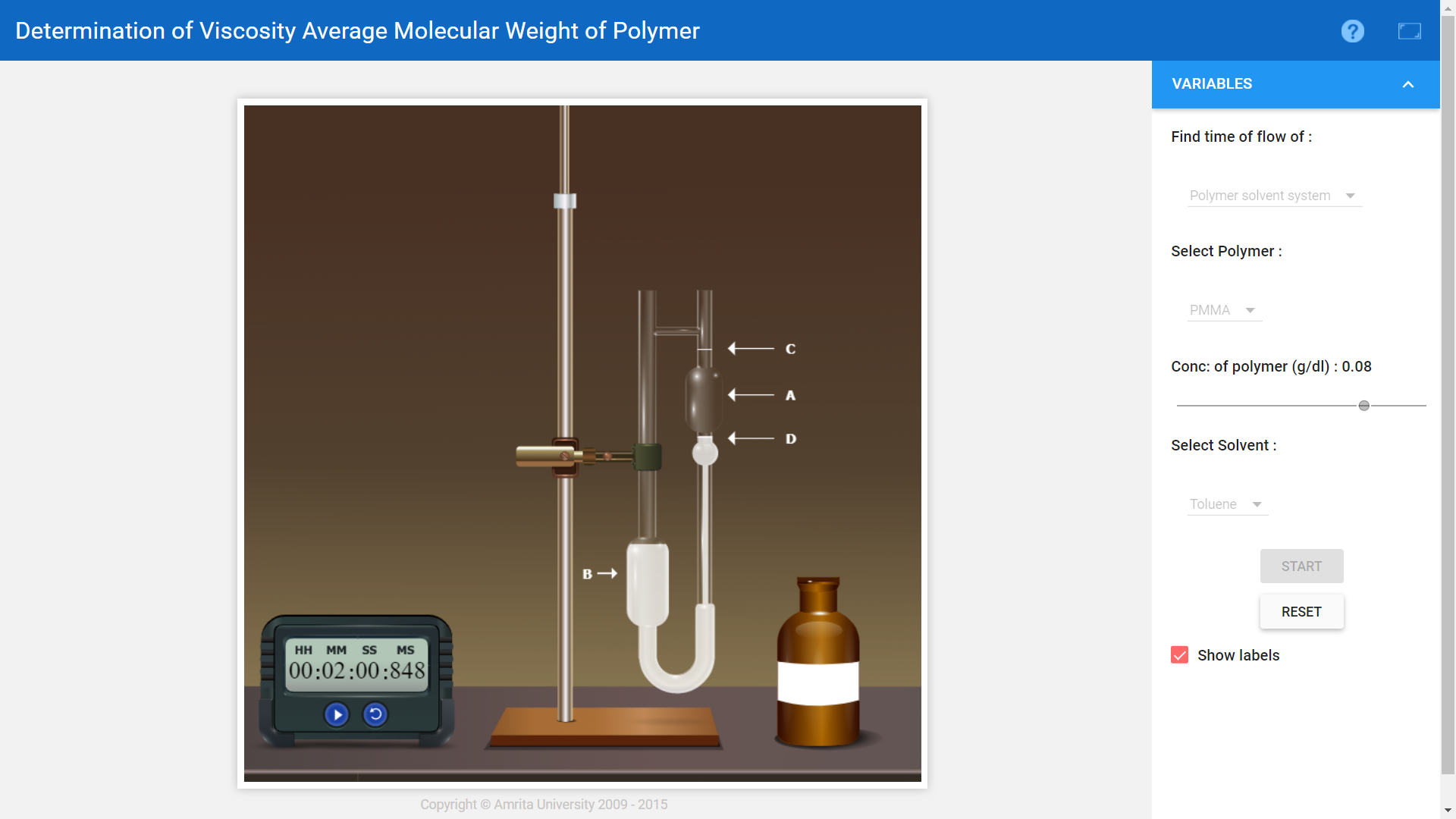
Solvent: Toluene

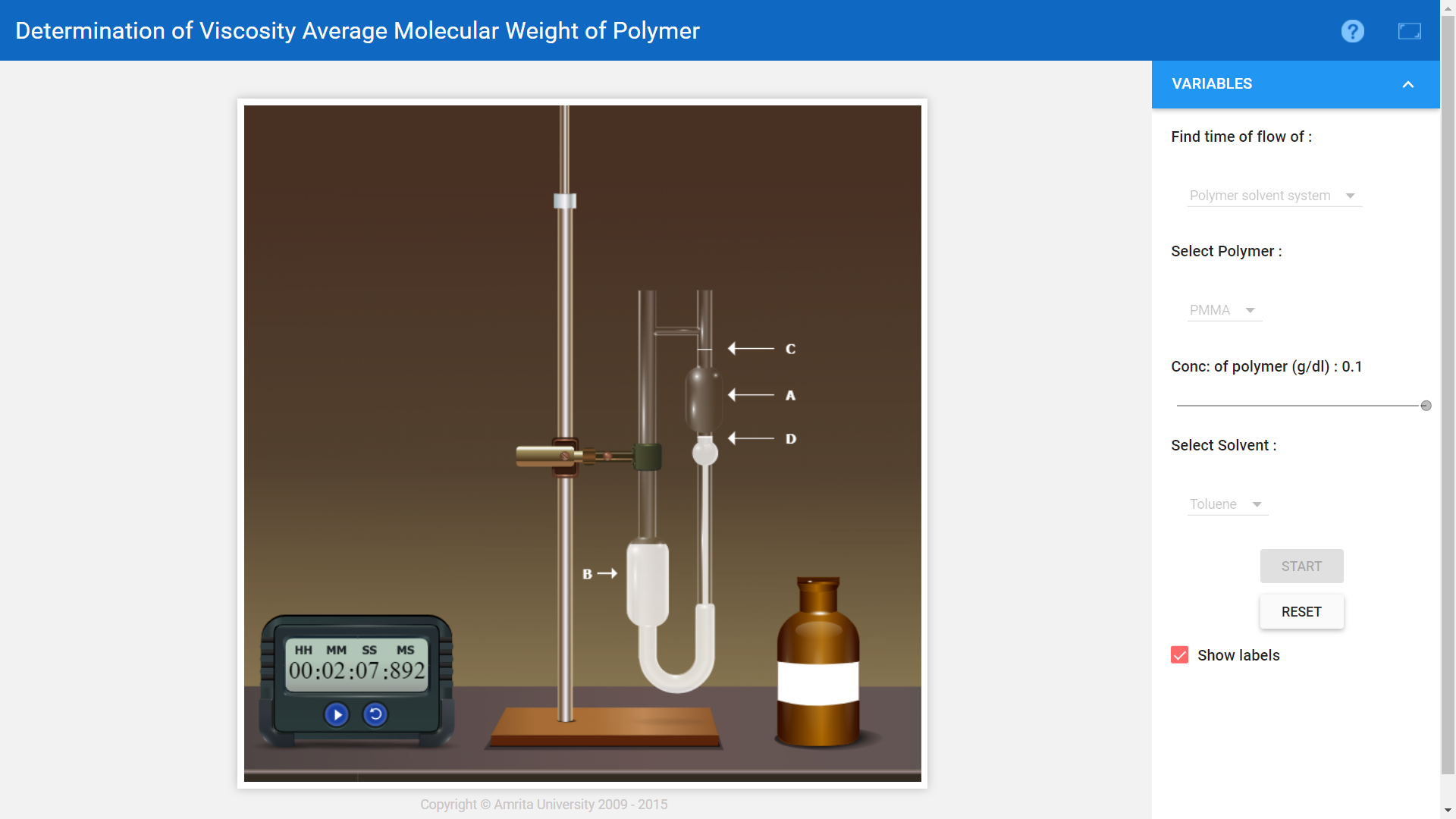
**Screenshot(s) Of Simulator:**

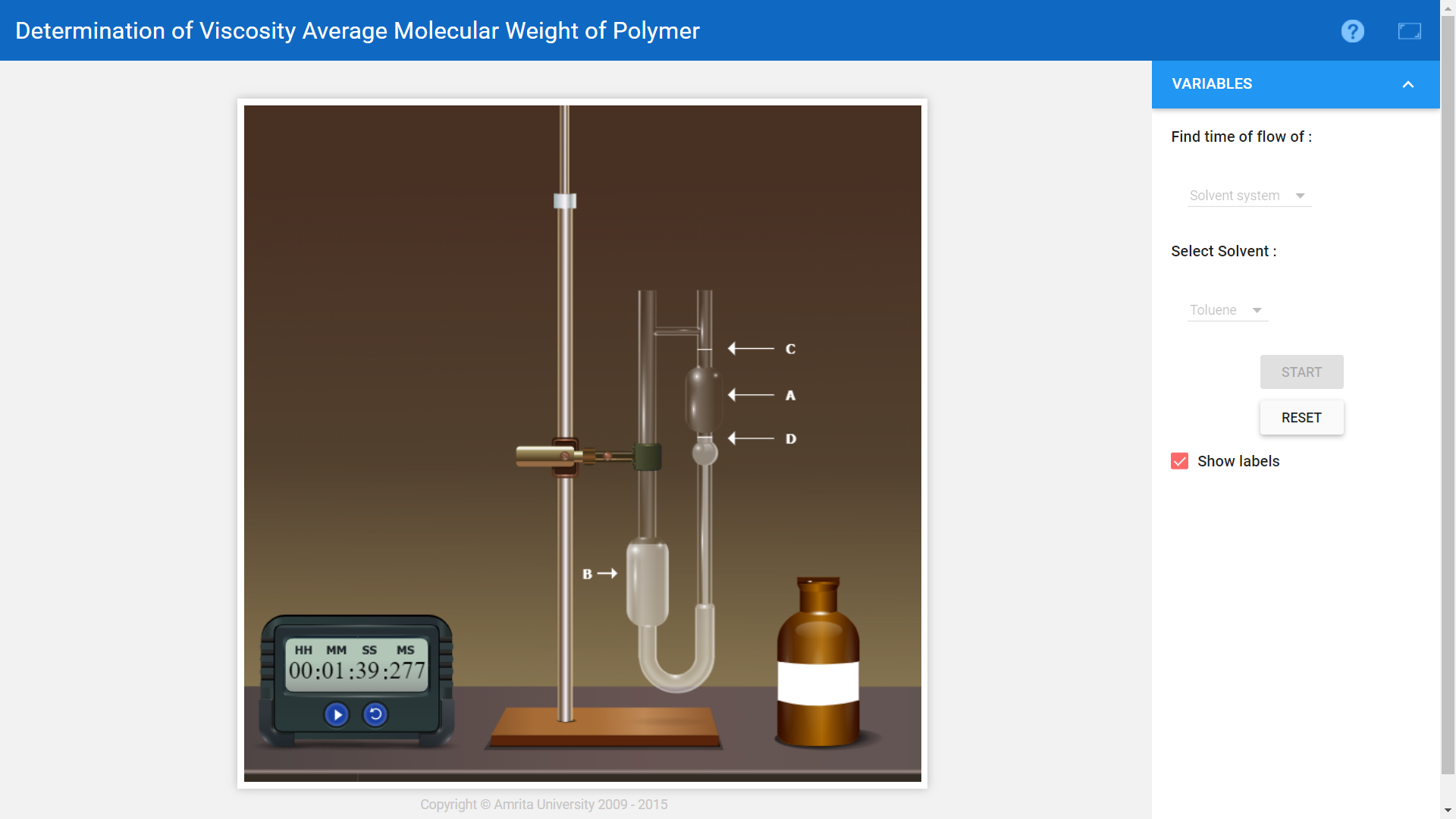












**Graph(s):**

**Graphical user interface, chart, application

Description automatically generated**

Diagram

Description automatically generated

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **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,**  «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» |
| 0.02 | 103.12 | 99.27 | 1.0387831168 | 0.0387831168 | 1.93915584 | 0.0380499480 | 1.9024974 |
| 0.04 | 108.55 | 99.27 | 1.0934824217 | 0.0934824217 | 2.33706054 | 0.0893674857 | 2.2341871 |
| 0.06 | 113.50 | 99.27 | 1.1433464289 | 0.1433464289 | 2.38910714 | 0.1339594262 | 2.2326571 |
| 0.08 | 120.84 | 99.27 | 1.2172861892 | 0.2172861892 | 2.71607736 | 0.1966239459 | 2.4577993 |
| 0.1 | 127.89 | 99.27 | 1.2883046238 | 0.2883046238 | 2.88304623 | 0.2533271088 | 2.5332710 |

**Observation Table:**

**Calculations:**

Text, letter

Description automatically generated

**Result:**

**The viscosity average molecular weight of the polymer «math xmlns=¨http://www.w3.org/1998/Math/MathML¨»«mi»M«/mi»«/math» is = *1.91446 \* 106.***