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Rheological and optical characterization of Polyvinylpyrrolidone (PVP) - Polyethylene glycol (PEG) polymer blends

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ABSTRACT

Polymer blends of different concentrations for PVP-K30 and different additive weights of PEG8000 have been prepared as polymeric blends solutions. The rheological and optical properties of the blends samples have been investigated using Ostwald viscometer and Refractometer. The results showed that the density, shear, relative and specific viscosities are increases with the increasing of PVP concentration and additive weight of PEG. The optical constant values such as refractive index, reflectance, molar reflectance, coefficient of finesse and Brewster Angle are increase with the increasing of PVP concentration and additive weight of PEG while the critical angle has the revers behavior.

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الخصائص الريولوجية والبصرية للخليط البوليمري بولي فينيل بيروليدون ((PVP- بولي إيثيلين كلايكول PEG))

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الكلمات المفتاحية:

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بولي إيثيلين كلايكول
خلائط بوليمرية
الخصائص البصرية والريولوجية

الــخُــلاصــة

تم تحضير محاليل خلائط بوليمرية من PVP-k30 وبأضافة أوزان مختلفة من PEG-8000. الخصائص الريولوجية والبصرية درست لنماذج الخلائط بأستخدام مقياس اللزوجة أوستلد ومقياس معامل الأنكسار. أظهرت النتائج أن الكثافة ولزوجة القص واللزوجة النسبية واللزوجة النوعية تزداد بزيادة تركيز ال PVP وزيادة الوزن المضاف من ال PEG . قيم الثوابت البصرية مثل معامل الانكسار ، الانعكاسية ، الانعكاسية المولية ، معامل الجودة وزاوية بروستر تزداد بزيادة تركيز PVP والوزن المضاف لـ PEG بينما الزاوية الحرجة لها سلوك عكسي.

1. INTRODUCTION

Polymer blends can be define as the physical mixtures of two or more homo-polymer or copolymers, which interact with secondary forces such as hydrogen bonding with no covalent bonding. Polymer blends are prepared by many methods and among them solutions blending is very simple and brisk. The latter properties of the blends mainly consist on the properties of the constituent polymers and also on the phase morphology developed during blending [1]. The Polymer blends are includes both crystalline and amorphous polymers and the mixing of two chemically dissimilar polymers is miscible or not depends on the thermodynamics of mixing [2].

Polyvinylpyrrolidone is nontoxic, have high molecular weight ranging from 40,000 to 360,000, watersoluble polymer [3,4]. PVP K-30 is in the powder form and its color white to light yellow. Due to its low toxicity and high water solubility, the aqueous solutions of (PVP) are used in pharmacy, medicine ,cosmetics , and it has been applied in wide variety of applications such as , biomaterials and coatings , blood plasma substitute, medicine, cosmetics, and macromolecular additives. (PVP) is also used in detergent formulations where its role is to prevent re-deposition of soil on fibers [5,6]. Polyethylene glycol is characterized as a non-toxic, water soluble polymer which resists recognition by the immune system. The term PEG is often used to refer to polymer chains with molecular weights below 20000 [7]. It exhibits rapid clearance from the body, and has been approved for a wide range of biomedical applications .Because of these properties, hydrogels prepared from (PEG) are excellent candidates as biomaterials. (PEG) may transfer its properties to another molecule when it is covalently bound to that molecule. This could result in toxic molecules becoming non-toxic or hydrophobic molecules becoming soluble when coupled to (PEG) [8,9]. Aqueous solutions of (PEG) are biocompatible and are used in organ preservation

and for tissue culture media [10]. PEG 8000 is in the form of powder its color is white and could be obtained from local markets. In the present work Polyvinylpyrrolidone and Polyethylene glycol polymeric blends with different concentrations were prepared in dilute Solutions.

2. EXPERIMENTAL

PVP-K30(Mw40000) solutions with different weight percentage (0.5%, 1%, 1.5 %, 2%, 2.5%, 3%, and 3.5%) g / ml have been prepared by dissolving the propagate weights of PVP-K30 powder in a fixed volume (100 ml) of distilled water by using magnetic stirrer in mixing process for 15 min to get homogeneous solutions. Then different blend solutions were prepared by mixing PVP (for all concentration) and different weights (0.3,0.6 and 0.9) g of PEG(Mw 8000). The resulting solution was stirred continuously for (15 min) until the solution mixture became a homogeneous. The concentration of the solutions is calculated by using the following equation [11]:

$$Concentration = \frac{m_{solute}}{V_{solution}} * 100\% \qquad ---(1)$$

$$C_m = \frac{m_{solute}}{V_{solution}} * \frac{1}{M_w} \qquad ---(2)$$

Where: msolute is the mass of solute, Vsolution is the volume of solution, and Mw is the molecular weight. The rheological properties for PVP and (PVP+PEG) polymeric blends have been measured by using Ostwald viscometer which also known as U-tube viscometer or capillary viscometer, this device used to measure the viscosity of the liquid with a known density. Whereas the optical properties of the prepared blends were studied by measuring the refractive index of the blends by using the Refractometer model ANR-IT Atago Co. LTD at room temperature.

3. RESULTS AND DISCUSSION

A- Rheological properties:

I- Density

The density was measured by using Picnometer for all polymer blends solutions of PVP before and after adding different weights of PEG as shown in Figure(1). The density values are increases with the increasing of PVP solutions concentration and with increasing the additive weight of PEG. The increase in density was indicates to increasing in cohesion forces due to powerful intermolecular interaction [12].

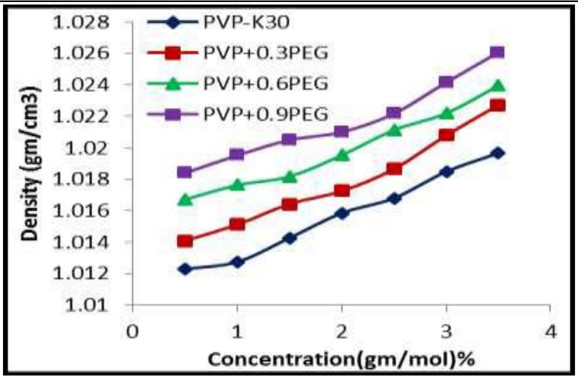

Figure (1): The density as a function of concentration for pure PVP and polymeric blend (PVP-PEG) solutions

II- Shear Viscosity:

The shear viscosity values have been calculated for polymer solutions by using the following equation [13]:

$$\frac{\eta_s}{\eta_o} = \frac{t_s \rho_s}{t_o \rho_o} \qquad ---(3)$$

Where: η_s is viscosity of the solution, η_o is viscosity of the solvent, t_s is flow time of solution and t_o is flow time of solvent.

The variation of shear viscosity versus concentration for polymeric solutions is shown in figure (2). The increasing in the shear viscosity with PVP polymer solutions concentration before and after adding different weights of PEG polymer offers more resistance to flow; this behavior can be explained by the hydrodynamic theory of rod shaped particles [13]

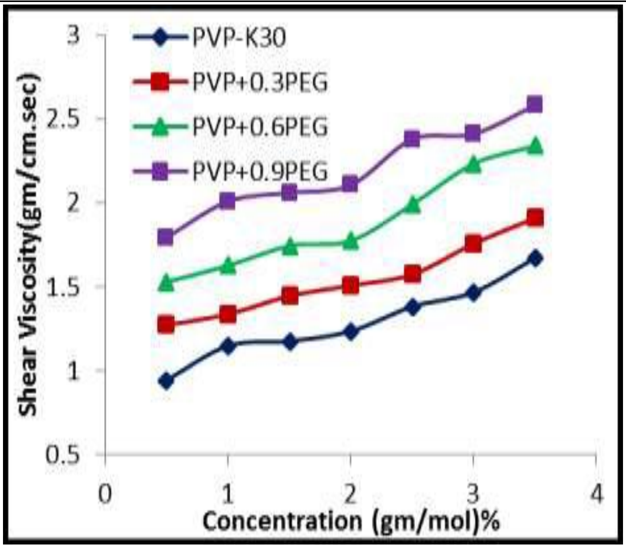

Figure (2): The shear viscosity as a function of concentration for (PVP and PVP-PEG) polymeric blends solutions.

III- Relative Viscosity

The relative viscosity ηrel values have been calculated for the polymer solutions by using the equation [14]:

$$\eta_{rel} = \frac{t}{t_o} \qquad ---(4)$$

The increasing relative viscosity with different concentrations of PVP before and after adding different weights of PEG as shown in the figure (3) offers more resistance to flow as discussed previously [14].

IV- Specific Viscosity

The specific viscosity η has been measured for different concentrations of PVP polymer solution before and after adding different weights of PEG polymer by using the following equation [15]

Figure (4) represent the variation of specific viscosity as a function of solutions concentration. The increasing specific viscosity with PVP concentration before and after PEG additive weights offers more resistance to flow [15]

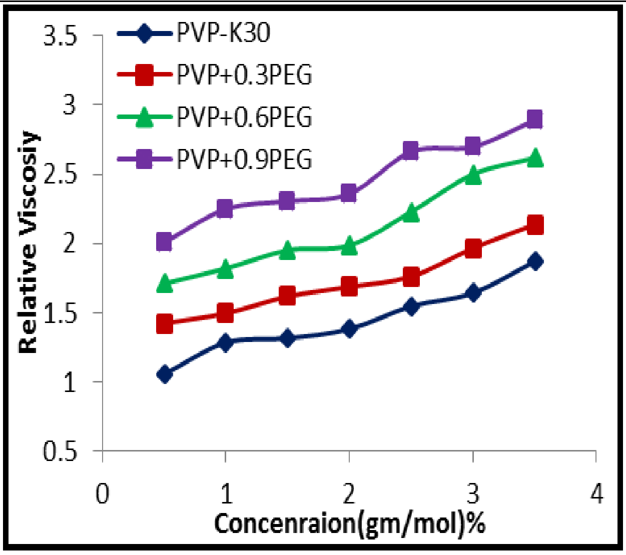

Figure (3): The relative viscosity as a function of concentration for (PVP and PVP-PEG) polymeric blends solutions.

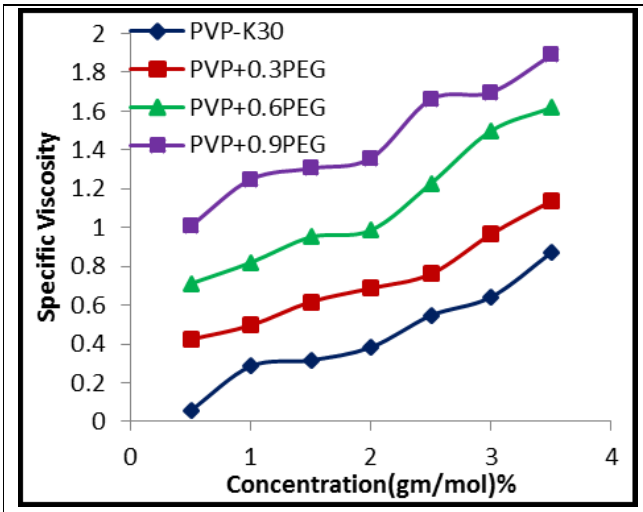

Figure (4): Specific viscosity as a function of concentration for (PVP and PVP-PEG) polymeric blends solutions.

B- Optical Properties

1- Refractive Index

The refractive index n is defined as a ratio between the velocity of light in vacuum to its velocity inside the material. It was measure practically for different concentrations of PVP solutions before and after adding different weights of PEG by using refractometer device. The refractive index linearly increasing with the increasing of PVP concentration and with the increasing of additive weight of PEG as shown in figure (5) . The increasing of refractive index may be referred to increase the value of density which is important function to calculate the refractive index [16].

2- Reflectance

The reflectance (reflectivity) R can define as the ratio of the reflected intensity to the incident intensity of light beam on the material surface which can be calculated by using following equation [16]:

$$R = \left[\frac{n-1}{n+1}\right]^2 \qquad ---(6)$$

The reflectance values for the prepared samples was increases with the increasing of PVP concentration and additive weights of PEG as shown ion figure (6) which can be attrebute to the increase the number of polymer molecules in the solution and therefore increase the density of the solution, whereas reflectivity is completely dependent on the density [16].

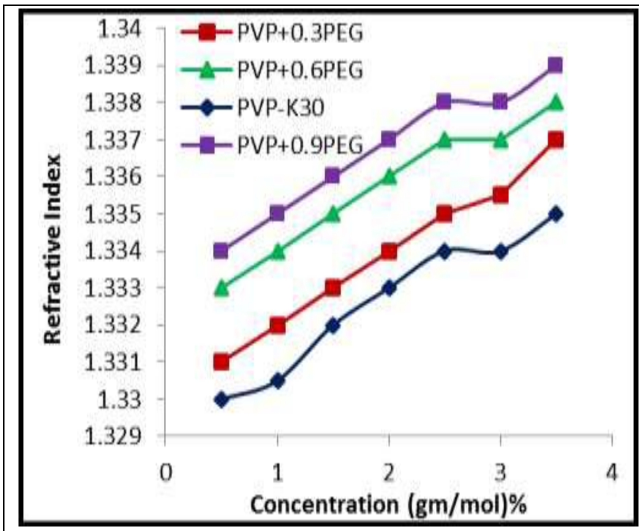

Figure (5): Refractive index as a function of concentration for (PVP and PVP-PEG) polymer blends solutions.

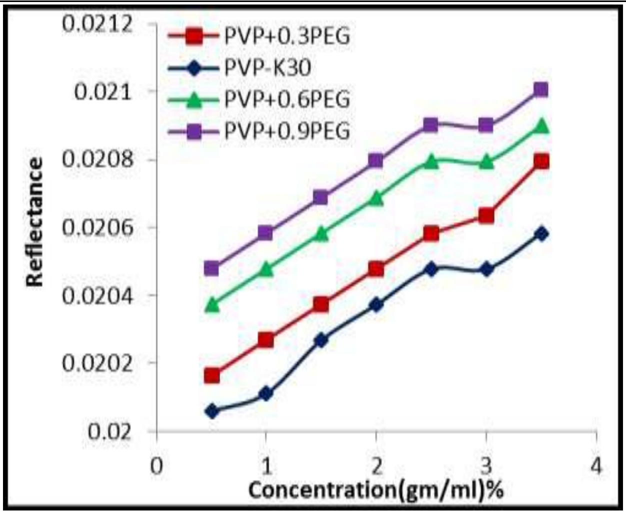

Figure (6): Reflectance as a function of concentration for (PVP and PVP-PEG) polymer blends solutions.

3- Molar reflectance

The molar reflectance R_m is calculated from the equation [17]:

$$R_m = \frac{n^2 - 1}{n^2 + 1}\frac{M}{\rho} \qquad ---(7)$$

Figure (7) show the variation of molar reflectance as a function of PVP concentration before and after addition different weights of PEG. From the figure a slight change in molar reflectivity values with increasing the concentration before and after the addition. The results also showed largely increased in molar reflectivity values after the addition of PEG is due to an increase in the values of viscosity average molecular weight under the influence of the addition due to the fact that molar reflectivity has a direct proportional with the molecular weight [17].

4- Coefficient of finesse

The finesse coefficient F is define as a measure of the severity of interference fringes and measured for the prepared samples by using the equation [18]:

$$F = \frac{4R}{(1-R)^2} \qquad ---(8)$$

The finesse coefficient increase with increasing the PVP concentration and with additive weights of PEG as shown in figure (8) ,which due to increase amount of light reflected as a result of increased density after the addition [18].

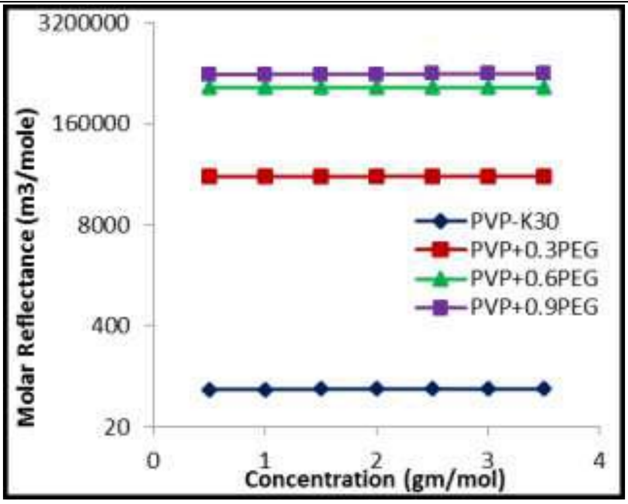

Figure (7): Molar reflectance Vs. concentration for (PVP and PVP-PEG) polymer blends solutions.

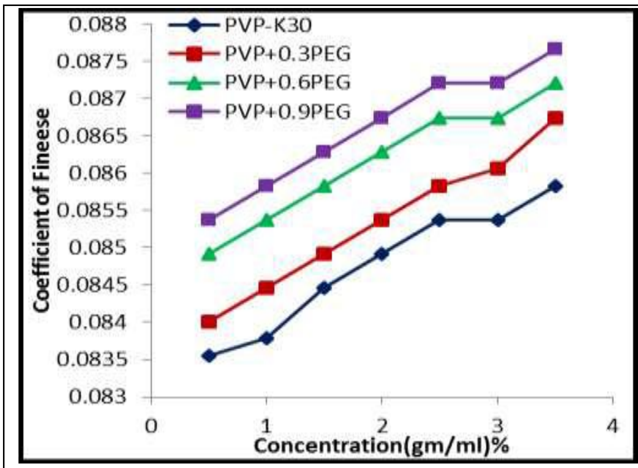

Figure (8) Finesse coefficient Vs. concentration for (PVP and PVP-PEG) polymer blends solutions.

.5- Critical Angle

The critical angle ϴc i is defined as the angle of incidence for which the angle of refraction is 90o and then reflected light fully reflection or internal reflection .The critical angle is calculated from equation [16]:

$$\theta_c = \text{Sin}^{-1}\left(\frac{1}{n}\right) \qquad ---(9)$$

Where: n is refractive index.

The critical angle values decrease linearly with the increase of the concentration as shown in figure (9), because it is inversely proportional of their refractive index, or it is clear that as concentration increase, the density also increase and causes critical angle to decrease [16].

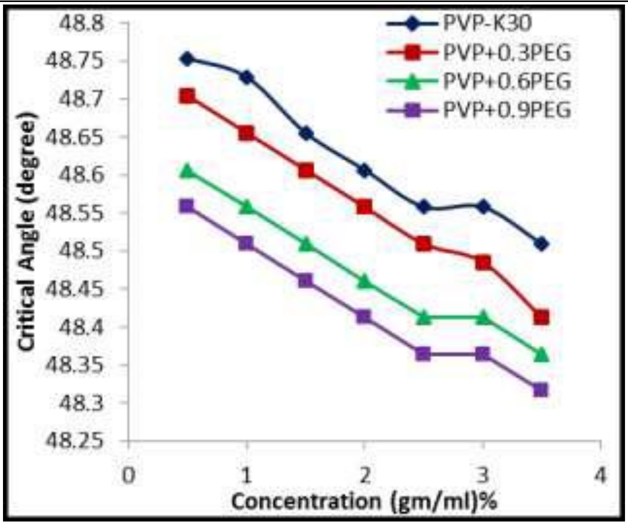

Figure (9) Critical angle versus concentration for (PVP and PVP-PEG) polymer blends solutions.

6- Brewster Angle

The Brewster angle ϴB is define the angle of incidence, which is then the reflected beam is completely polarized , it is calculated from equation [16]:

$$\theta_B = \tan^{-1}(n) \qquad ---(10)$$

The Brewster angle increases with increasing of PVP concentration before and after adding different weights of PEG as shown in figure (10) .Because Brewster angle values depend mainly on the values of the refractive index, where it is directly proportional to the refractive index [16].

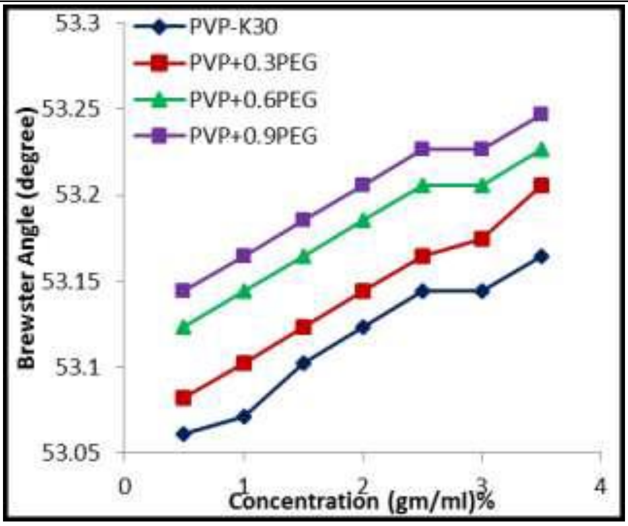

Figure (10) Brewster angle versus concentration for (PVP and PVP-PEG) polymer blends solutions.

4. CONCLUSION

The rheological and optical properties of polymeric blends for PVP k-30 with different solutions concentration and different weight additive of PEG have been investigated. These polymer blends show a continuous change in their rheological and optical properties as a result of concentration increasing of PVP and adding different weight of PEG which led to improvement of these properties. Increasing concentration of PVP and additive weight of PEG leads to increase the viscosity and thus these blends can be used as thicker colloid blend in coating process, oil drilling, pumping processes for reducing the friction of fluids because of its pseudo plasticity characteristic. Also the increasing concentration of PVP and additive weight of PEG leads to increase in the refractive index and the reflectivity of the solution blends, thus it can be used to protect the human skin from the sun's rays and for the manufacture of sunglasses so that the human eye can be protected from the risk of these rays.

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