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Investigation of Acoustical Parameters of Polyvinyl Acetate

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Abstract

In the present paper the ultrasonic velocity (v), density (ρ) and viscosity (η) have been measured for the solutions of polyvinyl acetate of average molecular weight 45000 approx. in acetic acid at concentration range 0.50% to 2.00% and in temperature range 35°C to 55°C respectively. Ultrasonic velocity has been measured using variable path ultrasonic interferometer at 1MHz frequency. Using above mentioned values of ultrasonic velocity, density and viscosity, various acoustical parameters like adiabatic compressibility, acoustic impedance, relaxation time and ultrasonic attenuation have been computed. The variation of adiabatic compressibility (**β**), acoustic impedance (**Z**), relaxation time (τ) and ultrasonic attenuation (**α/f^2**) with concentration and temperature have been studied. Acoustical parameters provide important information in understanding the solute-solvent interaction in a polymer solution.

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

1. Introduction

In recent years the measurement of ultrasonic velocity has been adequately employed in understanding the nature of molecular interaction in pure liquids and liquids mixtures. Ultrasonic propagation parameters yield valuable information regarding the behavior of liquid systems, because intramolecular and intermolecular association, dipolar interactions, complex formation and related structural changes affect the compressibility of the system which in turn produces corresponding variations in the ultrasonic velocity. The acoustical and thermo dynamical parameters obtained in ultrasonic study show that the ion solvation is accompanied by the destruction or enhancement of the solvent structure. Ultrasonic studies provide wealth of information about the state of the any solution (N.Karunanidhi, et. al., 1999). The propagation of ultrasonic waves in a substance has become a fundamental test to investigate its properties (S.C.Bhatt, et. al., 1999). The Measurement of ultrasonic velocity and various acoustical parameters derived from it, are of considerable interest in understanding the nature of intermolecular interaction in polymer-solvent mixture (Rita Mehra & Rekha Israni, 2000). It also provides valuable information regarding the nature and strength of molecular interaction, formation of hydrogen bond etc (V.Lalitha & K.Vijayalakshmi, 2000). Ultrasonic study of polymer solutions has got the attention of many workers in the past. There are different explanations available to predict the properties of mixtures based on the properties obtained in such study, which are used in turn to derive an insight into the molecular interaction present in such system (S.C.Bhatt, et. al., 2000 a, b).

Chee has suggested that the viscosity of the blend solutions can be used for finding out the miscibility (Chee. k.k, 1990). Sun et al have also used the viscosity parameters for the blends for finding out the miscibility of blends (Sun.Z, et. al., 1992). The dependence of ultrasonic attenuation on temperature for styrenebutadene-rubber (SBR) / acroylonitrile butadiene rubber and its blends were reported by Youssef (Youssef. M.H, 2001). Properties of liquid-liquid mixtures are thermodynamically very important as a part of studies of thermodynamic, acoustic and

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transport aspects. The compositional dependence of thermodynamic properties has proved to be very useful tool in understanding the nature and extent of pattern of molecular aggregation resulting from intermolecular interaction between components. This type of study is a powerful means of characterizing the various aspects of physico chemical behavior of liquid mixtures and studying the interaction between molecules (Nikam. P.S, et. al., 1997, and Oswal. S.L & Patel A.T, 1995). Ultrasonic velocity of the tert-butyl alcohol solutions in relation to structures of water and solution have been studied by Endo & Nomoto (Endo. H & Nomoto. O, 1973). In the present study, the polymer polyvinyl acetate (PVA) was taken for the investigation, due to its many application like adhesives, lacquers etc.

2. Methodology

The ultrasonic interferometer is a simple and direct device to determine the ultrasonic velocity in liquids. The principle used in the measurement of ultrasonic velocity is based on the determination of wavelength in the liquid mixture. The ultrasonic waves of known frequency are produced by a quartz crystal fixed at the bottom of the measuring cell. The measuring cell is connected to the output terminal of the high frequency generator through the spherical cable. A movable metallic plate kept parallel to the quartz crystal reflects these waves. If the separation between these two plates is exactly a whole multiple of the sound wavelength, standing waves are formed in the medium. This acoustic resonance gives rise to an electrical reaction on the generator, driving the quartz crystal and anode current of the generator becomes a maximum.

The high frequency generator is designed to excite the quartz crystal fixed at the bottom of the measuring cell at its resonant frequency to generate ultrasonic waves in the experimental liquid filled in the measuring cell. The least count of micrometer used for measuring the wavelength is 0.001 mm. The ultrasonic velocity is obtained if the wavelength is known.

3. Experimental study

In the present investigation solutions were prepared by adding the known weight of polyvinyl acetate of molecular weight approx.45000 to a fixed volume of acetic acid and stirring under reflex until a clear solution was obtained. The concentration range of the solution at which the study is carried out is 0.50%, 1.0%, 1.5% and 2% (m/v) respectively. Ultrasonic velocity is measured by using variable path ultrasonic interferometer at 1MHz frequency .An electronically controlled thermostatic water bath having an accuracy of ± 0.1^{o}C was used to maintain constant temperature. Viscosity and density measurements were also carried out for the solutions using Ostwald viscometer and specific gravity bottle of 10ml respectively for the above said range of temperatures. Single pan macro balance with an accuracy of 0.001gm has been employed for mass measurement. Various acoustical parameters like ultrasonic velocity, adiabatic compressibility, acoustic impedance, relaxation time, and ultrasonic attenuation were calculated for PVA solution and at different temperature, i.e., 35, 40, 45, 50 and 55^{o}C respectively.

4. Calculation of acoustical parameters

The ultrasonic velocity measurement is extensively used to study the physico-chemical behaviour of liquids. With the help of measurements of density and viscosity the following parameters like ultrasonic velocity, adiabatic compressibility, acoustic impedance, relaxation time and ultrasonic attenuation are calculated by using the following expressions (S.C.Bhatt, et. al., 2005 a, b, c) :-

(i) *Ultrasonic velocity*

$$V = \lambda f$$

(ii) *Adiabatic compressibility*

$$\beta = \frac{1}{v^2 \rho}$$

(iii) *Acoustic impedance*

$$Z = \rho v$$

(iv) *Relaxation time*

$$\tau = \frac{4\eta}{3\rho v^2}$$

(v) *Ultrasonic attenuation*

$$\frac{\alpha}{f^2} = \frac{8\pi^2\eta}{3\rho v^3}$$

Where; ρ = density of the solution,

ν = ultrasonic velocity in the solution,

η = viscosity of the solution,

ω = 2πf (angular frequency of ultrasonic wave),

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

f = frequency of ultrasonic wave.

5. Result and Discussion

In the present study, we have measured the density (ρ), viscosity (η) and the ultrasonic velocity (v) of the polyvinyl acetate solution, at different concentration and temperature, at 1MHz frequency which are shown in table-1, 2 & 3 respectively and the variation with temperature and concentration are shown in fig.1, 2,3,4,5 & 6 respectively. By using these values for PVA, adiabatic compressibility, acoustic impedance, relaxation time and ultrasonic attenuation have been calculated by using equations (ii), (iii), (iv) & (v) respectively and the results are presented in table 4, 5, 6 and 7. The variations of these acoustical parameters with temperature and concentration are shown in fig.7, 8,9,10,11,12,13 &14 respectively.

The variation of density with temperature and concentration is shown in table-1 and fig. 1 & 2 respectively. It is observed from table 1 and fig.1 & 2 that density decreases with increase in temperature and increases with increases in concentration. Table-2, presents the change in viscosity with temperature and concentration, the variation is shown in fig. 3& 4. It is evident from table-2 and fig 3& 4, that the viscosity decreases with increase in temperature and it increases with increase in concentration of PVA. The variation of ultrasonic velocity with temperature and concentration is shown in table-3 and fig. 5 & 6 respectively. It is evident from table-3 and from fig 5 & 6 that ultrasonic velocity decreases with increase in temperature and it increase with increasing concentration. An increase in the ultrasonic velocity with increase in concentration appears to be associated with an overall increase in the cohesion in the said system. From the values of ultrasonic velocity, it is apparent that a definite structural re-adjustment of molecular packing is taking place in solution. The increase in sound velocity is a consequence of the enhanced bulk modulus of the liquid mixture over and above its value for ideal mixing condition.

Table-4 and fig .7&8 show the variation of adiabatic compressibility with temperature and concentration respectively. It is observed from table 4 and fig 7&8 that adiabatic compressibility increases with increase in temperature and decreases with increase in concentration. The decrease in adiabatic compressibility indicates the enhancement of the bond strength at this concentration. The variation of acoustic impedance with temperature and concentration is shown in table-5 and fig. 9 & 10. It is seen from fig. 9 &10, that acoustic impedance decreases with increase in temperature and it increases with increase in concentration. This is in agreement with requirement as both ultrasonic velocity and density increase with increase in concentration of the solute, and also effective due to solute-solvent interactions. The variation of relaxation time with temperature and concentration is shown in table-6 and fig 11 & 12 respectively. It is observed from table-6 and fig 11&12, that relaxation time decreases with increase in temperature and increases with increasing concentration. This is similar change found in viscosity, showing that viscous forces play a dominant role in the relaxation process. The variation of ultrasonic attenuation with temperature and concentration are shown in table-7 and fig.13 & 14 respectively. It is seen from table 7 and fig.13&14 that ultrasonic attenuation of the solutions is found to decrease with increase in temperature and increases with increasing concentration, shows a similar trend to that of acoustical relaxation time. This is due to a modification in the nature of the molecular interaction. The measurements of ultrasonic attenuation and relaxation time seem to indicate that viscosity contributes in a significant way to the absorption. The above behavior is obvious as per kinetic theory of fluids, ultrasonic velocity, viscosity, density studies in PVA solutions revealed the presence of solute-solvent interaction.

6. Conclusion

Present investigation reveals that for the solution of polyvinyl acetate of average molecular weight 45000 in acetic acid, at different concentration and temperature:-

(i) Ultrasonic velocity decreases with increase in temperature and it increases with increasing concentration.

(ii) Adiabatic compressibility increases with increase in temperature and decreases with increase in concentration.

(iii) Acoustic impedance decreases with increase in temperature and it increases with increase in concentration.

(iv) Relaxation time decreases with increase in temperature and increases with increasing concentration.

(v) Ultrasonic attenuation decreases with increase in temperature and increases with increase in concentration.

The variation in the acoustical parameters with temperature and concentration for polyvinyl acetate in acetic acid suggest that there are strong polymer-solvent interactions at higher concentration.

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Table 1. Density (x 10^3 kg/m^3) at different temperature and Concentration, at 1MHz for PVA

Temperature (°C) → / Concentration (%) ↓	35	40	45	50	55
5	1.023	1.022	1.014	1.009	1.006
1	1.025	1.023	1.015	1.010	1.006
1.5	1.027	1.024	1.016	1.011	1.009
2	1.028	1.025	1.017	1.012	1.009

Table 2. Viscosity (x 10^{-3} Ns/m^2) at different temperature and Concentration, at 1MHz for PVA

Temperature (°C) → / Concentration (%) ↓	35	40	45	50	55
0.5	1.02	0.96	0.9	0.85	0.8
1	1.16	1.08	1	0.94	0.89
1.5	1.32	1.23	1.15	1.07	1.01
2	1.61	1.48	1.37	1.28	1.18

Table 3. Ultrasonic velocity (ms^{-1}) at different temperature and Concentration, at 1MHz for PVA

Temperature (°C) → / Concentration (%) ↓	35	40	45	50	55
0.5	1020.6	1012	995.3	980	970.4
1	1033.3	1022	1004.8	989.10	978.4
1.5	1045.9	1029.4	1015.4	997.7	988.4
2	1059.6	1039.3	1021.1	1008.6	994.7

Table 4. Adiabatic Compressibility (x 10^{-10} kg^{-1}ms^2) at different temperature and Concentration, at 1MHz for PVA

Temperature (°C) → / Concentration (%) ↓	35	40	45	50	55
0.5	9.381	9.553	9.952	10.309	10.555
1	9.132	9.356	9.75	10.114	10.376
1.5	8.898	9.214	9.544	9.931	10.144
2	8.656	9.031	9.421	9.709	10.011

Table 5. Acoustic Impedance (x 10^5 kgm^{-2}s^{-1}) at different temperature and Concentration, at 1MHz for PVA

Temperature (°C) → / Concentration (%) ↓	35	40	45	50	55
0.5	10.444	10.343	10.095	9.897	9.762
1	10.596	10.457	10.199	9.995	9.85
1.5	10.744	10.542	10.317	10.092	9.972
2	10.902	10.653	10.394	10.211	10.041

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Table 6. Relaxation time (x 10^{-12} s) at different temperature and Concentration, at 1MHz for PVA

Temperature (°C) → / Concentration (%) ↓	35	40	45	50	55
0.5	1.279	1.229	1.2	1.169	1.127
1	1.419	1.351	1.311	1.277	1.231
1.5	1.569	1.519	1.464	1.423	1.367
2	1.859	1.79	1.727	1.662	1.585

Table 7. Ultrasonic Attenuation (x 10^{-14} s^2m^{-1}) at different temperature and Concentration, at 1MHz for PVA

Temperature (°C) → / Concentration (%) ↓	35	40	45	50	55
0.5	2.477	2.399	2.383	2.358	2.295
1	2.714	2.611	2.578	2.551	2.486
1.5	2.965	2.916	2.85	2.818	2.733
2	3.466	3.404	3.342	3.256	3.149

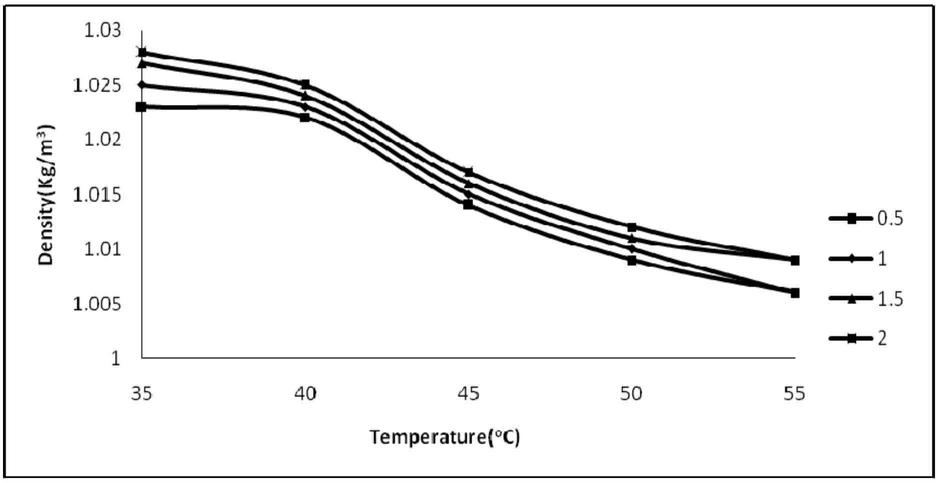

Figure 1. Variation of density with temperature at different concentration of PVA

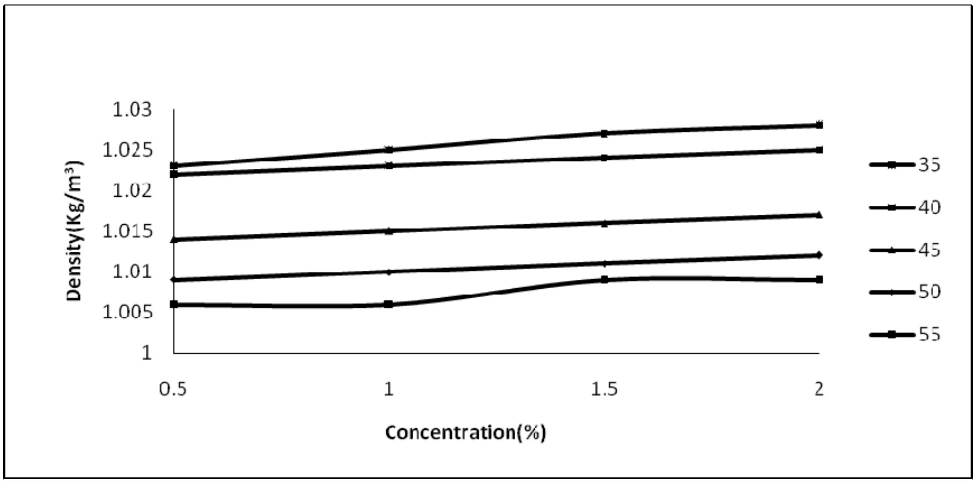

Figure 2. Variation of density with concentration at different temperature of PVA

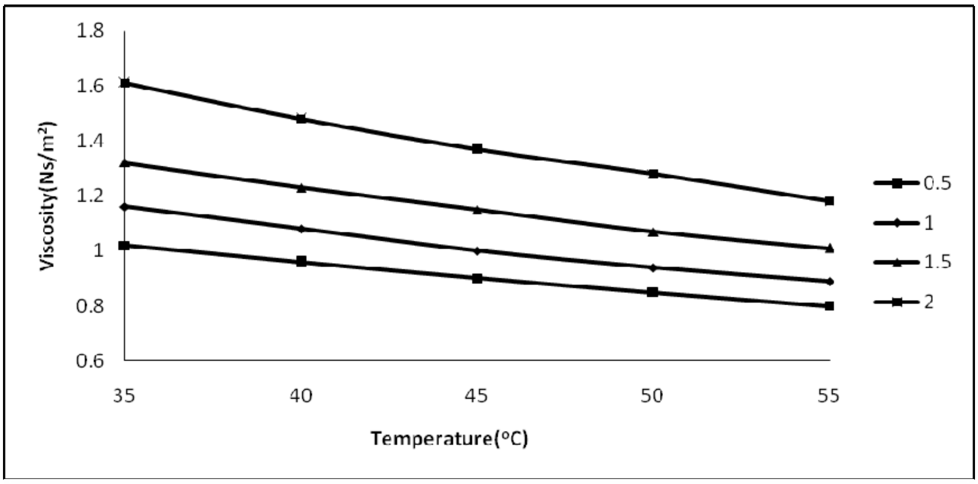

Figure 3. Variation of Viscosity with temperature at different concentration of PVA

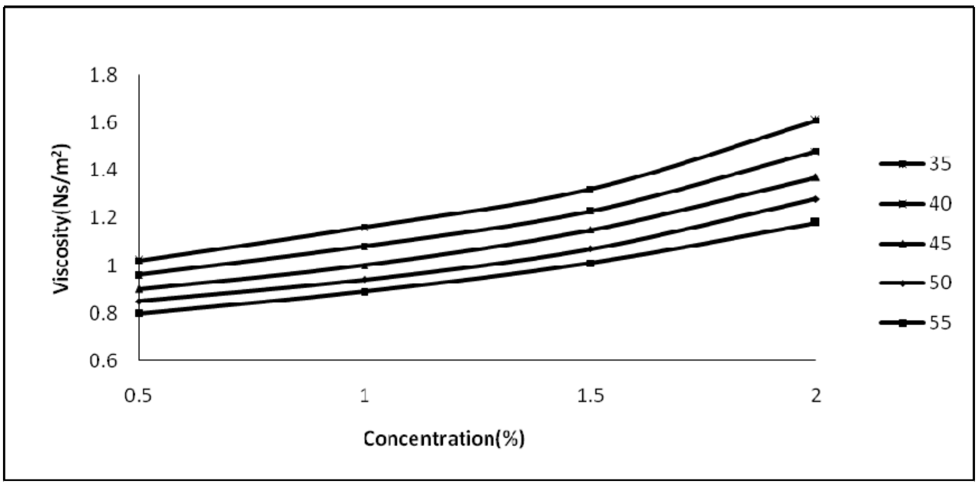

Figure 4. Variation of Viscosity with concentration at different temperature of PVA

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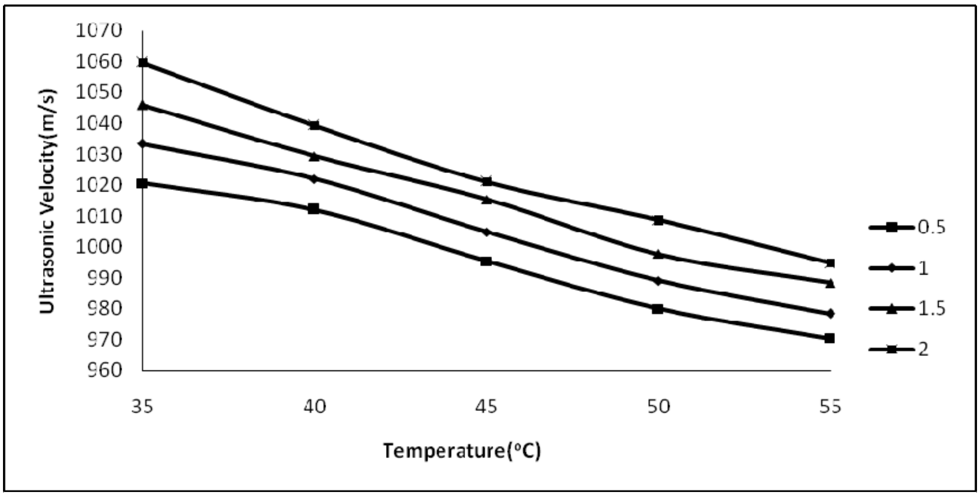

Figure 5. Variation of Ultrasonic velocity with temperature at different concentration of PVA

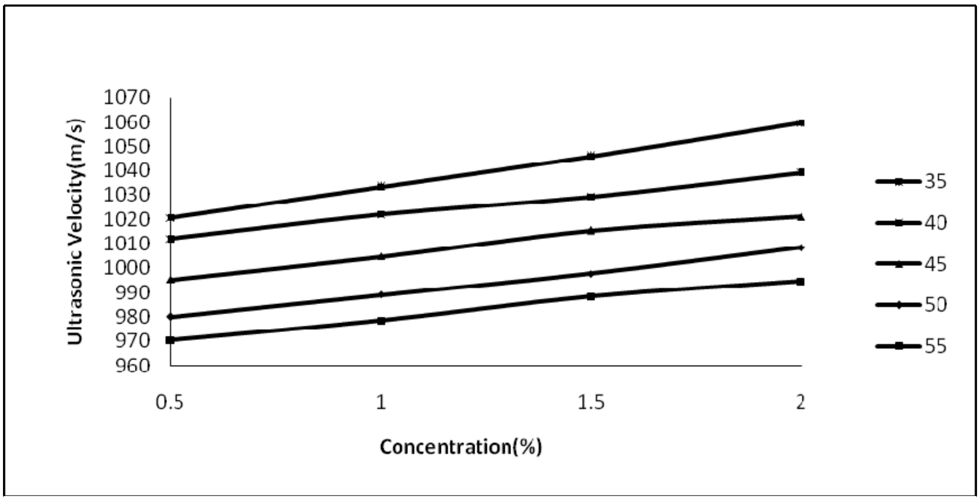

Figure 6. Variation of Ultrasonic velocity with concentration at different temperature of PVA

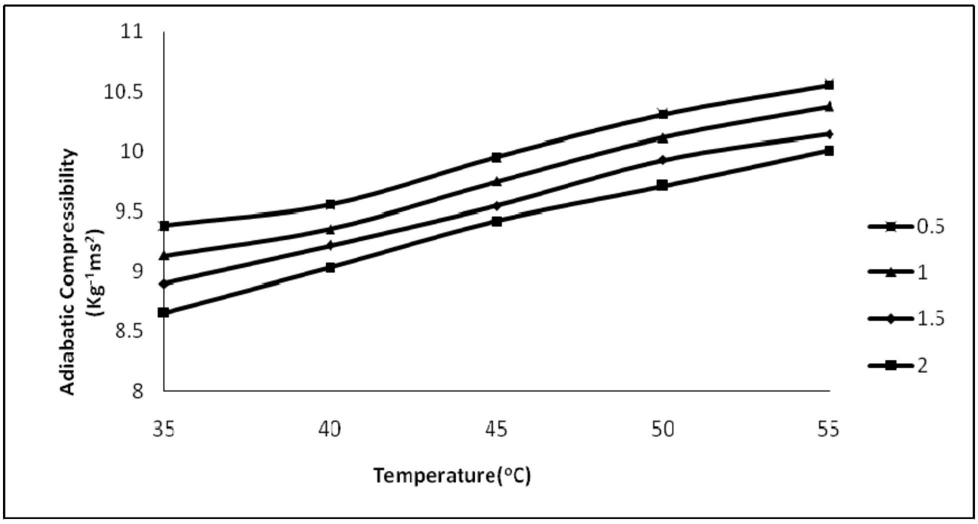

Figure 7. Variation of Adiabatic compressibility with temperature at different concentration of PVA

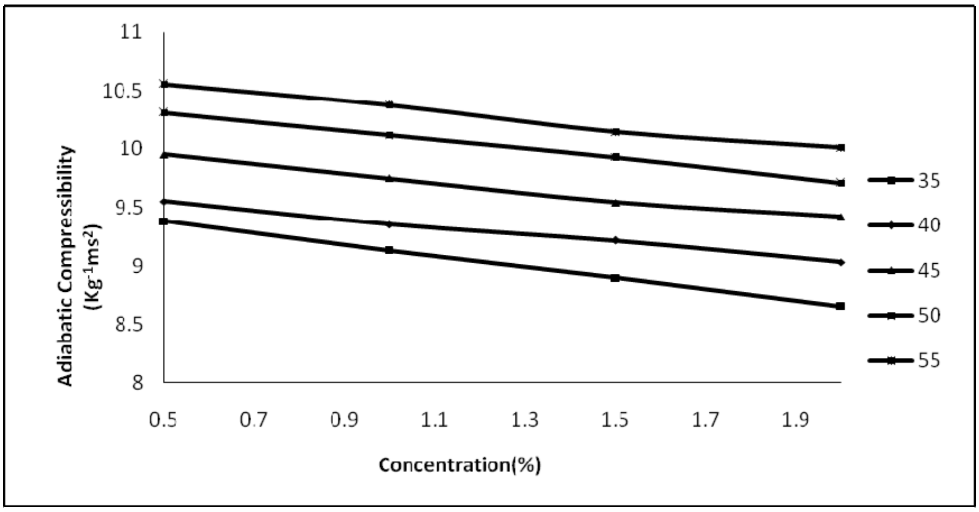

Figure 8. Variation of Adiabatic compressibility with concentration at different temperature of PVA

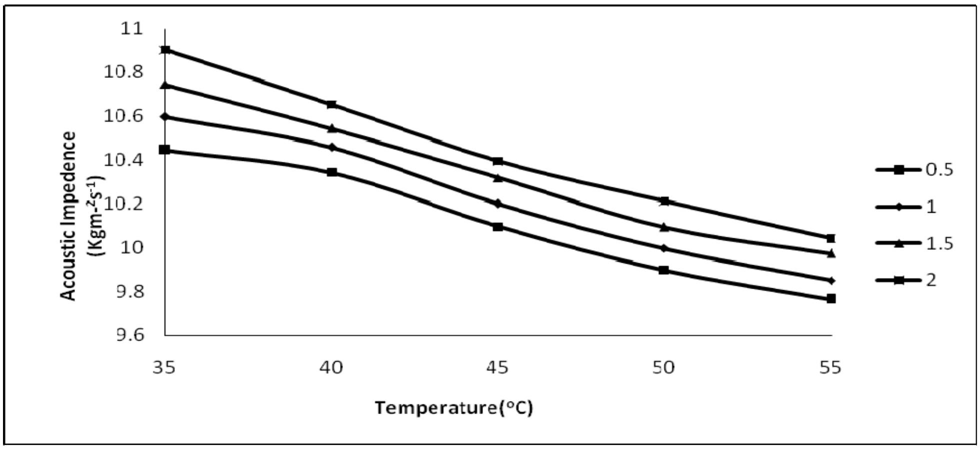

Figure 9. Variation of Acoustic impedance with temperature at different concentration of PVA

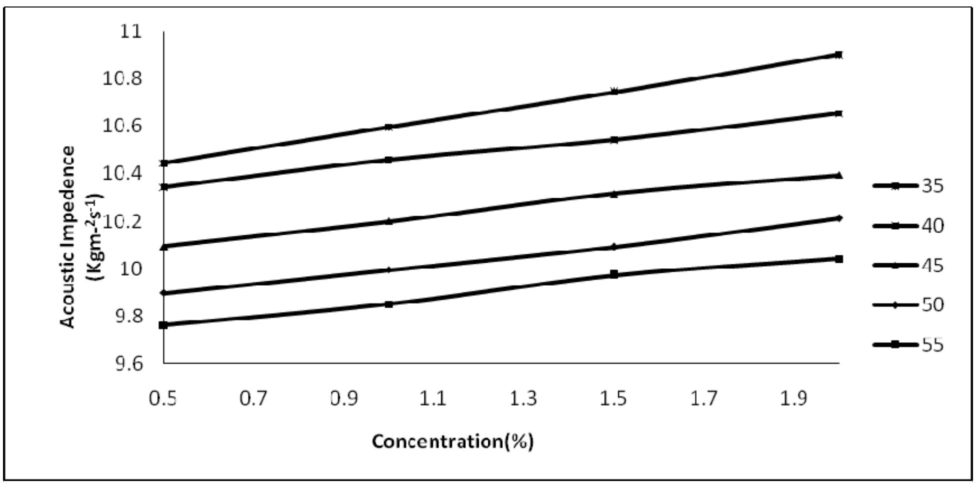

Figure 10. Variation of Acoustic impedance with concentration at different temperature of PVA

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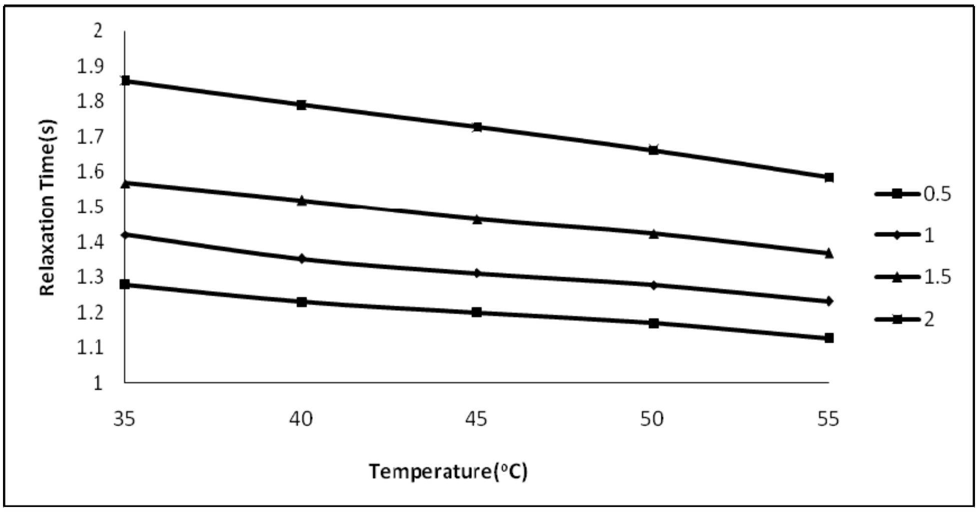

Figure 11. Variation of Relaxation time with temperature at different concentration of PVA

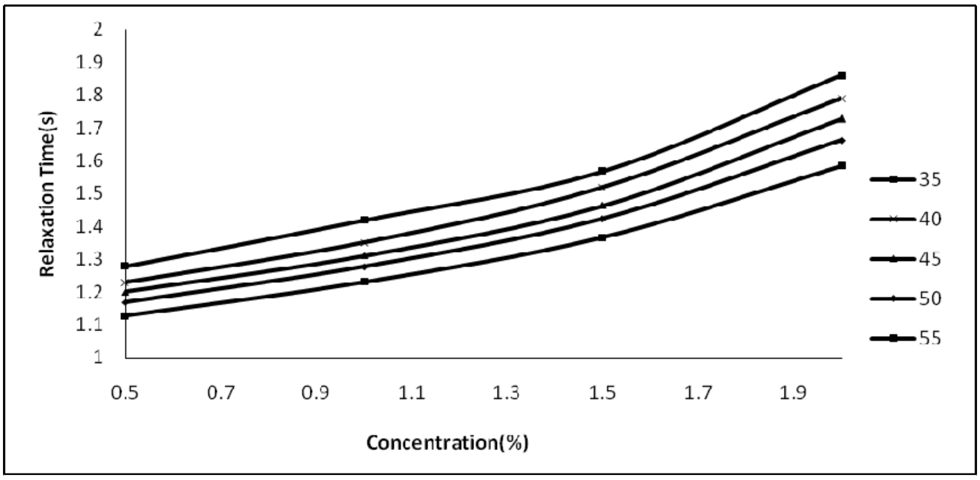

Figure 12. Variation of Relaxation time with concentration at different temperature of PVA

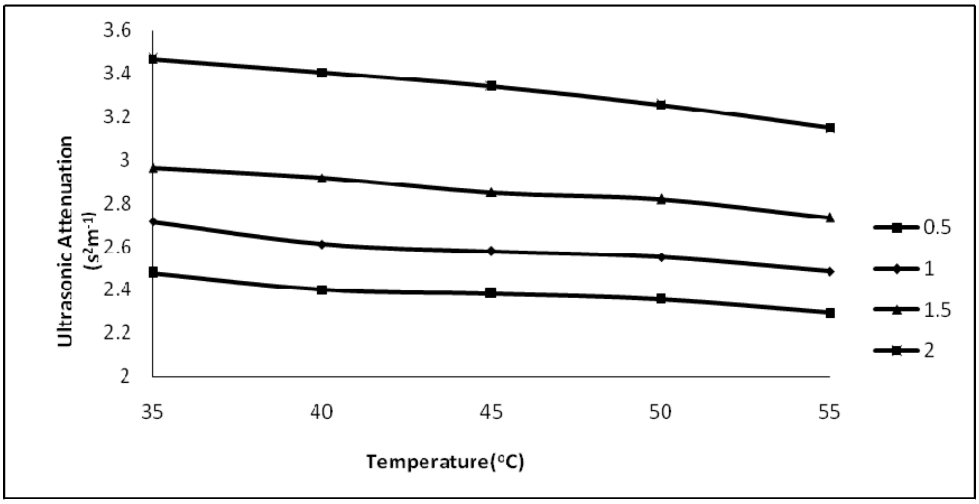

Figure 13. Variation of Ultrasonic attenuation with temperature at different concentration of PVA

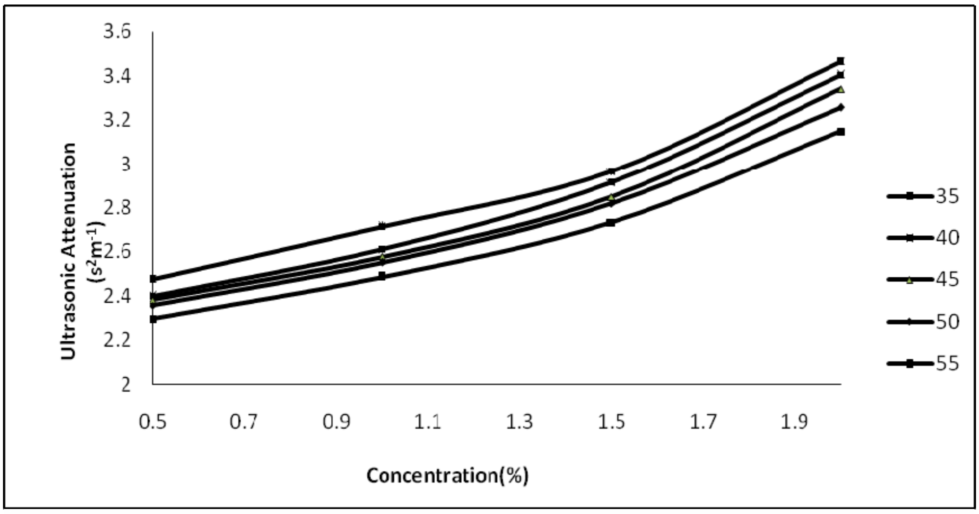

Figure 14. Variation of Ultrasonic attenuation with concentration at different temperature of PVA