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Ultrasonic study of polyvinyl butyral

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The Ultrasonic behavior of polyvinyl butyral has been studied in the solvent acetic acid at different temperatures in the range 35-45 °C. Acoustical and other related parameters like ultrasonic velocity, adiabatic compressibility, acoustic impedance, relaxation time etc., have been computed from the experimentally measured density and viscosity data. The results of these parameters are attributed to intermolecular interactions between solute and solvent.

Keywords: Ultrasonic velocity, Adiabatic compressibility, Acoustic impedance, Relaxation time.

1 Introduction

Ultrasonic velocity and derived ultrasonic parameters are of considerable interest in understanding the nature and strength of various intermolecular interactions. Such studies have been found to provide information regarding the intermolecular processes[1-2]. Ultrasonic measurement can be used as powerful probe to study the structural, physical and chemical properties of matter. The ultrasonic velocity is one of those physical properties that helps in understanding the nature of liquid state. Ultrasonic velocity together with density and viscosity data furnish a wealth of information about the sum total of interactions between ions, dipoles, H-bonding, multipolar and dispersion forces[3-6].

The extensive use of polymeric materials in technology have prompted ultrasonic studies to help to understand the structures of polymers and molecular interactions in solutions and nature of polymers[7-8]. The properties of polymer solution depend on the nature and size of the polymer chains and also on the interaction between polymer and solvent molecule.

2 Experimental Details

Solutions of polyvinyl butyral of different concentration were prepared by adding known weight of polyvinyl butyral to a fixed volume of solvent (acetic acid) and then stirring under reflex until a clear solution was obtained. The concentration range studied in the solution at which the present investigation is carried out is 0.5% & 1.0 (m/v) respectively. Ultrasonic velocities in the polymer solutions were measured by using ultrasonic interferometer at a frequency of 1MHz and at the temperatures 35 °C, 40 °C, 45 °C at above said concentration. The accuracy of ultrasonic velocity determination in the solution is 0.001%. The temperature of the measuring cell was maintained constant by circulating water from a thermostatically controlled water bath with an accuracy of ±0.1 °C. The densities of the solutions were measured to an accuracy of ±3 parts in 10^3 using a specific gravity bottle of 10 ml at different temperatures. The viscosities of the polymer solutions were measured to an accuracy of 1%, using an ostwald's viscometer at above said range of temperature by immersing the viscometer in the thermostatically controlled water bath. The viscometer was already calibrated with a standard liquid. Single pan macro balance with an accuracy of 0.001gm has been employed for mass measurements. Using the measured values of ultrasonic velocity, density and viscosity of the solutions for concentration range 0.5% -1.0 % at various temperatures, the related ultrasonic parameters are calculated and presented in tables and figures. Ultrasonic parameters are computed by using the following standard relations[9-13].

(i) Ultrasonic velocity $V = \lambda f$

(ii) Adiabatic compressibility $\beta = \frac{1}{v^2 \rho}$

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(iii) Acoustic impedance $Z = \rho\, \nu$

(iv) Relaxation time $\tau = \frac{4\eta}{3\rho v^2}$

Where;

ρ = density of the solution,

ν = ultrasonic velocity in the solution,

η = viscosity of the solution,

λ = wavelength of the ultrasonic wave, measured by micrometer,

f = frequency of ultrasonic wave.

3 Results and Discussion

The experimentally measured values of density (ρ), viscosity (η) and ultrasonic velocity (v) at different concentration and temperature, at 1 MHz frequency are listed in Table 1- 3 and the variation with temperature and concentration are represented graphically in Fig. 1 (a & b), 2a & b) and 3 (a & b), respectively. The variation of density with temperature and concentration is shown in Table 1 and Fig.1 (a & b). It is observed that density decreases with increase in temperature and increases with increases in concentration. Our results are in agreement with earlier workers results[14]. Table 2, presents the change in viscosity with temperature and concentration, the variation is shown in Fig. 2 (a & b). It is seen that the viscosity decreases with increase in temperature and it increases with increase in concentration of polyvinyl butyral. These results are similar to that reported in the literature[15].The variations of ultrasonic velocity with temperature and concentration have been shown in Table 3 and Fig. 3

Table 1 — Density (x 10^3Kgm^{-3}) of Polyvinyl Butyral (PVB) at different temperature and concentration at 1 MHz Frequency.

Temperature(°C) → / Concentration(m/v) ↓	35	40	45
0.5	1.023	1.016	1.010
1.0	1.025	1.017	1.011

Table 2 — Viscosity (x 10^{-3}Nsm^{-2}) of Polylvinyl Butyral (PVB) at different temperature and concentration at 1 MHz Frequency-

Temperature(°C) → / Concentration(m/v) ↓	35	40	45
0.5	1.082	0.977	0.912
1.0	1.243	1.158	1.086

Table 3 — Ultrasonic velocity (ms^{-1}) of Polyvinyl Butyral (PVB) at different temperature and concentration at 1 MHz Frequency-

Temperature(°C) → / Concentration(m/v) ↓	35	40	45
0.5	1102.7	1102.2	1099.1
1.0	1116.0	1115.4	1110.0

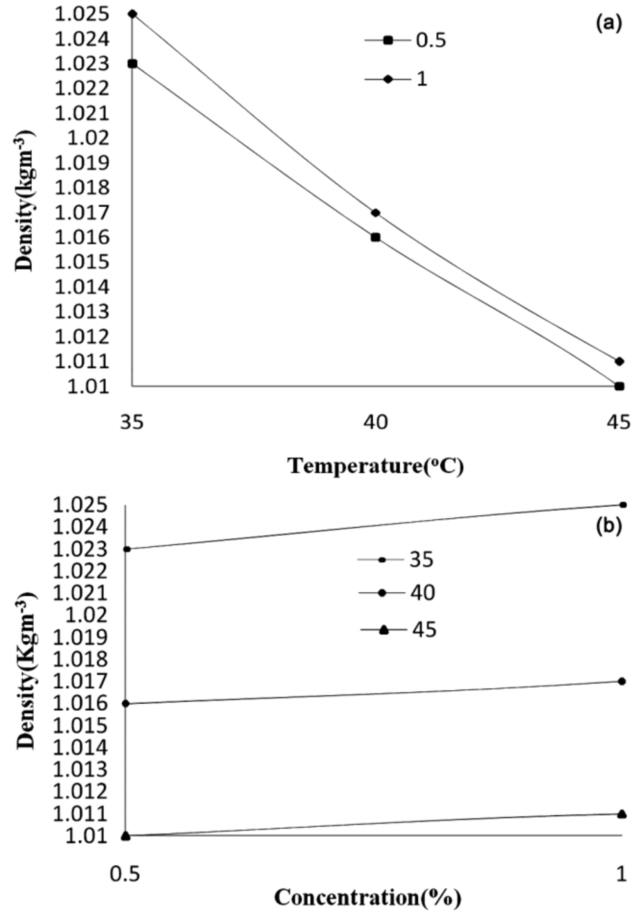

Fig.1 — Variation of Density of Polyvinyl Butyral (a) with temperature at different concentration and (b) with concentration at different temperature.

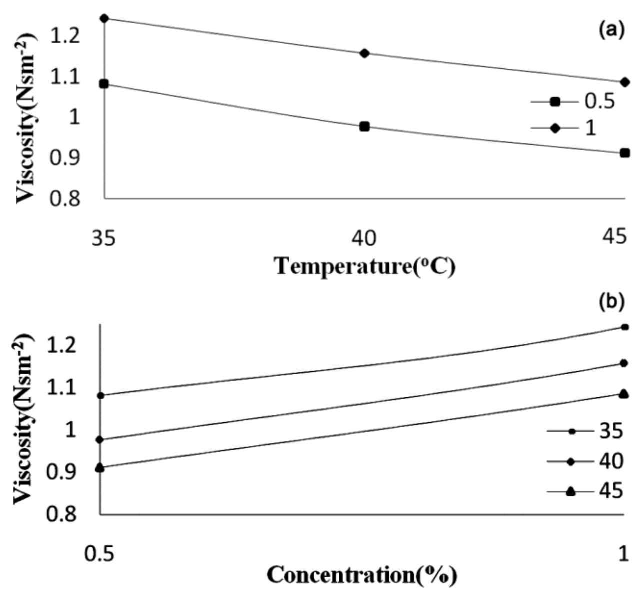

Fig. 2 — Variation of Viscosity of Polyvinyl Butyral (a) with temperature at different concentration and (b) with concentration at different temperature.

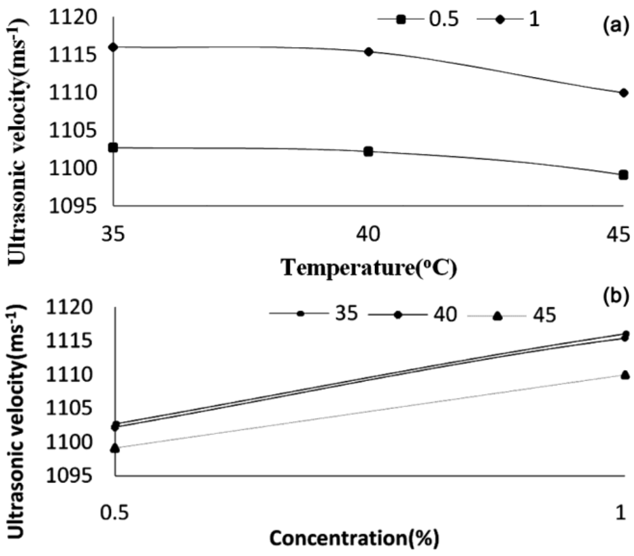

Fig. 3 — Variation of Ultrasonic velocity of Polyvinyl Butyral (a) with temperature at different concentration and (b) with concentration at different temperature.

(a & b), respectively. Figure 3 (a) shows that ultrasonic velocity decreases with increase in temperature and Fig. 3 (b) depict that ultrasonic velocity increases with increasing concentration of PVB in the solution, which is in agreement with the results reported by earlier workers[16].

Different acoustical parameters are calculated like adiabatic compressibility and acoustic impedance of polyvinyl butyral by using density, viscosity and ultrasonic velocity data presented. Table 4 and Fig. 4 (a) report the variation of adiabatic compressibility with temperature at different concentration. It is clearly seen that adiabatic compressibility increases with increase in temperature. Variation of adiabatic compressibility with concentration is shown in Table 4 & Fig. 4 (b) at different temperature. It is evident that adiabatic compressibility values decreases with increase in concentration of polyvinyl butyral in the solution. The rapid decrease of adiabatic compressibility with increase in concentration in the system indicates the formation of a more number of tightly bound system. Since the velocity increases with concentration and the density does so, the compressibility must decrease with concentration. Similar trends have been reported by other workers[17]. The increase in the value of temperature leads to less ordered structure and more spacing between the molecules (volume expansion)[18]. Variation of acoustic impedance with temperature is shown in Table 5 and Fig. 5 (a). It is observed that it decreases with increase

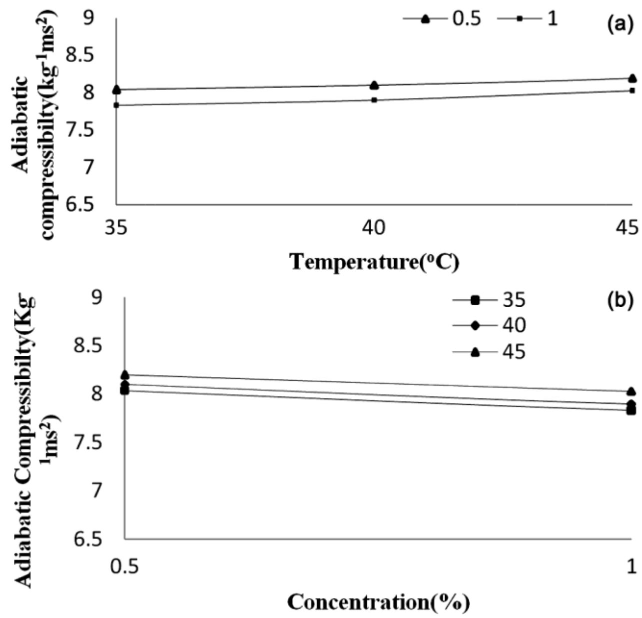

Fig. 4 — Variation of Adiabatic compressibility of Polyvinyl Butyral (a) with temperature at different concentration and (b) with concentration at different temperature.

Table 4 — Adiabatic compressibilty (x $10^{-10}Kg^{-1}ms^{2}$) of Polyvinyl Butyral (PVB) at different temperature and concentration at 1 MHz Frequency-

Temperature(°C) → Concentration(m/v) ↓	35	40	45
0.5	8.039	8.103	8.197
1.0	7.831	7.901	8.029

Table 5 − Acoustic impedance (x $10^{5}Kgm^{-2}s^{-1}$) of Polyvinyl Butyarl (PVB) at different temperature and concentration at 1 MHz Frequency-

Temperature(°C) → Concentration(m/v) ↓	35	40	45
0.5	11.281	11.196	11.100
1.0	11.443	11.347	11.220

in temperature. Table 5 and Fig. 5 (b) depicts the variation of acoustic impedance with concentration. It increases with increase in concentration of polyvinyl butyral in the solution. It shows the trend of linear increase of specific acoustic impedance with concentration at a given temperature. As the strength of the intermolecular attraction increases, the ultrasonic velocity also increases, consequently the acoustical impedance value also increases. These are in agreement with earlier workers[19].

Variation of relaxation time with temperature and concentration is shown in Table 6 and Fig. 6 (a & b), respectively. It is evident that relaxation time decreases with increase in temperature and increases

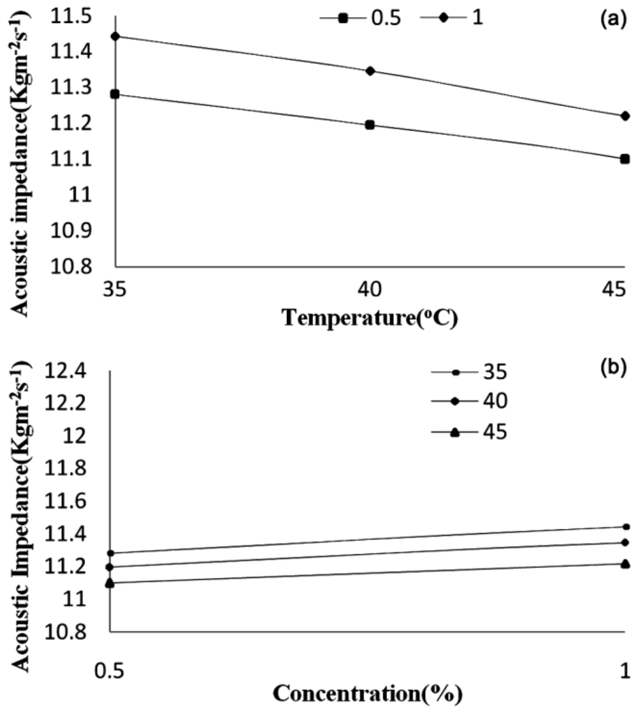

Fig. 5 — Variation of Acoustic impedance of Polyvinyl Butyral (a) with temperature at different concentration and (b) with concentration at different temperature.

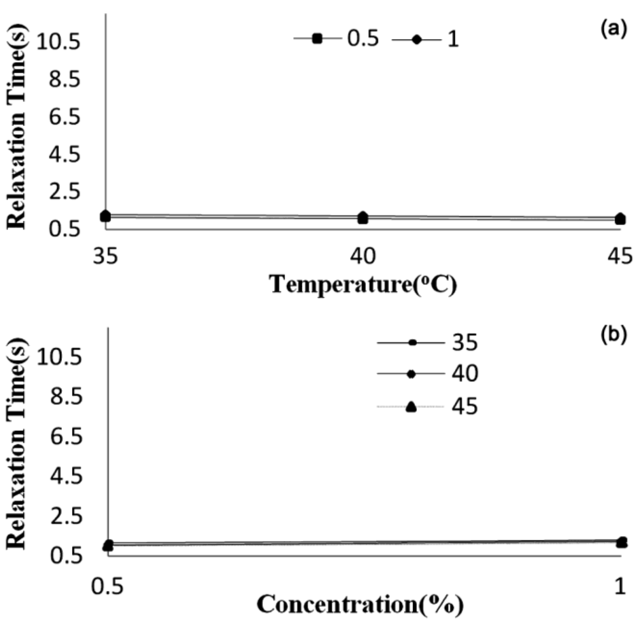

Fig. 6 − Variation of Relaxation time of Polyvinyl Butyral (a) with temperature at different concentration and (b) with concentration at different temperature.

with increase in concentration of polyvinyl butyral in solution. These are in agreement with reports of earlier workers[20]. Velocity studies shows that as a polymer concentration increases a more rigid molecular structure is formed perhaps by bonding between the large polymer molecules. Measurement of density and range of frequencies may lead to better understanding of the molecular mechanism responsible for absorption and velocity, such as relaxation.

Table 6 — Relaxation time (x 10^{-12}s) of Polyvinyl Butyral (PVB) at different temperature and concentration at 1 MHz Frequency-

Temperature(°C) → / Concentration(m/v) ↓	35	40	45
0.5	1.160	1.056	0.997
1.0	1.298	1.220	1.163

4 Conclusions

The derived acoustical parameters and their values show the nature of polymer in their respective solvents at various concentration and temperature. The study also shows the intermolecular interaction between the component molecules in the mixture.

References

1 Sadegi R, Khoshnavazi R & Parhizkar H, *Fluid Phase Equilibria*, 260 (2007) 335.
2 Ali A, Nain A K, Kumar N & Ibrahim M, *J Pure Appl Ultra*, 24 (2002) 27.
3 Wankhede D S, Lande M K & Arbad B R, *J Chem Eng Data*, 50 (2005) 260.
4 Pal A, Sharma H K & Singh W, *Indian J Chem*, 34A (1995) 987.
5 Oswal S L & Patel A, *J Chem Eng Data*, 40 (1995) 194.
6 Aminabhavi T M & Gopala K B, *J Chem Eng Data*, 40 (1995) 856.
7 Nikam P S & Kharat S J, *J Chem Eng Data*, 50 (2005) 455.
8 Chen J T, Shiah I M & Chu H P, *J Chem Eng Data*, 50 (2005) 1038.
9 Bhatt S C, Semwal H K, Lingwal V, Singh K & Semwal B S, *J Acoust Soc India*, 28 (2000) 275.
10 Bhatt S C, Semwal H K, Lingwal V, Singh K & Semwal B S, *J Acoust Soc India*, 28 (2000) 293.
11 Marcue Y, Introduction to liquid state Chemistry, New York, Wiley-Interscience, (1977).
12 Singh K, Pankaj & Bhatt S C, *Appl Phys Res*, 2 (2010) 35.
13 Saxena R & Bhatt S C, *Int J Chem*, 2 (2010)164.
14 Ottani S, Vitalini D, Comelli F & Castellari C, *J Chem Eng Data*, 49 (2004) 148.
15 Hassun H K, Shihab A A & Jassim F A, *Chin J Polym Sci*, 7 (1989).
16 Awasthi A, Rastogi M, Gupta M & Shukla J P, *J Mol Liq*, 80 (1999) 77.
17 Patel Y V & Parsania P H, *Eur Polym J*, 38 (2002) 1971.
18 Pethrick R A & Poh B T, *Brit Polym J*, 15 (1983) 149.
19 Syal V K, Chauhan A & Chauhan S, *J Pure Appl Ultra*, 27 (2005) 61.
20 Amrutia R R, Mehta N M, Karia F D & Parsania P H, *J Sci Indus Res*, 65 (2006) 905.