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Elasticity and viscosity of polyvinyl alcohol / sodium bicarbonate (PVA/ $NaHCO_3$) and polyvinyl alcohol /sodium chloride (PVA/ NaCl) samples

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ABSTRACT

Polyvinylalcohol solutions of different concentrations (0.1, 0.2, 0.3, 0.4, 0.5%) of Sodium bicarbonate and Sodium chloride were prepared, then poured onto a glass plate and allowed to dry at room temperature. Thin films were formed. Viscosity, stress and strain were measured for samples The results indicate that the elasticity of the samples in the case of $NaHCO_3$ decreased, where the sample with zero concentration was cut with stress (166X 10^5 N), while the sample with a concentration 5% for $NaHCO_3$ was cut with stress equal to (107X10^4 N), but, in the case of NaCl it increased, where the sample with zero concentration was cut with stress (166X 10^5 N) while the sample with a concentration 5% for NaCl was cut with stress equal to (808X10^6 N. Young's modulus decreases with respect to the samples in the case of $NaHCO_3$, while it increases in the case of NaCl, The relative viscosity increased. Viscosity of the samples that contained $NaHCO_3$ was higher than that of the samples that contained NaCl, while the intrinsic viscosity of all the samples decreases. These results can be used to benefit from them in many fields.

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1. INTRODUCTION

Poly (vinyl alcohol) (PVA) is a thermoplastic synthetic polymer that, unlike many synthetic polymers, is not obtained by polymerization, but by hydrolysis of poly (vinyl acetate) (PVAc),it is well known in its application to the production of fibers, including its use in artificial leather, casing, surgeries, packaging with good stability to rubber articles, petroleum derivatives, emulsifiers,conveyor belts, adhesives for paper and cardboard, and in general special adhesives for gluing paper, textiles, leather and porous ceramic surfaces. Dorel Feldman. [1].

PVA is a creamy or off-white, biocompatible, tasteless, non-toxic, odorless, thermosetting, granular, linear synthetic polymer or powdery semi-crystalline. It has amazing optical properties, high dielectric strength, and excellent charge storage capacity. Its mechanical, optical and electrical attributes can be easily combined by doping with nanofillers, it has different qualities depending on the viscosity and the degree of hydrolysis.

M. Aslam et al. [2], is one of the potential candidates in composite film application due to its hydrophilic properties. In addition to that, PVA has the structure where its carbon backbone has been attached to a hydroxyl group (-OH) to the carbon of methane. P. A. Putro et al. [3].

Sodium bicarbonate is widely available as baking soda and combination products, reacts almost instantly to neutralize HCl and produce CO2 and NaCl. David. H.S. [4]. When sodium bicarbonate dissolves in water, it ionizes and forms $HCO3^{-}$ ions that then react with the H^{+} ions of acids. Mild alkalinity and mild abrasiveness make baking soda a versatile product. It is also classified as a safe food. Sathyasree. M et al. [5]. Sodium bicarbonate (NaHCO3) as an efficient, inexpensive, air-stable and environmentally friendly EIL material in various printed organic electronic devices, including organic solar cells (OSC), organic light-emitting diodes (OLED), organic photodiodes (OPD) and organic n-channel thin film transistors (OFET). The results of UV photoelectron spectroscopy indicated that the output work of several common electrodes used for organic devices such as ITO, Au, Al, and poly (3,4-ethylenedioxythiophene): poly (styrenesulfonate) decreased significantly by more than 1 eV after from the deposition of a thin film of NaHCO3.
Dang. X. L and Yong.Y. N. [6].

Sodium chloride (NaCl) is present in our lives from the chemical balance of our body to the geophysical and biological balance of the Earth. It is also widely used in industry, especially for food preservation. Therefore, it is important to understand the physicochemical properties of sodium chloride as a pure substance or in mixtures. Ra´ul. F.A, and Marcia. C. B. [7].

In solid (NaCl), each ion is surrounded by six oppositely charged ions as expected on electrostatic bases. The surrounding ions are found on top of a regular ctahedron. In the language of compaction, the largest chloride ions are arranged in a cubic lattice, while the smallest sodium ions fill all the cubic spaces (octahedral voids) between them. This same basic structure is found in many other compounds and is commonly referred to as a halite or rock salt crystal structure. It can be represented as a face-centered cubic lattice fcc with a base of two atoms or as two interpenetrating face-centered cubic lattices. The first atom is located at each point in the lattice and the second atom is located midway between the lattice points along the edge of the unit cell (fcc). In addition to its use in the food industry, salt has uses in the agricultural and chemical industries, as well as in the packaging and transportation of water. The antimicrobial activity of the salt can be both direct and indirect depending on the amount added and the purpose for which it serves. Since the amount of sodium chloride that needs to be added to food to prevent microbial growth is large and will cause unacceptable taste, it is usually added in combination with other barriers. S. Ravishankar, and V.K. Juneja. [8].

A stress test is probably the most basic type of mechanical test you can perform on a material. Tensile tests are simple, relatively inexpensive, and completely standardized traction. Material properties are used as the main method of material acceptance, quality control and design limits. The main parameters that describe the stress-strain curve obtained during the tensile test are the tensile strength, the elastic limit, the modulus of elasticity, the percentage elongation and the reduction of the surface. Osoka. E.C, Onukwuli.O. D. [9].The stress-strain state of the composite structures in the connection areas of the elements under the action of forced deformations that break along the contact line of the elements is characterized by an exponential characteristic. The stress-strain state in the irregular point zone of the surface limit under the action of forced deformations, particularly those of temperature, is determined by solving the problem of the homogeneous limit value of the elasticity theory. Lyudmila Frishter. [10]. The stress that a material can withstand can be described by its ultimate strength, while yield strength describes the maximum amount of stress required to elastically deform the part.[11]

Viscosity is an important property of a fluid produced by resistance between its own layer of particles as it flows. This would not only suggest a vital effect on the fluid's motion characteristics, but would also affect its application potentials. Therefore, it is a property of the fluid that provides an indication of resistance to liquids and takes into account one of the specifications of the liquid, as well as an important concept that is considered in different fields. This property is used as a quality index to monitor applications using oils, paints and other fluids where liquid flows are considered a critical property. Sarah. H. A et al.[12]. The viscoelastic properties of polymer solutions are widely used to better understand the structure and conformation of polymers in solution, and the modulus of elasticity also plays a key role in the spreading performance of polymers. Leilei. T et al. [13].

2. RESEARCH METHOD

2.1. Samples and Measurements

Materials were provided by Sigma-Aldrich GMBH, polyvinyl alcohol (PVA: 99 + 40 hydrolyzate, Mw 85000), sodium bicarbonate and sodium chloride were used to prepare the samples for this article by dissolving 0.75 g of PVA in 40 ml twice -distilled water for one hour, while stirring and heating to 80 ° C. The solution was kept under stirring until it cooled to room temperature, then adding sodium chloride and sodium bicarbonate in different solutions of polyvinyl alcohol in equal concentrations (0.1, 0.2, 0.3, 0.4, 0.5%). The solutions flow time were measured, poured onto a level glass plate and allowed to dry at room temperature for approximately 120 h. Thin films almost 0.05 mm thick were formed, then the changes in the length of the thin films by the effect of increasing loads were measured.

Note: Sodium chloride must be dissolved in a little water before adding it to the solution, so that it does not have a mass like the phenomenon in figure 1 when added to the solution directly, taking into account the concentration of the polyvinyl alcohol in the Solution.

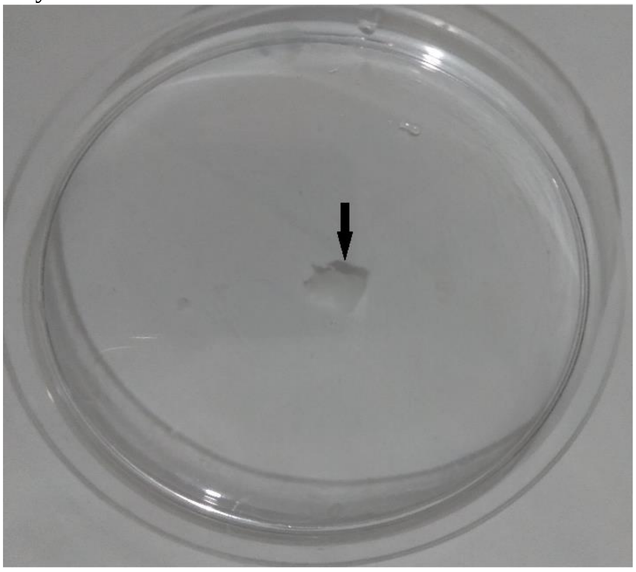

Figure 1. Sodium chloride clumps together and does not dissolve when added directly to the polymer solution

2.2. Calculations

2.2.1. Mechanical properties

By known cross sectional area A, and F is the fource applied by the tensil testing machinc, then the tensile stress σ_s is. A.V.Pocius. [14]:

$$\sigma_s = \frac{F}{A} \qquad (1)$$

If the original length of the sample is L_0 and the length of the sample after a certain amount of tensile stress was applied is L, so the engineeting tensile strain ε defined as. A.V.Pocius. [14]:

$$\varepsilon = \frac{(L - L_0)}{L_0} \qquad (2)$$

The relationship of stress and strain is as:

$$\sigma_s = E\, \varepsilon \qquad (3)$$

Where E is a constant called elastic modulus. Chao. C et al. [15]:

The dependence of stress- strain relation for different test samples is given by:

$$\frac{\sigma_s}{2(\lambda - \lambda^{-2})} = C_1 + C_2 \lambda^{-1} \qquad (4)$$

Where λ is extension ratio (λ = 1+ε), C_1 is a quantitiy pertaining to the ideal elastic behavior, and C_2 express the departure from the ideal elastic behavior. S.S. Hamza et al. [16], M. Abu- Abdeem. [17].

2.2.2. Viscosity measurements

To determine the flow time of the solutions, the methodology provided by ASTM (1989) was used. The flow time of the solvent and the solutions was measured with a capillary glass viscometer. The measured values were expressed in terms of the relative (η_r), specific(η_{sp}), and intrinsic([η]) viscosities of intersection of all solutions as follows. EL-Ashhab. F et al. [18]:

$$\eta_r = \frac{t_{solution}}{t_{solvent}} \qquad (5)$$

$$\eta_{sp} = \eta_r - 1 \qquad (6)$$

$$[\eta] = \lim_{c\to\infty} \frac{\eta_{sp}}{C} \qquad (7)$$

Where C is the mass concentration of sodium bicarbonate or sodium chloride in the solutions. EL-Ashhab. F et al. [18].

The Huggins equation is an empirical equation used to relate the reduced viscosity of a dilute polymer solution to the concentration of the polymer in solution. P.Ramón et al. [19]. Then equations of Huggins (K_H) and Kramer (K_K), defined respectively as. M. Acevedo et al. [20]:

$$\frac{\eta_{sp}}{c} = [\eta] - K_H [\eta]^2 c \qquad (8)$$

$$\frac{\text{Ln}\ \eta_r}{c} = [\ \eta\ ] + K_K [\eta]^2 c \qquad (9)$$

2.2.3. Figures and Table

Figure 2(a) shows plot of stress against strain for PVA/ $NaHCO_3$ thin films, while the figure 2(b) represented the relationship between stress and strain for PVA/ NaCl thin films.

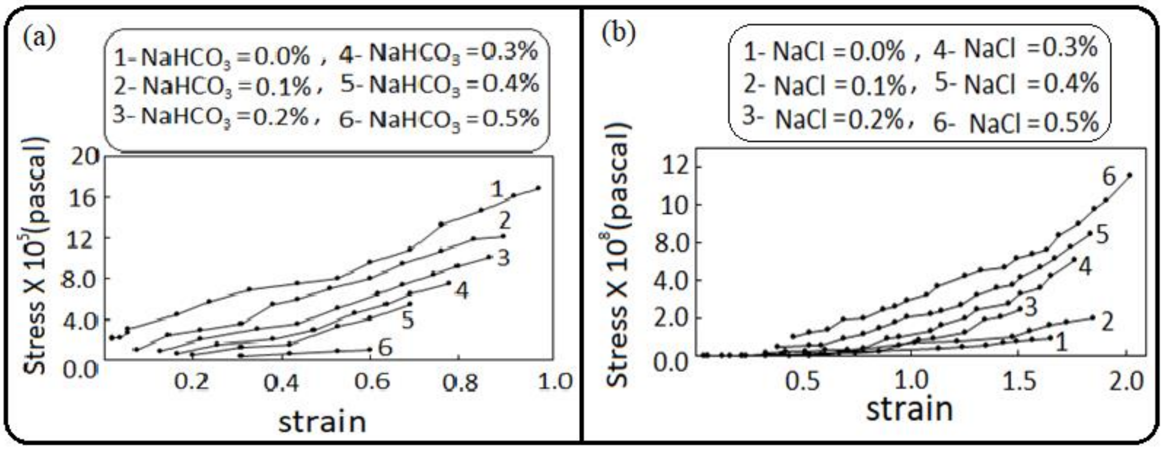

Figure 2. (a)The effect of concentration of $NaHCO_3$ on stress-strain curves for PVA thin films.
(b) The effect of concentration of NaCl on stress-strain curves for PVA thin films.

Young’s modulus curves which are represented the relationship between Young’s modulus and the concentration of $NaHCO_3$ or NaCl ploted in Figure 3(a) for PVA/ $NaHCO_3$ thin films and in Figure 3(b) for PVA/ NaCl thin films.

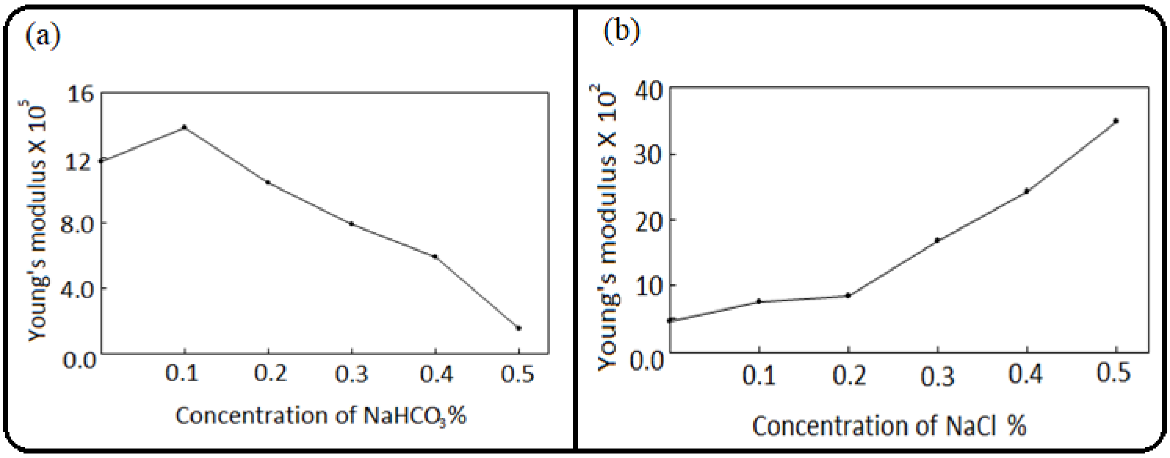

Figure 3. (a) Young’s modulus curve of PVA/ $NaHCO_3$ thin films.
(b) Young’s modulus curve of PVA/ NaCl thin films.

The Strain amplification factor curve for PVA/ $NaHCO^3$ thin films and PVA/ NaCl thin films were ploted in figure 3(a) and figure 4(b) respectively.

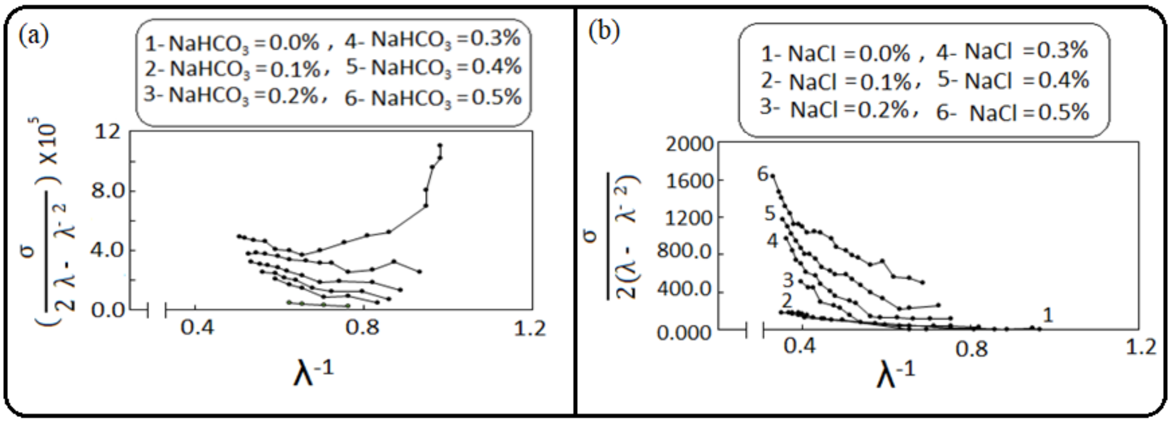

Figure 4. (a) Strain amplification factor curve for PVA/ NaHCO[3] thin films.
(b) Strain amplification factor curve for PVA/ NaCl thin films.

The relative viscosities of PVA/ $NaHCO_3$ and PVA/ NaCl solutions are compared in figure 5 by plotting it as a function of concentrations, while in figure 6 ploted the specific viscositeis versus the concentrations for same solutions.

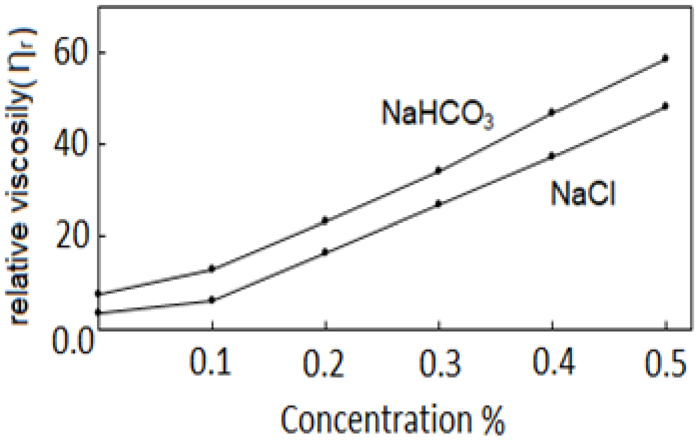

Figure 5. Relative viscosity vs concentration for PVA/ $NaHCO_3$ and PVA/ NaCl solutions at 30^{o}C.

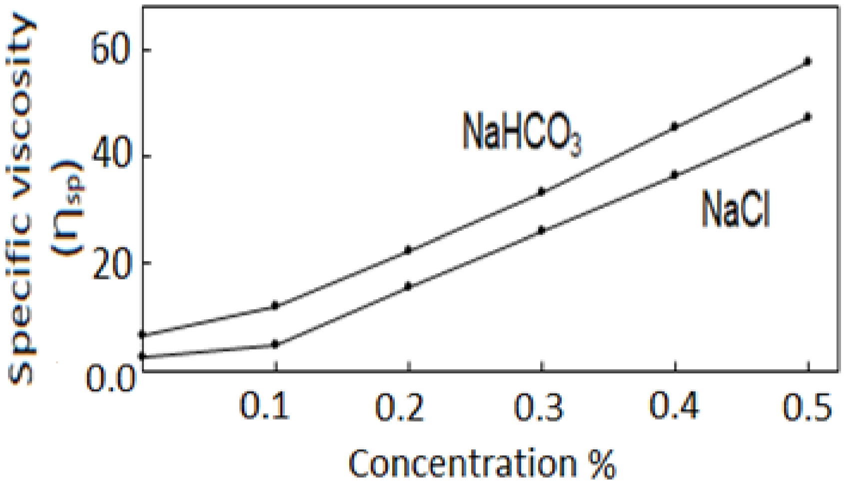

Figure 6. Specific viscosity vs concentration for PVA/ $NaHCO_3$ and PVA/ NaCl solutions at 30^{o}C.

The relationship between rdruced viscosity and specific viscosity for the PVA/ $NaHCO_3$ and PVA/ NaCl solutions are shown in figure 7.

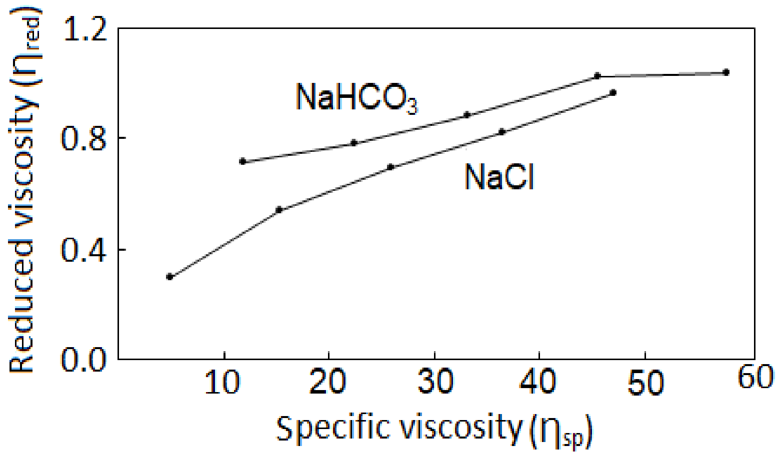

Figure 7. Rdruced viscosity vs Specific viscosity for PVA/ $NaHCO_3$ and PVA/ NaCl solutions at 30ºC.

Figure 8 shows the evolution of the intrinsic viscosity as the concentration changes; however, Figure 9 shows the plot of the Schulz-Blaschke constant ksb versus flow time.

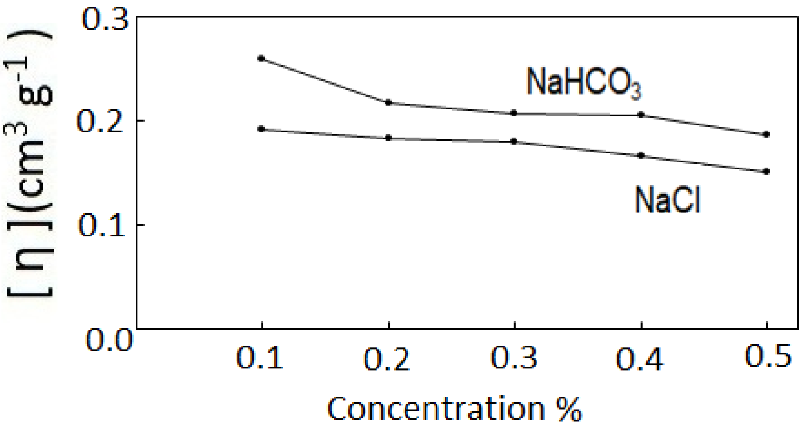

Figure 8. Intrinsic viscosity vs concentration for PVA/ $NaHCO_3$ and PVA/ NaCl solutions at 30ºC.

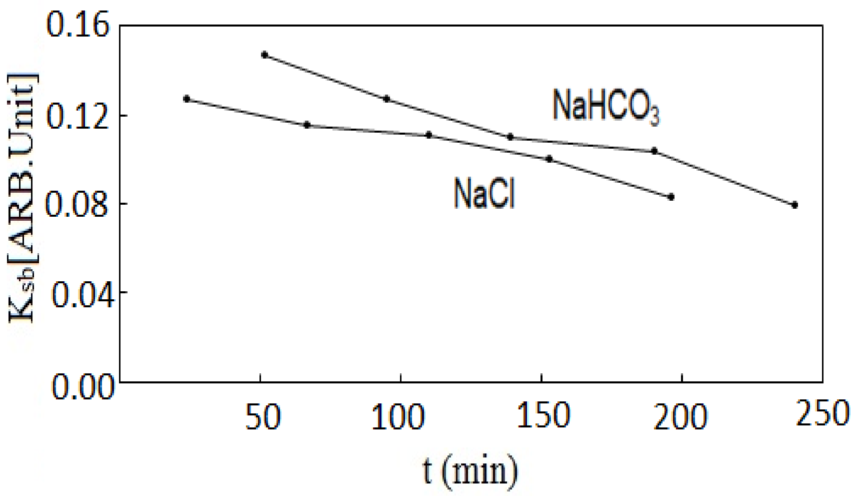

Figure 9. Schulz-Blaschke constant vs Flow times of solutions

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The constants K_H and $K_{K \text{ in table.1}}$ can be calculated from the slopes of figure8, used equation. (8) and equation. (9) respectively. These constants depend on the solution state.

Table1. Huggins and Kraemer constants of solutions with different concentrations of NaCl and $NaHCO_3$.

Concentration (%)	K_k of NaCl	K_H of NaCl	$(K_H + K_K)$ of NaCl	K_k of $NaHCO_3$	K_H of $NaHCO_3$	$(K_H + K_K)$ of $NaHCO_3$
17	0.138478	0.171701	0.310179	0.094425	0.405577	0.500002
29	0.088854	0.375565	0.464419	0.079304	0.420696	0.500000
38	0.075856	0.424145	0.500001	0.070300	0.427846	0.498146
45	0.68962	0.536226	0.605188	0.063458	0.438407	0.501865
50	0.064349	0.741633	0.805982	0.058600	0.441399	0.499999

The tables. 1 and 2 contain variable values for the two constants C_1 and C_2 with the variable values of the NaCl and $NaHCO_3$ concentration in the solutions.

Table2. The value of constant C_1 and C_2 for different concentration of PVA/ $NaHCO_3$ samples.

Concentration $NaHCO_3$ (%)	C_1	C_2	$C_1 + C_2$
0.0	-11038470.2	15772215	4733744
0.1	0	466677.6	466677.6
0.2	0	359336.2	359336.2
0.3	0	253087	253087
0.4	0	331249.5	331249.5
0.5	0	50733.74	50733.74

Table3. The value of constant C_1 and C_2 for different concentration of PVA/ NaCl samples.

Concentration NaCl (%)	C_1	C_2	$C_1 + C_2$
0.0	-145.999	181.2594	35.26016
0.1	-290.375	321.8725	31.49732
0.2	-326.062	367.2212	41.15893
0.3	-809.083	826.7407	17.65788
0.4	-760.06	739.7154	-20.345
0.5	-2119.28	1984.826	-134.452

3. RESULTS AND DISCUSSIONS

3.1. Mechanical properties

In the figure 2 (a), the slope of the stress curve decreases with increasing $NaHCO_3$ concentration in solutions, while increasing NaCl concentration in solutions increases the slope of the stress curve shown in the figure 2 (b), this result is confirmed by the relationship of Young's modulus with concentration in the two figures 3(a) and (b), where a decrease in Young's modulus appears with an increase in $NaHCO_3$ concentration in the figure 3 (a) and the modulus increases with an increase in concentration of NaCl in the figure 3 (b).

From the strain amplification factor graphs in Figures 4 (a) and (b), the constants C1 and C2 are easily determined, C1 from the intercept with the ordinate and C2 from the slope. The wave behavior of C1 and C2 with concentrations may be due to competition between increasing and decreasing the number of crosslinks in the network and other defects in the network. S.S. Hamza et al. [16], M. Abu- Abdeem. [17].

3.2. Viscosity measurements

Figure 5 demonstrates that the relative viscosity increases monotonically with increasing concentration. Also, taking into account the Figure 5 indicates that the relative viscosity values of the PVA / NaCl solutions are lower than the viscosity values of the PVA / $NaHCO_3$ solutions. Therefore, it is clear that concentrations produce changes in the viscosity of all solutions. Viscosity is an important parameter during the electrospinning process. Zhao. Y, Wu et al. [21]. As the viscosity increases, meaning there will be more polymer chain entanglements in the solution, the charges on the electrospinning jet will be able to fully stretch the solution with the distributed solvent molecules between polymer chains. Hosnie. B et al [22]. This is probably due to the solution's greater resistance to being stretched by jet loads. . Hosnie. B et al [23]. The specific viscosity (η_{sp}) of two types of solutions that are calculated by the equation 6 compared to the concentrations of NaHCO and NaCl solutions are represented in the figure 6, where it indicates an increase in specific viscosity with increasing concentration. Specific viscosity depends on concentration and interaction forces. R. Pamies et al. [24]. As shown in Figure 8, the intrinsic viscosity decreased with increasing concentration of nanoparticles, however, the intrinsic viscosity which is calculated by equation 7 of PVA/.$NaHCO_3$ solutions still greater than that of PVA/.NaCl solutions. The Schulz–Blaschke constant k_{sb} values against flow time, it reflects how far the values of Schulz–Blaschke constant of the solutions decreased with increasing the flow time, as showen in in Figure 9. This could be attributed to scission on the polymer chains. EL-Ashhab. F et al. [18].

The constants K_H and K_K can be calculated from the slopes of the previous figures, used respectively by equation (4) and equation (5). These constants depend on the state of the solution. A. K. Mahanta et al. [24]. The range of 0.25 to 0.5 in the Huggins coefficient (K_H) is attributed to good solvation. M. Acevedo. [20]. As shown in table 1 K_H values ranged from 0.17 to 0.7 for solutions with different concentrations of NaCl, but ranged from 0.49 to 0.5 for solutions with different concentrations of $NaHCO_3$, this indicates that the polymer is a good solvent for $NaHCO_3$ and not good for NaCl.

4. CONCLUSION

The results indicate that the elasticity of the samples in the case of $NaHCO_3$ decreased, while in the case of NaCl it increased, as well as the Young's modulus, and for the figures of the viscosity of solutions indicate increased viscosity with increased concentration, but PVA/NaHCO solutions have viscosities higher than that of PVA/ NaCl. The treatment of viscosity data based on Huggins and Kraemers relationships allowed for evaluation of intrinsic viscosity of the PVA solutions with different concentration of NaHCO and NaCl.

Therefore, these results can be used to improve the properties of polymers, their solutions and segments, to benefit from them in many fields, such as industrial and medical applications and scientific studies.

REFERENCES

[1] Dorel Feldman.(2020). " *Poly (Vinyl Alcohol) Recent Contributions to Engineering and Medicine*", Journal of composites science, 4, 175; doi: 10. 3390/jcs4040175.

[2] M. Aslam, M. A. Kalyar, Z. Al. Raza. (2018). *"Polyvinyl Alcohol: A Review of Research Status and Use of Polyvinyl Alcohol Based Nanocomposites"*, Research Gate, Polymer Engineering and Science· DOI: 10.1002/pen.24855

[3] P. A Putro, N. Yudasari, and A. Maddu. (2019). *"Spectroscopic Study on the Film of Polyvinyl Alcohol and Carboxymethyl Cellulose as Polymer Electrolyte Materials"*, Journal of Physics: Conference Series, 1491.012033 doi:10.1088/1742-6596/1491/1/012033.

[4] David H.S. (2017)." *Pharmacology and Therapeutics for Dentistry, 28 - Drugs Acting on the Gastrointestinal Tract",*Science Direct journal and book, Pages 404-416.seventh edition. https://www.sciencedirect.com/science/article/pii/B978032339307200028X https://www.sciencedirect.com/topics/neuroscience/sodium-bicarbonate

[5] Sathyasree. M, and Sivakumar.J. (2018). "Sodium bicarbonate: A review and its uses in dentistry", REVIEW ARTICLE, Volume 29, Issue 5, Page 672-677. DOI: 10.4103/ijdr.IJDR_30_17.

[6] *Dang. X. L and Yong.Y. N. (2018). "Baking soda: an ultra-cheap and air stable electron injection layer for organic electronic devices",* Journal of Materials Chemistry C, 6, 12871-12878. DOI https://doi.org/10.1039/C8TC04421J.

[7] Ra´ul. F.A, and Marcia. C. B.(2018). "*Sodium Chloride, NaCl/ϱ: New Force Field*", Cornell University, arXiv:1508.01971v2. https://arxiv.org/pdf/1508.01971.pdf.

[8] S. Ravishankar, and V.K. Juneja. (2014)." *Reference Module in Food Science, Encyclopedia of Food Microbiology, PRESERVATIVES | Traditional Preservatives – Sodium Chloride*", Science Direct journal and book, 2014, Pages 131-136. Second Edition. https://doi.org/10.1016/B978-0-12-384730- 0.00259-7.

[9] Osoka. E.C, Onukwuli.O. D. (2018). "*Determination of Mechanical Properties from Stress-Strain Data: A New Approach",* International Journal of Engineering Research and Advanced Development, Volume 4, Issue 05, DIP: 18.03.08/20180405. http://www.ijerad.redmac.in

[10] Lyudmila Frishter. (2018). "*Comparison of the stress and strain intensity factors for the corner area of the structure boundary*", MATEC Web of Conferences 193, 03029. https://doi.org/10.1051/matecconf/201819303029

[11] Maurya. G.*" Selection of material through 'Thermal-Stress' analysis on Fusion 360 for a brake rotor"*, International Journal of Engineering and Applied Physics (IJEAP), Vol. 1, pp. 285~294, 2021.

[12] Sarah. H. A, Ali. A. D, Anwar. H. Al, and Haidar. J.M. (2019). *"Measure liquid viscosity by tracking falling ball Automatically depending on image processing algorithm"*, Journal of Physics: Conf. Series 1294 022002 doi:10.1088/1742-6596/1294/2/022002.

[13] Leilei. T, Meng.Y, Xiang. L, Wenhui. L, Bo. Z, Zhen. C, Yufei. Z. (2019). "Research on polymer solution rheology in polymer flooding for Qikou reservoirs in a Bohai Bay oilfield" , Journal of Petroleum Exploration and Production Technology .703–715. https://doi.org/10.1007/s13202-018-0515-7

[14] A.V.Pocius. (2002). *"Adhesion and Adhesives Technology AnIntroduction*", Carl Hanse Verlag Munich UK 2nd edition.

[15] Chao. C, M. A. Garrido, J. Ruiz-Hervias, Zhu. Z,1 and Le-le Zhang.(2018)." *Representative Stress-Strain Curve by Spherical Indentation on Elastic-Plastic Materials"*, Advances in Materials Science and Engineering Volume 2018, Article ID 8316384, 9 pages. https://doi.org/10.1155/2018/8316384

[16] S.S. Hamza, S. El-sabbagh, and F. Shokr. (2008)." *Elastic Behavior of NR/IIR Rubber BlendLoaded with Different Compatibilizers",* Internatioal Journal of polymeric Materials, 57. 203. 215.

[17] M. Abu- Abdeen. (2001). "*Degradation of the Mechanical properties of composite vulcanizates loaded with paraffin wax*", Journal of Applied Polymer, vol.81, 2265-m2270.

[18] EL-Ashhab. F, Sheha. L, Abdalkhalek. M, Hussein. A. K. (2013). "*The influence of gamma irradiation on the intrinsic properties of cellulose acetate polymers"*, Journal of the Association of Arab Universities for Basic and Applied Sciences, 14,pp. 46–50. http://dx.doi.org/10.1016/j.gaubass.2012.12001

[19] P.Ramón, G. H. Cifre, José, L. Martínez, M.del Carmen, G. de la Torre. (2008)." *Determination of intrinsic viscosities of macromolecules and nanoparticles. Comparison of single-point and dilution procedures"*, Colloid Polym Sci. 286:1223–1231. DOI 10.1007/s00396-008-1902-2.

[20] M. Acevedo, J. Laitano, M. Marrugo, A. Herrera, Á. Realpe. (2017), International Journal of ChemTech Research, 10. 199-208.

[21] Zhao. Y, Wu. X, Wang. L, Xua. L, Weib. S. 2012. A facile method for electrospinning of Ag nanoparticles /poly (vinylalcohol)/carboxymethyl-chitosan nanofibers, Applied Surface Science 258, 8867– 8873. http://dx.doi.org/10.1016/j.apsusc.2012.05.106.

[22] Hosnie. B, Seyed.H.B. (2015). Chitosan/ Nanosilver Composites with Enhanced Morphology and Microbiogical properties, Journal of Textiles and polymers, vol 3, No 2.

[23] R. Pamies, J. Ginés. H, M.del Carmen, J. García. (2008). "*Determination of intrinsic viscosities of macromolecules and nanoparticles. Comparison of single-point and dilution procedures*" Colloid Polym Sci (2008) 286:1223–1231. DOI 10.1007/s00396-008-1902-2

[24] A. K. Mahanta, P. K. Pattnayak.(2015)." *Green analytical methods for determination of intrinsic viscosity of hydroxyl terminated polybutadiene* "J. Mater. Environ. Sci. 6 (9) 2377-2385