Original Research Article

Ultrasonic Characterization of aqueous Polyvinyl Pyrrolidone (PVP)

ABSTRACT

Aim: Various thermo acoustic parameters such as adiabatic compressibility (β_a), relaxation time(τ), acoustic impedance (z), classical absorption ($\frac{\alpha}{f^2}$), free length (L_f), isothermal compressibility (β_i), volume expansivity (α) and Moelwyn-Hughes parameter (C_1) of aqueous polyvinyl pyrrolidone (PVP) solution were obtained from the measurement of ultrasonic velocity (u) , density(ρ) and viscosity(η).
Methodology: All these measurements were made by Pulse Echo technique at different concentration of the range 0.05 to 0.3wt.% and at 288K, 293K, 298K, 303K and 308K. The ultrasonic velocity (u) was observed to vary linearly with concentration of polyvinyl pyrrolidone (PVP) solution.
Results: This indicates the single phase formation and the compatibility of aqueous PVP. The compatibility is due to the linear chain structure of the polymer. Adiabatic compressibility and free length decreases linearly with increase in concentration of aqueous PVP solution indicates that the strong interactions, association and non-dominance of PVP in water, because there is no abrupt change in the variation at any concentration. The increase in acoustic impedance (z) of aqueous PVP solution indicates that there is a strong molecular interaction between the polymer and the solvent molecules and the structural arrangement may be affected. This change in the structure of solvent or solution is a result of hydrogen bond formation and structure making property of PVP in solution.
Conclusion: Due to linear nature of ultrasonic parameters like ultrasonic velocity, adiabatic compressibility, etc. in polyvinyl pyrrolidone (PVP) solution indicates that this (PVP) water soluble polymer can be used as tablet binder in pharmaceutical industries.

Keywords: Pulse echo, Polyvinyl Pyrrolidone (PVP),ultrasonic velocity, adiabatic compressibility, other thermoacoustical parameters, etc.

1. INTRODUCTN

Thermo-acoustic properties of water soluble polymer are of considerable scientific and technological interest. These are important for understanding solute-solvent and solute-solute interactions. Knowledge of volumetric properties of polymer solutions has been proven to be a very useful tool in evaluating the structural interactions occurring in the solution. Many research groups have focused their attention to obtain information on the thermodynamics of aqueous polyethylene glycol (PEG), which is often used in biotechnology. In this respect, thermodynamic properties such as vapour + liquid equilibria, density and viscosity have been obtained[1]. However, similar information on the thermodynamics of aqueous solution of polyvinyl pyrrolidone (PVP), which is also a very important system in respect to its use in biotechnology, in scarce. In the present study an attempt has been made to obtain information on hydration[2] of PVP by measuring various thermo acoustic properties such as ultrasonic velocity (u), density (ρ), viscosity (η), adiabatic compressibility (β_a), relaxation time(τ), acoustic impedance (z), classical absorption ($\frac{\alpha}{f^2}$), free length (L_f), volume expansivity (α) and parameter (C_1) of aqueous polyvinyl pyrrolidone (PVP) solution at different temperature, different concentration & at different frequencies (1MHz, 2MHz & 5MHz).

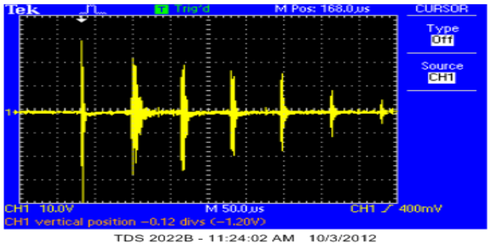
2. MATERIALS AND METHODS

Ultrasonic velocity, density and viscosity values are estimated in the aqueous polyvinyl pyrrolidone solution. The solution was prepared by adding a known weight of polyvinyl pyrrolidone to a fixed volume of distilled water and then stirring until clear solution were obtain. The concentration range chosen in the solution are 0, 0.05, 0.1, 0.15, 0.2, 0.25, & 0.3 wt%. Velocity measurements are carried out using ultrasonic pulse echo technique using MHF-400 pulser receiver and Tektronix- 2 Channel Digital Storage Oscilloscope from Roop Telsonic Ultrasonix Ltd. Mumbai- India at different frequencies of 1 MHz, 2MHz & 5MHz and at temperature range 288K-308K with an accuracy of ±0.1m/sec. Density has been measured by pycnometer method. The viscosity of liquid was measured by Oswald's viscometer. Temperature is maintained at a fixed range by Plasto Crafts Thermostat and other related parameters calculated by standard formulae given below:

2.1 Formulae

1. Density $\rho = \frac{M_l}{M_w}\rho_w$
2. Viscosity $\eta = \frac{\rho_l t_l}{\rho_w t_w}\eta_w$
3. Adiabatic compressibility $\beta_a = \frac{1}{u^2\rho}$
4. Relaxation Time $\tau = \frac{4}{3}\eta.\beta_a$
5. Acoustic Impedance $Z = \rho.u$
6. Classical Absorption $({}^{\alpha}/_{f^2})class = \frac{8\pi^2\eta}{3\rho u^3}$
7. Free Length $L_f = K_j\beta_a^{1/2}$ *Where, K_j - Jacobson's constant*
8. Volume Expansivity $\alpha = -\frac{1}{\rho}(\frac{\partial\rho}{\partial T})$ *Where, T- temperature*
9. Moelwyn-Hughes parameter $C_1 = [{}^{13}/_3 + (\alpha T)^{-1} + {}^{4}/_3\,\alpha T]$

Echo Pattern



Echo obtained from pulser receiver

3. RESULTS AND DISCUSSION

Graphical and tabular representation of various thermo-acoustic parameters such as ultrasonic velocity (u), density (ρ), viscosity (η), adiabatic compressibility (β_a), relaxation time(τ), acoustic impedance (z), classical absorption ($\left(\frac{\alpha}{f^2}\right)$), free length ($L_f$), volume expansivity (α) and parameter (C_1) shown below:

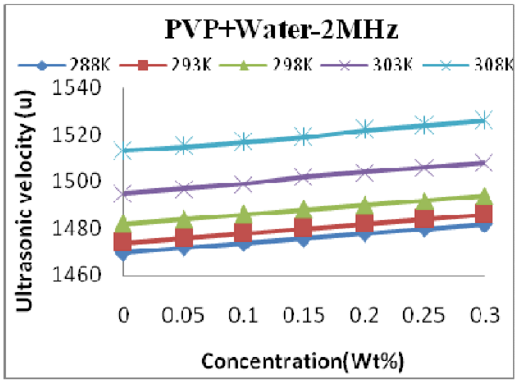


Figure 1

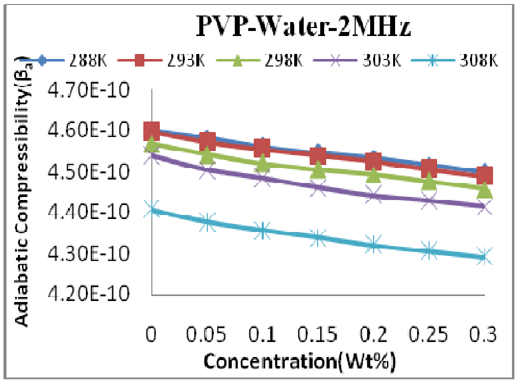


Figure 2

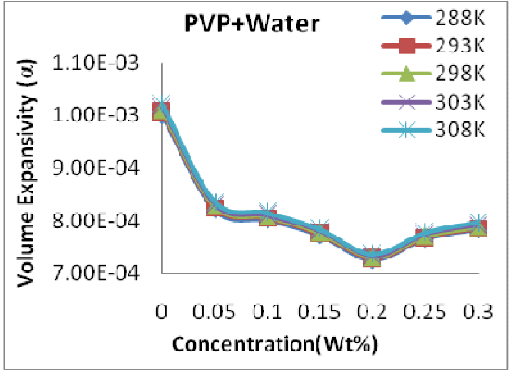


Figure 3

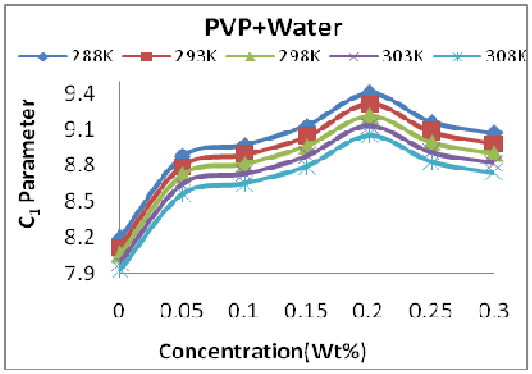


Figure 4

Table for thermo-acoustic parameters

T= 298K and f= 2MHz

Parameters/Conc. (wt%) →	0.00	0.05	0.1	0.15	0.2	0.25	0.3
Density(ρ)	996.798	999.935	1001.86	1002.26	1002.77	1003.48	1004.99
Viscosity(η)	8.93E-04	9.02E-04	9.04E-04	9.11E-04	9.12E-04	9.19E-04	9.34E-04
Acoustic Impedance (Z)	1.48E+06	1.48E+06	1.49E+06	1.49E+06	1.49E+06	1.50E+06	1.50E+06
Relaxation Time(τ)	5.44E-13	5.46E-13	5.45E-13	5.47E-13	5.46E-13	5.49E-13	5.55E-13
Free Length (L_f)	4.18E-11	4.17E-11	4.16E-11	4.15E-11	4.14E-11	4.13E-11	4.12E-11
$(\alpha/f^2)_{class}$	7.24E-15	7.26E-15	7.23E-15	7.25E-15	7.23E-15	7.25E-15	7.33E-15
Volume Expansivity(α)	1.01E-03	8.28E-04	8.07E-04	7.78E-04	7.31E-04	7.71E-04	7.89E-04
Parameter (C_1)	8.06	8.72	8.81	8.96	9.21	8.99	8.9

Figure 1 shows variation of ultrasonic velocity with concentration (wt.%) at 288K to 308K. It is observed that the ultrasonic velocity varies linearly with increase in concentration of poly vinyl pyrrolidone in solution. It shows molecular association in PVP solution. It also gives the evidence to enhance the miscibility [1] among the molecules presence in the poly (vinyl pyrrolidone) solution. The hydration state and its dynamic behavior are also explained in the light of formation of inter- or intra-molecular hydrogen bonds between adjacent OH groups [2-3].

Figure 2 shows variation of adiabatic compressibility with concentration (wt.%) at 288K-308K and at 2MHz. It gives exactly opposite behavior that of ultrasonic velocity, it shows molecular association in PVP solution [4]. This behavior shows strong association at higher concentration of PVP in water.

Table shows Acoustic impedance (Z) increases with increase in concentration (wt.%) of PVP solution. The increase in acoustic impedance (Z) indicates that there is a strong molecular interaction between the polymer and the solvent molecules and the structural arrangement may be affected [5]. This change in the structure of solvent or solution is a result of hydrogen bond formation and structure making property of PVP in solution.

Variation of density and viscosity with concentration (wt. %) is as shown in table. It increases with increase in concentration of polyvinyl alcohol solution. Increase in density is due to the fact that the number of PVP chains added to the solution increases with increasing PVP concentration (wt.%). Polymers are characterized by the large molecular weight compared to the solvents. This also contributes to increase in the density of the solution. The value of density and viscosity increases with increase in concentration of PVP solution. This change in the structure of solvent or solution is a result of hydrogen bond formation and structure making property of PVP in solution [6].

Linear variation of free length with concentration (wt.%) in PVP solution shown in above table. It decreases linearly with increase in concentration of PVP in solution indicates that the strong interactions, association and non-dominance of PVP in solvent, because there is no abrupt change in the variation at any concentration (wt%).

Table shows relaxation time and classical absorption increases with increase in concentration (wt.%) of PVP in solution. It indicates that the solution is highly ordered due to outstanding hydration and such solution generally absorbs more ultrasonic energy [6-7].
The variation of density with temperature gives volume expansivity. Figure 3 and 4 shows variation of volume expansivity and Moelwyn-Hughes parameter. It exhibits exactly opposite behavior shows strong association between PVP and water molecules due to the formation of inter or intra-molecular hydrogen bonds between adjacent OH groups [7].

4. CONCLUSIONS

I. The linear variation of ultrasonic velocity with concentration gives the evidence to enhance the compatibility among the molecules presence in the PVP solution.
II. The linear decrease in adiabatic compressibility and free length with increase in concentration of PVP solution indicates the strong interactions, association and non-dominance of PVP in water.
III. The hydration state and its dynamic behavior are also explained in the light of formation
of inter or intra-molecular hydrogen bonds between adjacent OH groups.
IV. The linearity in all the parameters indicates there is a single phase formation. It predicts strong polymer-solvent interaction and strong association in the PVP solution.
V. This water soluble polymer (PVP) is used in pharmaceutical industries for tablet binder.

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