ISSN: 2476- 2334

Research Article

International Journal of Nanotechnology and Nanomedicine

Rheological Properties of Aqueous Solutions Based on Polyvinylpyrrolidone

Bagirova SR

Baku State University

*Corresponding author
Bagirova SR, Baku State University, Baku, AZ 1148 Azerbaidjan; Email: maarif.jafarov@mail.ru

Submitted: 11 Oct 2019; **Accepted**: 18 Oct 2019; **Published**: 04 Nov 2019

Abstract
The study describes the dependences of the density and viscosity of aqueous solutions of polyvinylpyrrolidone (1 -5%) on temperature (15-50°C) were investigated and the intrinsicviscosity [η] and the Huggins constant (k) were determined. It was obtained that the viscosity decreases monotonically and Hugginsconstant increases with increasing temperature.

Keywords: Polyvinylpyrrolidone (PVP), Polymer, Aqueous Solution, Hugginsconstant, Intrinsic Viscosity

Introduction
Polyvinylpiyrrolidone (PVP) is an extensively used polymer due to its low toxicity to humans and the environment as well as high water solubility. The aqueous solutions of PVP are used in cosmetics (toothpastes, shampoos), pharmacy (tablets), medicine (blood plasma substitute, biomaterials) [1-10].

It is known that high molecular weight (HMW) compounds solutions, in contrast to low molecular weight compounds, have an abnormally high viscosity, which is highly dependent on temperature and concentration [11]. According to modern concepts, long mobile molecules ofHMW solid solutions receive different conformations [11, 12]. As a result of temperature and external influences, the conformation of the coil is changed, and these changes determine the structure and properties of the solution. This conformation can vary from a rigid spherical shape (in poor solvents) to a rigid rod [11, 13].

At a certain velocity gradient during laminar flow, different parts of the macromolecule move with different speeds. As a result, macromolecules are under the influence of double forces that cause it to collapse during flow. During rotation of the macromolecule, a friction force arises between its segments and the solvent molecule, which also increases the viscosity of the solution relative to the solvent.

In this paper, we present the results of the investigations of the dependences of the density and viscosity of aqueous solutions of polyvinylpyrrolidone (1 -5%) on temperature (15-500C).

Experimental Part
Materials
Polyvinylpyrrolidone with molecular weight 10 000, 12 000, 25 000 and 44 000, and 45 000 q/mol were purchased from Alfa Aesar. The provenance and purity of the polyvinylpyrrolidoneare listed in Table 1.

Table 1: The provenance and purity of the polyvinylpyrrolidone

Chemical	CAS number	Source	Formula	Form	Purification
polyvinylpyrrolidone	9003-39-8	Alfa Aesar	$(C_6H_9NO)_n$	powder	as stated by supplier

Sample preparation
Stoichiometric amounts of the Polyvinylpyrrolidone were weighed with accuracy ±0.00001 g. Then they were dissolved in bidistilled water to obtain a solution of a certain concentration and left 1 day for polymer swelling. Then the solution was heated in a water bath without boiling (~80-90°C) to completely polymer dissolve.For experiments, the optimal solution volume was 60 ml.

Methods
The rheological properties were measured using Ostwald viscometer. The measurements uncertainty was 3%. The rheological properties were measured within temperature interval 15-50°C.

The increase in solubility due to the rotation of individual macromolecules is determined by intrinsic viscosity [η]. The density value varies depending on the intensity of the interaction of the macromolecule with the solvent and is described by Mark-Kuhn-Houwink equation [14, 15]:

$$[\eta]=KM^{\alpha} \quad (1)$$

Here K and α are constants for given polymer-solvent system and temperature. M- The weight of macromolecule. The α constant varies between 0÷2 depending on the shape of the polymer molecule. Taking into account that the solvent cannot penetrate into the spherical shape of the molecule, then α=0 while for rigid molecules α=2. If the solvent penetrates into the spherical molecules, then α=2. Intrinsic viscosity η_{int} is determined by extrapolation of the viscosity to zero concentration. This dependence is illustrated by the empirical Huggins equation:

$$\frac{\eta_{int}}{\tilde{n}} = [\eta] + k'[\eta]^2 \tilde{n} \qquad (2)$$

Here c- is solution concentration, *k′*- Huggins constant [16, 17], which characterizes the rheological properties of the solution. From here

$$[\eta] = \lim_{\tilde{n}\to 0} \frac{\eta_{int}}{\tilde{n}} \qquad (3)$$

For each polymer, 5-6 concentrations were measured and then found the average data.

Based on the obtained experimental results, the intrinsic viscosity and Huggins constant were calculated. The results дляfor one sample (5% polymer solution with a molecular weight 25 000) are listed in Table 2 and Figures 1, 2.

Table 2

t°C	ρ_{water}, q/m³	η_{water}, mPa·s	τ_{water}, s	ρ_{sol}, q/m³	τ_{sol},s	η_{sol}, mPa·s
15	0.99862	1.1383	13.36	0.996226	29.1	2.473067
20	0.99823	1.0020	12.36	0.995988	27.2	2.200968
25	0.99681	0.8902	11.34	0.995962	23.5	1.842876
30	0.99568	0.7973	10.51	0.995742	20.8	1.577108
35	0.99372	0.7191	9.6	0.995478	18.8	1.409554
40	0.99225	0.6527	9.15	0.995214	17	1.215227
45	0.98898	0.5961	8.7	0.994906	15.7	1.082167
50	0.9881	0.5471	8.39	0.994599	14.4	0.944504

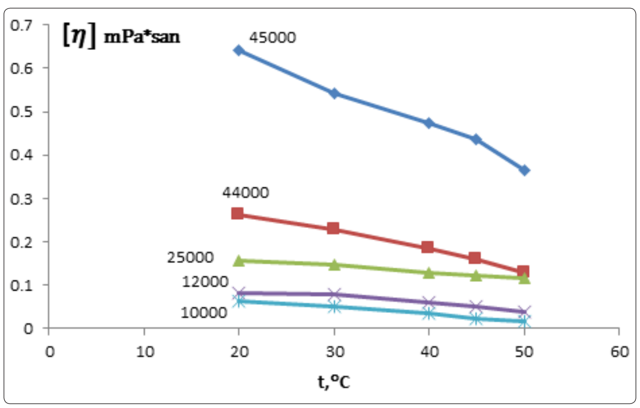

Figure 1: The density as a function of temperature for several polymers

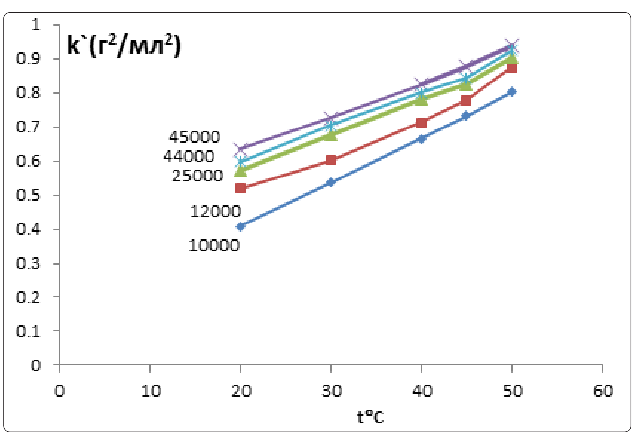

Figure 2: Higgins constant dependences from temperature for several polymers

Results

Apparently, with increasing temperature, the intrinsic viscosity monotonically decreases with monotonicity, but the parameter k′ increases. The nature of this relationship indicates that the polyvinylpyrrolidone (PVP) water system has a low critical solubility temperature. Thus, with increasing temperature, the viscosity of the PVP decreases, which means that the thermodynamic quality of the water is deteriorating. At this time, the coils are compressed, their size decreases, and the viscosity, which characterizes the hydrodynamic resistance during flow, decreases.

The Huggins constant, which characterizes the resistance of solvent permeability to macromolecules in polymer solutions, increases with temperature. It is well known that the Huggins constant characterizes the degree of deformation of a stable molecular particle. For elastic molecules, the value of k′ is greater, and its shape differs from sphericity.

It should be noted that at low molecular weights, the dependence on concentration $\frac{\eta_{max}}{\tilde{n}} - \tilde{N}$ is parallel to the c axis, i.e.

k′ = 0. The permeability of the solvent is high.

Conclusion

Thus, the work presents the results of a study of the dependence of the rheological properties of polyvinylpyrrolidone (1-5%) on temperature (15-50 °C) and the characteristic viscosity [η] and the Huggins constant (k) are determined. The obtained data could be used in different applications.

References

1. Alkhayatt AHO, Al-Azzawi AH, Alakayash Z (2016) Rheological and optical characterization of Polyvinylpyrrolidone (PVP) - Polyethylene glycol (PEG) polymer blends. IOSR Journal of Applied Physics 8: 11-18.
2. Hui Q, Shengqiang N, Chong C, Fen R (2014) Insights into the surface property and blood compatibility of polyethersulfone. polyvinylpyrrolidone composite membranes:toward high-performance hemodialyzer. Polym. Adv. Technol.
3. Marani D, Sudireddy BR, Kiebach R, Nielsen L, Ndoni S (2014) Rheological properties of poly (vinylpiyrrolidone) as

a function of molecular weight. Annual Transactions of the Nordic Rheology Society 209.
4. Acosta M, Wiesner V L, Martinez C J, Trice R W, Youngblood J P (2013) Effect of Polyvinylpyrrolidone Additions on the Rheology of Aqueous, Highly Loaded Alumina Suspensions. J. Am. Ceram. Soc 96: 1372-1382.
5. Fenga Y, Wanga K, Yaoa J, Webleya PA, Smartc S, et al. (2013) Effect of the addition of polyvinylpyrrolidone as a pore-former on microstructure and mechanical strength of porous alumina ceramics. Ceram Inter 39: 7551-7556.
6. Marijana J, Igor S, Zoran Z, Stjepan M (2012) Effect of Polyvinylpyrrolidone on the formation AgBr grains in gelatine Media, Croat. Chem. Acta 85: 269-276.
7. Veeran GK, Guru VB (2011) Water soluble polymers for pharmaceutical applications. Polymers 3.
8. Aboud SR, Al- Bermany AKJ, Megahed N (2009) Effect of Temperature on Some Rheological Properties of Polyvinyl Pyrrolidone (PVP). Egypt. J. Solids 32: 81-88.
9. Zhang J, Jiang D, Lin Q Poly (2005) a dispersant for non-aqueous processing of silicon carbide. Journal of Dispersion Science and Technology 88: 1054.
10. Bashir A, Noor A, Akhtar S (1995) Rheology of polyvinylpyrrolidone in aqueous and organic media. Jour.Chem. Soc.Pak 17: 7-10.
11. Tager AA, Vishvkov SA, Andreeva VM, Sekacheva TV (1974) High molecular weight compounds 16: 9.
12. Uskov IA, Tsylyaeva AM, Klenin VI, Raevsky VS (1976) High molecular weight compounds 18: 243.
13. Flory P J (1953) Principles of Polymer Chemistry. Cornell University Press 266.
14. Bareiss RE (1975) Polymer Handbook, 2nd edition. Wiley Interscience 115-130.
15. Martin Alberto Masuelli (2014) “Mark-Houwink Parameters for Aqueous-Soluble Polymers and Biopolymers at Various Temperatures.” Journal of Polymer and Biopolymer Physics Chemistry 2: 37-43.
16. Huggins M (1942) The Viscosity of Dilute Solutions of Long-chain Molecules. IV. Dependence on Concentration. J. Am. Chem. Soc 64: 2716-2718.