Calculation of the Molecular Weight of a Polymer by the Experimental Method

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ABSTRACT

The article describes the most convenient and simple process - the viscometric method for the experimental determination of the molecular weight of a polymer. With the introduction of the developed methodology in the laboratory practice of the chemistry of macromolecular compounds, the comprehensibility of students will average 72-89%.

Keywords: molecular compounds, molecular weight, solubility, macromolecule, viscometer, rubber, polystyrene,

One of the main features that distinguish high molecular weight compounds from low molecular weight substances is that they have a large molecular weight. Molecular weight is the most important constant for polymers and is a necessary indicator for a complete description of each high molecular weight compound.

Changes that occur during the processing of polymers and their operation can be detected by molecular weight.

The molecular weight determines the temperature yield strength of the compound, its properties such as swelling and solubility. Its value is greatly influenced by the mechanical properties of polymers, including strength, deformation, and elasticity. The molecular weight inherent in low molecular weight compounds, the simple and clear concepts associated with them, are extremely complex compared to high molecular weight compounds.

The most convenient and simple method for experimental determination of the molecular weight of polymers is the viscometric method. The German scientist Staudinger found that the viscosity of solutions depends on the size of the molecular weight of macromolecular compounds and the shape of the macromolecule. In this case, all macromolecules in solution are in a strictly linear form, in the form of a cylinder. This ratio is explained by the following equation:

$$M = \frac{\eta_{нис} - 1}{KC}$$

In this case, ηnis is the relative viscosity, K is the constant characteristic of the given polymer, c is the molar concentration, mol/l.

The value of K is reflected in the specific chemical structure of the macromolecule and is constant for the same polymer in a given solvent. Relative viscosity - (ηnis) - is the ratio of the flow rate of the solution to the flow rate of the solvent. The flow rate is determined on a viscometer.

In the laboratory, we determined the molecular weight of several polymers using the viscometric method. The following is a procedure for determining the molecular weight of polymethyl methacrylate, polystyrene and natural rubber.

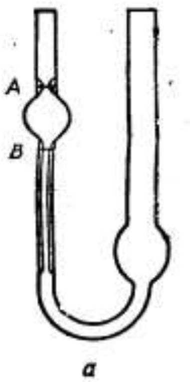
Determination of the molecular weight of polymethyl methacrylate

To determine the molecular weight of polymethyl methacrylate, two laboratory experiments were carried out.

First lab work

Students are briefly introduced to solutions of high molecular weight compounds, focusing more on the relationship between viscosity and molecular weight. Then the structure and maintenance of the viscometer device are explained.

The Ostwald viscometer consists of a U-shaped glass tube (shown in the figure). One side of the tube is expanded, and the other side is provided with a capillary with a diameter of 0.6-1.0 mm. An expanded sphere with a volume of 2-3 ml is attached to the upper part of the capillary. Attached to the bottom of the expanded glass tube is a small tube, on which the top and bottom of the spherical extension (A and B) are marked. The viscometer is installed on a water thermostat at a temperature of 200C.



Ostwald viscometer

12 ml of a solvent, such as benzene, is poured into the expanded part (this part must be filled with a solvent). There should be no air bubbles in the capillary. (In general, the liquid should not be drawn by mouth, otherwise an accident may occur, since many solvents are toxic)

After removing the rubber nozzle, we observe that benzene is poured into the expanded part of the viscometer. When liquid (A) reaches the top of the mark, a stopwatch is used and the time is set until the second volume of solvent (B) reaches the bottom of the mark. The stopwatch stops and the result is recorded. The process is repeated 3-4 times and an average value is obtained. For example: I result - 94.5 sec; II result - 94.6 sec; III result - 94.7 sec. The average time is 94.6 seconds.

Then the viscometer is removed from the thermostat with water, the solvent is poured into another vessel, the device is washed and dried in an oven.

In this lab, students prepare a 1% solution of poly(methyl methacrylate) in benzene. To do this, take a clean and dry test tube, fill it with 0.2 g of polymethyl methacrylate and pour 20 ml of benzene, stopper and leave at room temperature for 3.0-3.5 hours.

Second Lab

Students determine the flow rate of the polymethyl methacrylate solution in the same way as they determined the flow rate of the solvent in the first laboratory work. (The temperature in the thermostat must be the same for solvent and solution)

The relative viscosity is calculated, the found value is entered into the equation and the molecular weight is determined

Below are the molecular weight calculations for poly(methyl methacrylate) obtained under laboratory conditions:

Solution transit time: 235.8 sec (average)

$$\eta_{нис} = \frac{t_1}{t_0} = \frac{235{,}8}{94{,}6} = 2{,}493 \quad К = 2{,}4 * 10^{-4}$$

$$M = (\eta_{нис} - 1) \cdot \frac{1}{KC} = (2{,}493 - 1) \cdot \frac{1}{2{,}4 \cdot 10^{-4} \cdot 0{,}1} = (2{,}493 -$$

Determination of the molecular weight of polystyrene

Prepared a 1% solution of polystyrene in benzene. (0.2 g of polystyrene add 20 ml of benzene and leave for 3 hours). Some students prepare block polystyrene (industrially produced polystyrene) in the same way, while other students prepare emulsion polystyrene (laboratory derived polystyrene) solutions.

Constants K and α in the equation [η]=KMα

№	Polymers	Elementary link	Solvent	Temperature 0C	К·10^{-4}	α
1	Polystyrene	$-CH_2-CH(C_6H_5)-$	Toluene Benzene	25 25	1,28 4,17	0,70 0,60
2	Polyacrylonitrile	$-CH_2-CH(CN)-$	Dimethyl formamide	20 25	1,75 3,95	0,66 0,75
3	Polyvinyl acetate	$-CH_2-CH-$ | $OCOCH_3$	Acetone	50	2,82	0,67
4	Polyisoprene Rubber (natural)	$-CH_2-C=CH-CH_2$ | CH_3	Toluene Benzene	25 20	3,60 14,0	0,64 0,50
5	Polymethyl methacrylate	$-CH_2-C(CH_3)-$ | $COOCH_3$	Chloroform Benzene	20 20	0,94 2,40	0,75 0,54
6	Polymethyl acrylate	$-CH_2-C(CH_3)-$ | $COOCH_3$	Benzene	30	0,45	0,78
7	Polyacrylamide	$-CH_2-CH-$ | $CONH_2$	Water	25	0,631	0,80

Determination of the molecular weight of polystyrene

Prepared a 1% solution of polystyrene in benzene. (0.2 g of polystyrene add 20 ml of benzene and leave for 3 hours). Some students prepare block polystyrene (industrially produced polystyrene) in the same way, while other students prepare emulsion polystyrene (laboratory derived polystyrene) solutions.

Solution transit time: 220.5 sec (average)

$$\eta_{нис} = \frac{220{,}5}{94{,}6} = 2{,}330 \quad К = 4{,}17 * 10^{-4}$$

$$M = (2{,}330 - 1) \cdot \frac{1}{4{,}17 \cdot 10^{-4} \cdot 0{,}096} = (2{,}330 - 1) \cdot \frac{10000}{4{,}17 \cdot 0{,}096} = 33250$$

Then each student receives an additional task: some students calculate the molecular weight of industrial block polystyrene, some students calculate the molecular weight of emulsion polystyrene obtained in the laboratory, the rest of the students determine the molecular weight of emulsion polystyrene obtained in industry. For example,

Industrially obtained block polystyrene M = (3,58 -1) * 24980 = 64448,4

Lab made emulsion polystyrene M = (2,33 -1) *24980 = 33223,4

Industrially produced emulsion polystyrene M = (8,7 - 1) * 24980 =192346

Determination of the molecular weight of natural rubber

Prepared a 0.2-0.3% solution of rubber in benzene. Placed 40-50 mg of rubber into the flask, poured 20 ml of benzene and closed the neck with a cork and left for 12 hours.

Before determining the molecular weight of rubber, undissolved rubber is separated from the solution (filtered through a cotton swab) and then the concentration of the solution is determined. To do this, take 2 ml of the solution and place it in a porcelain bowl, evaporate the solution, measure the residue and calculate the concentration of 2 ml of the solution.

The relative viscosity of rubber is determined at 200C. Knowing the molar concentration and the constant (1.4 * 10-4) (from the table below), students calculate the molecular weight of natural rubber.

Solution transit time: 118.4 sec (average)

$$\eta_{нис} = \frac{118,4}{94,6} = 1,298$$

$$К = 1,4 * 10^{-4}$$

$$M = (1,298 - 1) \cdot \frac{1}{1,4 \cdot 10^{-4} \cdot 0,193} = 11028,87$$

The proposed method was applied in group 2.1.Chem.-17. The group consisted of 20 students who were divided into 4 groups. Of these, in 3 groups, non-traditional methods for determining the molecular weight were carried out, and in 1 group, the traditional method, that is, based on the methodology given in the source [4]. The students of group I were instructed to determine the "Molecular weight of polymethyl methacrylate", the students of group II to determine the "Molecular weight of polystyrene", the students of group III to determine the "Molecular weight of natural rubber", and the students of group IV to determine the molecular weight of the polymer in the traditional way.

During the experiment, it was noted that students of groups I, II and III quickly and accurately determined the molecular weights of polymers. Group IV students, on the other hand, spent a lot of time experimenting and experienced great difficulty in determining the molecular weight of a polymer based on a complex equation.

At the end of the experiments, when a report was received from the students of the groups, the mastery of the laboratory topic in groups I, II and III averaged 72-89%, while the mastery of students in group IV was 60-74%.

A technique has been developed for conducting laboratory classes to determine the molecular weight of polymers using a viscometric method for determining the viscosity of polymer solutions. The results obtained are of great practical importance and are used to determine the areas of application of polymers.

Thus, the proposed laboratory method for the experimental calculation of the molecular weight of a polymer has a positive effect on increasing knowledge, acquiring the skills to apply their knowledge in practice and developing students' qualifications for determining the molecular weight of polymers.

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