

Comparison of the Change in Viscosity of a Polyvinylalcohol Solution by Adding Polyethylene Glycol and Polyvinylpyrrolidone to Solutions of Polyvinylalcohol

Najla Ali Elgheryani^{1*}

¹Physics Department, Faculty of Education, University of Benghazi, Benghazi, Libya.

*Corresponding author: nagla.elgerani@uob.edu.ly

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Abstract

The aim of this research is to improve the flow properties of polymers, in particular viscosity, by mixing polymers to be used in various fields. Samples prepared by stirring polyvinyl alcohol on fire for half a second in a fixed weight ratio with divergent weight ratios of polyethylene glycol and polyvinylpyrrolidone, both separately. Other samples were prepared in the same way by mixing the three polymers followed by measuring the molecular weight of all the samples. This method of preparation made the polymers insoluble in water, therefore nitric acid was used to dissolve them. Flow time of the solvent and all solutions were measured, which was used to calculate the viscosities, It has been shown that these viscosities increase with increasing concentrations of polymers in solutions by establishing a positive relationship between them, It was found that the intrinsic viscosity decreases with increasing concentrations after being graphed using intrinsic viscosity calculations from the relationship between specific viscosity and relative viscosity logogram with concentration. These results may be used in industrial medical applications as well as scientific studies.

1. Introduction:

The viscosity is the resistance of a liquid to the displacement of one layer in relation to another layer under the influence of external forces, or in other words, measuring the resistance of a liquid to flow or internal friction [1]. It is used in a wide range of scientific and technical fields and is also one of the important parameters for quality control in many polymeric process products [2]. Viscosity is the resistance of a substance to flow, it is a measure of the resistance of a fluid to deformation under shear stress. There are two main types of viscosity, kinematic viscosity and dynamic viscosity. Dynamic viscosity, sometimes called absolute viscosity, is obtained by dividing the shear stress by the rate of shear strain. Kinematic viscosity is the measure of the rate at which momentum is transferred through a fluid. It can be obtained from the dynamic viscosity by dividing it by the density of the substance [3]. Polymers

are versatile materials that play an important role in a wide range of industrial applications. Polymeric solutions or suspensions lubricate the joints of the human body, give foods a rich, creamy appearance, and provide stability to inks and paints. In these and many other applications, the rheological characteristics of the polymer solution have a decisive influence on the performance and functionality of the product [4]. Polyvinyl Alcohol (PVA) is a biocompatible and biodegradable polymer that is non-toxic in nature. It is an odorless and tasteless ivory powder that can be easily mixed physically or chemically with other polymers. PVA is considered an environmentally friendly food packaging material that exhibits excellent water absorption, is resistant to chemicals and gases, and has film-forming properties [5]. Very large chains (polymers) contain a variety of functional groups, can be mixed with other low or high molecular weight materials, to be adapted to all applications. Polymers are becoming increasingly important in the field of drug delivery, and advances in polymer science have led to the development of several new drug delivery systems, proper consideration of surface and vol-

ume properties can help in the design of polymers for various drugs applications [6]. Polyvinylpyrrolidone (PVP), a non-ionic, non-toxic, water-soluble amorphous polymer with high solubility in polar solvents, has been widely used in nanoparticle synthesis. Due to its amphiphilic nature, PVP can affect the morphology, stabilizing the discriminating surface, controlling crystal growth, acting as a shape control agent, and facilitating growth of specific crystal faces while preventing further [7]. Aqueous solutions of polyvinylpyrrolidone are used in cosmetics, medicine, pharmacy and have been applied in a wide variety of applications such as blood plasma, medicine, biomaterials, coatings, substitutes, macromolecular and cosmetics additives, because it has low toxicity and high solubility in water. Polyethylene glycol (PEG) is characterized as a non-toxic, water-soluble polymer that resists recognition by the immune system. The term PEG is often used to designate polymer chains with a molecular weight of less than 20,000. It is rapidly cleared from the body and has been approved for a wide range of biomedical applications. Due to these properties, hydrogels prepared from polyethylene glycol are excellent candidates as biomaterials. Polyethylene glycol can transfer its properties to another molecule when it is covalently attached to that molecule. This could cause toxic molecules to become non-toxic or hydrophobic molecules to become soluble when coupled to polyethylene glycol [8]. Chemical modification of polymers is one of the methods used to produce new polymeric materials to broaden the application of existing polymers that lack the required properties [9]. The aim of this work is to improve the flow properties of polymers, in particular viscosity, by mixing polymers for use in various fields.

2. Experimental:

2.1 Samples:

Polyvinylalcohol (PVA: 99+40 hydrolysed, Mw 85000 g mol⁻¹), polyvinylpyrrolidone (PVP has Mw 10000 g mol⁻¹) and polyethylene glycol (PEG with Mw 12000 g mol⁻¹) used were supplied by Sigma-Aldrich GMBH. The samples for this research are divided into three portions, the first consists of 0.7 wt % of polyvinyl alcohol, to which a different concentration of polyethylene glycol (0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7 wt%) is added, while the second sample is added to the same weight of polyvinyl alcohol, and the same concentration of polyethylene glycol in the first sample, but of polyvinylpyrrolidone (0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7 wt%). The third part of the samples is added to the same weight of polyvinyl alcohol, the same concentration of polyethylene glycol (0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7 wt%) and polyvinylpyrrolidone (0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7 wt%) together. One of the concentrations of polyethylene glycol or polyvinylpyrrolidone or both was added to the weight of the polyvinyl alcohol It was heated with stirring for half a second, and all the samples were prepared in this way to obtain a solid samples of polymers, then dissolved in

100 milliliters of nitric acid with a concentration of 70 wt% to give solutions at room temperature (30°C).

2.2 Measurements:

The average molecular weight of the samples using the molar mass and Avogadro's number is calculated for all solid samples from the following equation [10] , [11]:

$$M_w = \frac{\sum M_i^2 N_i}{\sum M_i M_i} \quad (1)$$

Where, N_i is a number of molecules in the polymer and M_i is a molecular weight of the polymer. To determine the flow time of the solutions, the methodology provided by ASTM(1989) was used. The exit time of the solvent as well as the exit time of the other three samples were measured with a capillary glass viscometer. The measured values were expressed in terms of relative (η_r), specific (η_{sp}), reduced (η_{red}), and inherent (η_{inh}) viscosities of all samples as follows[12] , [13]:

$$\eta_r = \frac{t_{solution}}{t_{solvent}} \quad (2)$$

where $t_{solution}$ is the efflux time of pure solvent and $t_{solvent}$ is the efflux time of the samples. The specific viscosity is given by:

$$\eta_{sp} = \eta_r - 1 \quad (3)$$

and η_{red} is,

$$\eta_{red} = \frac{\eta_{sp}}{C} = \frac{\eta_r - 1}{C} \quad (4)$$

Where C is the mass concentration of polyethylene glycol or polyvinylpyrrolidone or both and η_{inh} can be expressed as: Intrinsic viscosity $[\eta]$ is the relationship between the specific viscosity of a solution and the concentration of the solute, extrapolated to zero concentration.

$$\eta_{inh} = \frac{\ln \eta_r}{C} \quad (5)$$

$$[\eta] = \lim_{C \rightarrow \infty} \frac{\eta_{sp}}{C} \quad (6)$$

$$[\eta] = \sqrt{\frac{2(\eta_{sp} - \ln \eta_{rel})}{C}} \quad (7)$$

$[\eta]$ can be calculated using equations (6) and (7), but has been calculated in this article using equation (7) [13].

3. Results and Discussion:

3.1 Calculation of the Molecular Weight of Solid Samples:

Table 1 includes the molecular weights of the solid samples that were calculated using equation (1), it is clear that the molecular weight of the solid samples containing polyethylene glycol or polyvinylpyrrolidone increases and the molecular weight of the samples containing polyethyleneglycol is higher than that of the samples containing polyvinylpyrrolidone, but the molecular weight of samples containing polyethyleneglycol and polyvinylpyrrolidone together decreases with increasing concentration. The above results indicate the possibility of modifying the molecular weight of the polymers using the mixing method.

3.2 Viscosities:

After mixing and stirring the polymers by heating for half a second, they were no longer soluble in water, so they dissolved in nitric acid. Figures (1-4) represent the relationships between certain types of viscosity for samples used in research and the concentrations of polymers they contain, where Figure 1 shows is the relative viscosity and concentration, Figure 2 reveals the relationship between specific viscosity and concentration, Figure 3 and Figure 4 show the evolution of intrinsic viscosity and the ratio between reduced viscosity and inherent viscosity by changing the concentration, respectively.

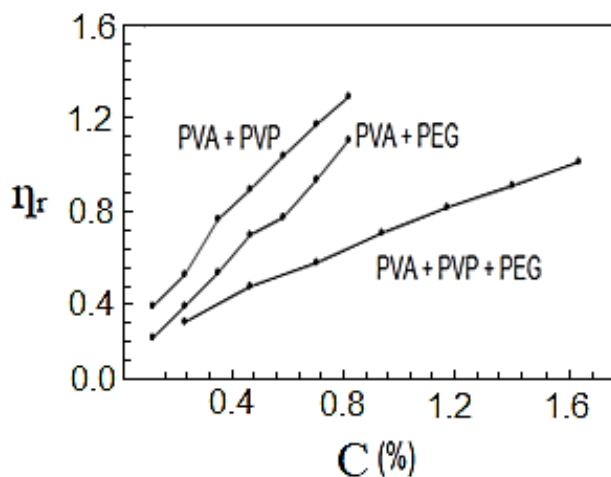


Figure 1. vs. concentration%.

From the figures shown in the results it is clear that the viscosities of the samples of different types increased with increasing concentration [14], exception of intrinsic viscosity which is decreased with increasing concentration [15]. On the other hand the viscosity of the samples containing PVP was higher than that of the samples containing PEG. In all the drawings, the samples made from the three polymers were always lower than the viscosity of the other samples. Figure 1 in [16], Figure ?? in [17] and Figure 3 in [18] indicates an

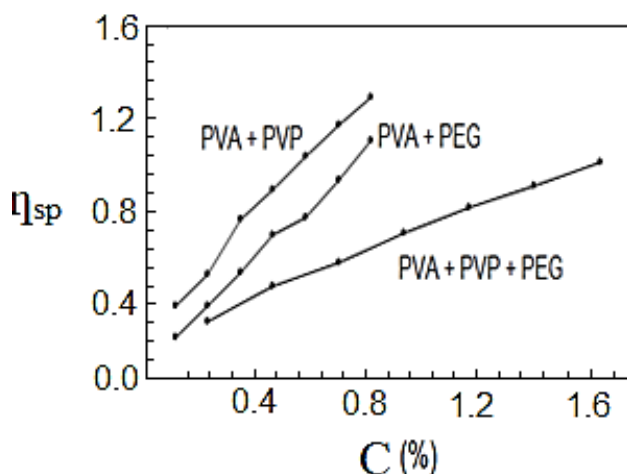


Figure 2. vs. concentration %.

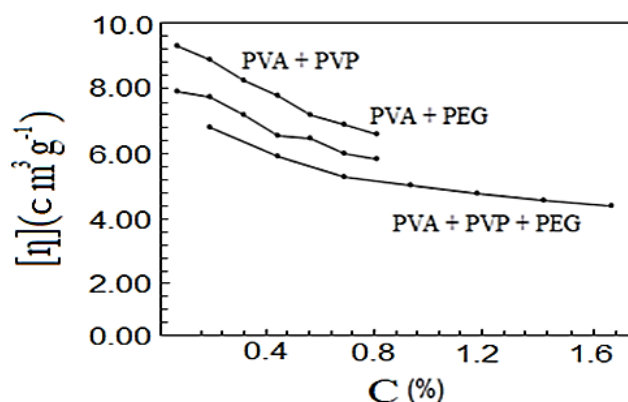


Figure 3. $[\eta]$ vs. concentration %.

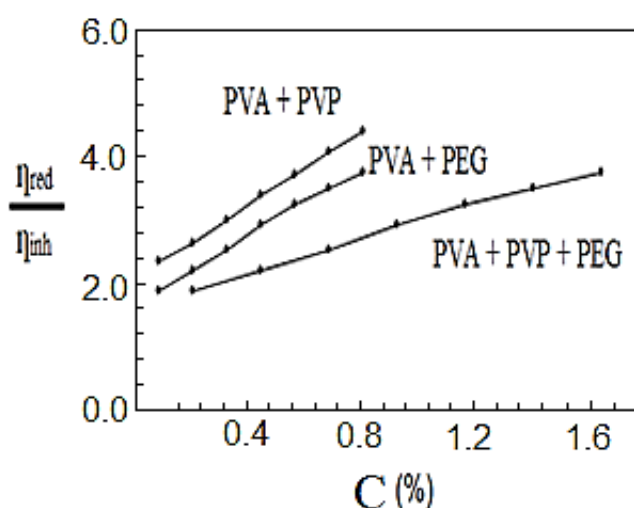
increase in sample viscosity as shown by the results of this study [16] - [18]. It is observed in Figure 4 of [18] that the intrinsic viscosity decreases with increasing concentration, and this is evidenced in Figure in this study [19].

4. Conclusion:

It is clear that the viscosity of polymer solutions can be changed by mixing the polymers in different ways. Note that adding PVP to PVA increases the viscosity of the solution more than its increases by adding PEG to PVA, while adding PVP and PEG together to PVA produces a solution that has a lower viscosity than the previous two solutions, which gives them many uses, there forces according to the results of this research it can be recommended to change the properties of polymers solutions and use them in industrial applications, medical services and scientific studies.

Table 1. The Molecular Weight of Solid Samples.

PVA (0.7%)						
PVA+PEG		PVA+PVP		PVA+PEG+PVP		
Concentration of PEG %	Mw (g mol ⁻¹)	Concentration of PVP%	Mw (g mol ⁻¹)	Concentration of PEG %	Concentration of PVP %	Mw (g mol ⁻¹)
0.1	5.73×10^{31}	0.1	4.48×10^{31}	0.1	0.1	68600
0.2	9.56×10^{31}	0.2	7.96×10^{31}	0.2	0.2	58100
0.3	1.29×10^{32}	0.3	1.07×10^{32}	0.3	0.3	58000
0.4	1.56×10^{32}	0.4	1.30×10^{32}	0.4	0.4	45500
0.5	1.79×10^{32}	0.5	1.49×10^{32}	0.5	0.5	41500
0.6	1.98×10^{32}	0.6	1.65×10^{32}	0.6	0.6	38300
0.7	2.15×10^{32}	0.7	1.79×10^{32}	0.7	0.7	35700

**Figure 4.** The ratio between η_{red} and η_{inh} vs. concentration%.**Declarations:****Funding:** None.**Conflict of interest:** The authors declare that they have no conflict of interest.**Data Availability Statement:** All of the data supporting the findings of the presented study are available from corresponding author on request.**References**

- [1] Arkan MA Seddiq. Effect of working hours on the physical-chemical properties of hydraulic oil for agricultural tractors. *kirkuk university journal for scientific studies*, 13(3):289–309, 2018.
- [2] Wei-Qi Xie and Xin-Sheng Chai. Measurement of viscosity in polymer solutions by a tracer-based gas chromatographic technique. *CSJ Journals*, 46(10):1161–1164, 2017.
- [3] Rymantas Kazys and Regina Rekuviene. Viscosity and density measurement methods for polymer melts. *Ultrasonic and Acoustic Measurements*, 66(4):20–25, 2012.
- [4] D. John. *Measuring the rheology of polymer solutions*. Malvern Instruments Worldwide, 2015.
- [5] Naveed Ahmed Khan, Muhammad Bilal Khan Niazi, Farooq Sher, Zaib Jahan, Tayyaba Noor, Ofaira Azhar, Tazien Rashid, and Naseem Iqbal. Metal organic frameworks derived sustainable polyvinyl alcohol/starch nanocomposite films as robust materials for packaging applications. *Polymers*, 13(2307):1–16, 2021.
- [6] Hala MG Alzahawi. Synthesis, characterization and bio-hydrolysis drug release studies of polymer carrier with naproxen. *kirkuk university journal for scientific studies*, 13(1):1–11, 2018.
- [7] Marina Voronova, Natalia Rubleva, Nataliya Kochkina, Andrei Afineevskii, Anatoly Zakharov, and Oleg Surov. Preparation and characterization of polyvinylpyrrolidone/cellulose nanocrystals composites. *Nanomaterials*, 8(12):1011, 2018.
- [8] Adel H Omran Alkhayatt, Ali H Al-Azzawi, and Zahraa Alakayashi. Rheological and optical characterization of polyvinylpyrrolidone (pvp)-polyethylene glycol (peg) polymer blends. *Journal of Kufa-Physics*, 11(02), 2019.
- [9] Farah Kh H Al-juboory and Ahmed AH Al-kadhimi. Preparation of some mercurated polyacrylamide and it's copolymers and their industrial applications. *kirkuk university journal for scientific studies*, 12(2), 2017.
- [10] Robert O. Ebewe. CRC Press, Boca Raton, New York, 1st edition, 2000.

- [11] Technical Overview. Polymer molecular weight distribution and definitions of mw averages. 2015.
- [12] Victor Spelling, Mathias Axelsson, Lovisa Ringström, Johanna Munck af Rosenschöld, and Anton Lindblad. Mapping the intrinsic viscosity of hyaluronic acid at high concentrations of oh, 2017.
- [13] Martin Alberto Masuelli. Intrinsic viscosity determination of high molecular weight biopolymers by different plot methods. chia gum case. *Journal of Polymer and Biopolymer Physics Chemistry*, 6:13–25, 2018.
- [14] H. Mustafiz A. Moughes A. Shams B. Mohd, F. Mohd. Application note: Automated method for intrinsic viscosity determination in polymeric materials. *Academic journal of polymer sciences*, 6:555–573, 2018.
- [15] Mohd Bilal Khan, Mohd Faizan Khoker, Mustafiz Husain, Moughes Ahmed, and Shams Anwer. Effects of nanoparticles on rheological behavior of polyacrylamide related to enhance oil recovery. *Academic Journal of Polymer Science*, 1:1–2, 2018.
- [16] WM Obeidat and JC Price. Viscosity of polymer solution phase and other factors controlling the dissolution of theophylline microspheres prepared by the emulsion solvent evaporation method. *Journal of microencapsulation*, 20(1):57–65, 2003.
- [17] Xiankang Xin, Gaoming Yu, Zhangxin Chen, Kelu Wu, Xiaohu Dong, and Zhouyuan Zhu. Effect of polymer degradation on polymer flooding in heterogeneous reservoirs. *Polymers*, 10(8):857, 2018.
- [18] G Sun, D Li, D Zhang, and TH Xu. Study on improving viscosity of polymer solution based on complex reaction. In *IOP Conference Series: Materials Science and Engineering*, volume 369, pages 1–5, 2018.
- [19] S. Karakus N. Baydogan Y. Yigit, A. Kilislioglu. Determination of the intrinsic viscosity and molecular weight of poly (methyl methacrylate) blends. *Journal of Investigations on Engineering and Technology*, 2(2):34–39, 2019.

مقارنة التغيير في لزوجة محلول كحول عديد الفاينيل بإضافة بولي إيثيلين جلايكول وبولي فينيل بيروليدون إلى محاليل كحول بولي فينيل

نحلاء علي الغرياني

قسم الفيزياء، كلية التربية، جامعة بنغازي، بنغازي، ليبيا

الخلاصة

الهدف من هذا البحث هو تحسين خواص تدفق البوليمرات وخاصة اللزوجة وذلك بخلط البوليمرات لاستخدامها في مختلف المجالات وقد تم استخدام عينات من كحول البولي فينيل والبولي ايثيلين جلايكول والبولي فينيل بيروليدون والتي تم تحضيرها عن طريق تحريك كحول البولي فينيل على النار لمدة نصف ثانية بنسبة وزنية ثابتة مع نسب أوزن مختلفة من البولي إيثيلين جلايكول والبولي فينيل بيروليدون ، كلاهما منفصلين، وحضرت عينات أخرى بنفس الطريقة عن طريق خلط البوليمرات الثلاثة وتم قياس الوزن الجزيئي لجميع العينات. طريقة التحضير هذه جعلت البوليمرات غير قابلة للذوبان في الماء ، لذلك أذيت في حمض النيتريك. تم قياس وقت تدفق المذيب وأوقات تدفق جميع المحاليل ، والتي تم استخدامها لحساب اللزوجة النسبية (η_r) ، حيث استخدمت لحساب اللزوجة المحددة (η_{sp}) ، واللزوجة المنخفضة (η_{red}) ، واللزوجة المتأصلة (η_{inh}). تبين أن هذه اللزوجة تزداد مع زيادة تركيزات البوليمرات في المحاليل عن طريق إنشاء علاقة إيجابية بينها ، بينما تنخفض اللزوجة الجوهريّة مع زيادة التركيزات التي حسبت من العلاقة بين اللزوجة المحددة و لوغريثم اللزوجة النسبية ورسمت مع التركيز. يمكن استخدام هذه النتائج في التطبيقات الصناعية والتطبيقات الطبية والدراسات العلمية.

الكلمات الدالة: اللزوجة؛ كحول بولي فينيل؛ بولي فينيل بيروليدون؛ البولي ايثيلين جلايكول