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Acoustical Parameters of Polyvinyl Alcohol

Richa Saxena[1] • S C Bhatt[2] • Manish Uniyal[2] • S C Nautiyal[3]

[1]IFTM University, Lodhipur, Rajput, Moradabad 244001, India
[2]Department of Physics, H N B Garhwal University Srinagar (Garhwal) 246174, India
[3]Department of Physics, Govt.Degree College,Raipur, Dehraun

Corresponding author Email: saxena.richa23@gmail.com

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Abstract
Ultrasonic investigation provides a wealth of information in understanding the intermolecular interaction of solute and solvent. An attempt has been made to measure density, viscosity and ultrasonic velocity of aqueous solution of polyvinyl alcohol of molecular weight approximately 140,000 at different temperatures 35ºC, 40ºC, 45ºC, 50ºC, 55ºC, 60ºC, 65ºC at 0.8% concentration. Ultrasonic velocity is measured using ultrasonic interferometer at 1 MHz frequency. The acoustical parameters like, adiabatic compressibility, acoustic impedance, intermolecular free length and relaxation time have been calculated at different temperatures. These parameters were used to understand the behaviour of solute and solvent.

Introduction

Ultrasonic studies provide a wide range of information in understanding the molecular behaviour and intermolecular interaction of polymer solvent mixtures. This technique has been used extensively used to determine ion-solvent interactions in aqueous solution containing electrolytes or non electrolytes. Ultrasonic studies in polymeric solutions have drawn the attention of many researchers in the recent years (Sreenath et.al. 2012, Praharaj 2013, Nagarjun 2013, Godhani 2017). A survey of literature (Jacobson 1952, Lageman and Dunbar 1945, Kannappan 2007) indicates that acoustical parameters are useful in understanding the nature and strength of molecular interactions in the liquid mixtures and solutions. They also provide information about the process involving polymer production and their applications (Beth and Jack 2003). Polymer dissolution plays a important role in many industrial uses in a variety of application areas (Selvakumar and Bhat 2008). M. Vigneswari et al. (Vigneswari et.al. 2016) studied the molecular interactions in solutions of polyvinyl alcohol, they reported the strong solute and solvent interactions in aqueous solution of polyvinyl alcohol. Ultrasonic velocity measurements were reported for aqueous solution. They have suggested the presence of solute solvent interactions. Kavitha et al. (2012) studied the molecular interactions in aqueous solution of ternary mixture in polyvinyl alcohol. Ravichandran and Ramnathan. (2012) have reported, the acoustical properties and surface tension study of some potassium salts in polyacrylamide solution at 303K by ultrasonic investigations and concluded the concentration, nature of the solvent and nature of the solute play an important role in determining the interactions occurring in the solutions. The acoustical parameters like adiabatic compressibility, intermolecular free-length, apparent molar compressibility, specific acoustic impedance, relative association and solvation number have been determined as they are functions of ultrasonic velocity by Ali and Nain. (1997). The present investigation is undertaken, in order to study the dependence of molecular interaction strength. The results are discussed in terms of interaction between solute and solvent.

Experimental details

In the present investigation Polyvinyl alcohol of molecular weight approximately 140,000 at different temperatures 35°C, 40°C, 45°C, 50°C, 55°C, 60°C, 65°C at 0.8% concentration is used. The solutions were prepared by adding known weight of polyvinyl alcohol to fixed volume of water and stirring under reflex, until a clear solution was obtained. The polyvinyl alcohol of molecular weight approximately 140,000 at different temperatures 35°C, 40°C, 45°C, 50°C, 55°C, 60°C, 65°C at 0.8% concentration is studied. Different acoustical parameters like adiabatic compressibility, acoustic impedance, intermolecular free length, and relaxation time were calculated at 35°C, 40°C, 45°C, 50°C, 55°C, 60°C, 65°C temperature and at 0.8% concentration at 1MHz frequency. The ultrasonic velocity was measured by using variable path ultrasonic interferometer with accuracy of ±0.4m/s at 35°C. By circulating water from the thermostatically controlled (±0.1°C) water bath, the temperature of the solution has been kept constant. The densities of PVA at different temperature were also measured. The accuracy in density measurements was about 0.5 kg/m^3. The viscosity of the mixtures was determined by using Ostwald's viscometer at constant temperature also. The accuracy in the viscosity measurements is within ±0.5%. These parameters are calculated by using standard relations (Bhandakkar and Rode 2012, Saxena and Bhatt (2010,2017, Saxena et al 2020).

Result and Discussion

The experimentally obtained valued of density, viscosity and ultrasonic velocity at 35°C, 40°C, 45°C, 50°C, 55°C, 60°C, 65°C temperature and at 0.8% concentration at 1MHz frequency are used to calculate different acoustical parameters adiabatic compressibility, acoustic impedance, intermolecular free length and relaxation time for aqueous solution of Polyvinyl alcohol, that have been presented in Table 1, 2, 3, 4, 5, 6 and 7 respectively.

Density is a measure of solute-solvent interaction. Table-1 and Fig 1 represent the variation of density with temperature at 0.8%

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concentration for polyvinyl alcohol. It is found that with increase in temperature, density decreases. Present results are in good agreement with earlier reported data (Sridevi 2004, Kannapan and Shanti 2005, Kerrboub et.al 2005). Viscosity decreases with increase in temperature of polyvinyl alcohol (Table 2, Figure 2). It may be due to decrease in the cohesive forces. Results are in similar trend with the earlier researchers (Esquivel et al 1993). It is observed that with the increase of temperature , ultrasonic velocity decreases in polyvinyl alcohol solution. (Table 3, Figure 3). It may be

Table: 1- Density(x10^3kg/m^3) of Polyvinyl alcohol (PVA) with temperature at 0.8% concentration at 1 MHz frequency-

TEMPERATURE (°C)	DENSITY
35	0.983
40	0.981
45	0.979
50	0.977
55	0.972
60	0.964
65	0.956

Table: 2-Viscosity(x10^{-1}Pa.sec) of Polyvinyl alcohol (PVA) with temperature at 0.8% concentration at 1MHz frequency-

TEMPERATURE (°C)	VISCOSITY
35	0.086
40	0.084
45	0.081
50	0.0781
55	0.069
60	0.059
65	0.056

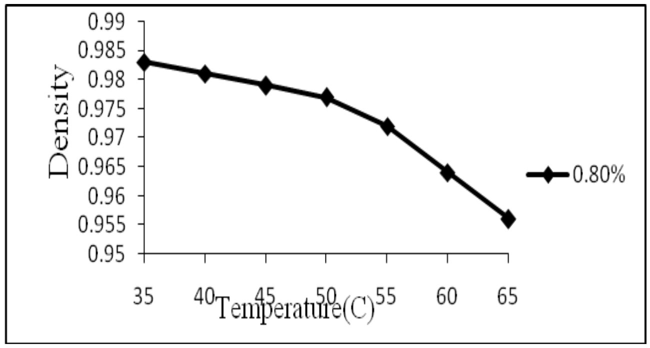

Fig.-1: Variation of density with temperature at 0.8% concentration

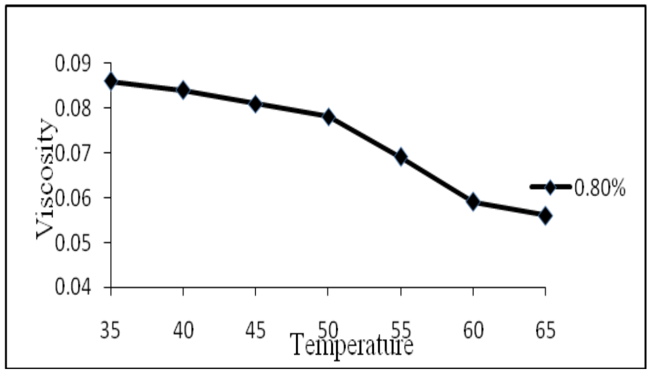

Fig.-2: Variation of viscosity with temperature at 0.8% concentration

due to increase in temperature, available thermal energy facilitates the breaking of bonds between the associated molecules. The increase in thermal energy weakens the molecular forces which decreases the ultrasonic velocity. The variation of ultrasonic velocity in solution depends on intermolecular free length on mixing. On the basis of a model, for sound propogation proposed by Eyring and Kincaid (1938), ultrasonic velocity should decrease, if the intermolecular free length increase and vice-versa. This is observed in the present investigation. This increase or decrease in value of ultrasonic velocity with composition indicates interactions between contributing molecules. This behaviour is in good agreement with the behavior reported by earlier reported data(Baba and Subha, 2002). Table 4 and Fig. 4 reports the variation of adiabatic compressibility with temperature. It is clearly seen that adiabatic compressibility increases with temperature of polyvinyl alcohol in solution. This indicates solute solvent interaction. Similar results are reported by other researchers (Syal et al 2005). Variation of acoustic impedance with temperature is shown in (Table 5 and Fig.5) it is seen that it decreases with increase in temperature. These results also support the conclusions drawn from deviation in ultrasonic velocity. It is observed from Table 6 and Fig.6 that Intermolecular free length increases with increase in temperature. Variation of relaxation time with temperature at 0.8% concentration is shown in Table 7 and Fig 7. It decreases with increase in temperature. This trend is quite normal as the variation in these parameters is the cumulative effect of the variations in density, viscosity and ultrasonic velocity of the solutions under the given condition. This may be due to as per the kinetic theory of fluid.

Table: 3-Ultransonic velocity (m/s) of polyvinyl alcohol (PVA) with temperature at 0.8% concentration at 1MHz frequency

TEMPERATURE (°C)	ULTRASONIC VELOCITY
35	1503.2
40	1500.1
45	1498.8
50	1488.7
55	1473.4
60	1470.6
65	1467.7

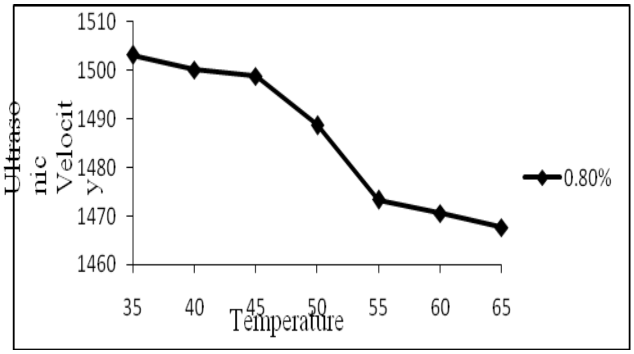

Fig.-3: Variation of ultrasonic velocity with temperature at 0.8% Concentration

Table: 4- Adiabatic compressibility($x10^{-10}kg^{-1}ms^{2}$) of Polyvinyl alcohol (PVA) with temperature at 0.8% concentration 1MHz for polyethylene glycol (PEG)-

TEMPERATURE (°C)	ADIABATIC COMPRESSIBILITY
35	4.502
40	4.53
45	4.547
50	4.618
55	4.739
60	4.747
65	4.856

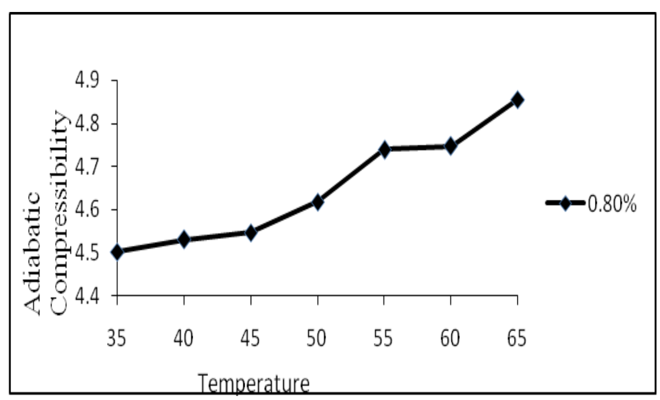

Fig.-4: variation of adiabatic compressibility with temperature at 0.8% Concentration

Table: 5- Acoustic impedance (x10^{3}kgm^{2}s^{-1}) of Polyvinyl alcohol (PVA) with temperature at 0.8% concentration at 1MHz-

TEMPERATURE (°C)	ACOUSTIC IMPEDANCE
35	1477.6
40	1471.6
45	1467.3
50	1454.5
55	1432.1
60	1417.7
65	1403.1

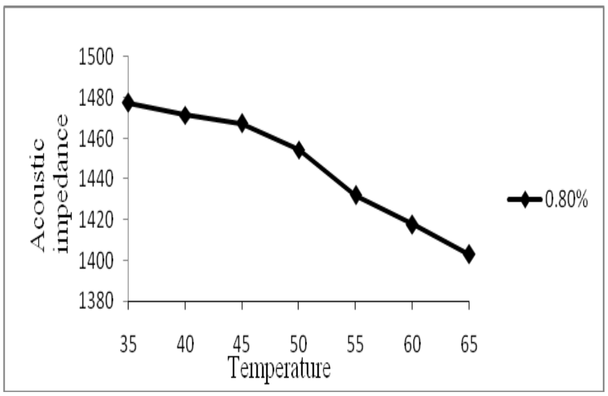

Fig.-5: Variation of Acoustic Impedance with temperature at 0.8% Concentration

Table: 6- Intermolecular Free Length (x10^{-13}m) of Polyvinyl alcohol (PVA) with temperature at 0.8% concentration at 1MHz-

TEMPERATURE (°C)	INTERMOLECULAR FREE LENGTH
35	2.872
40	2.881
45	2.886
50	2.909
55	2.946
60	2.964
65	2.983

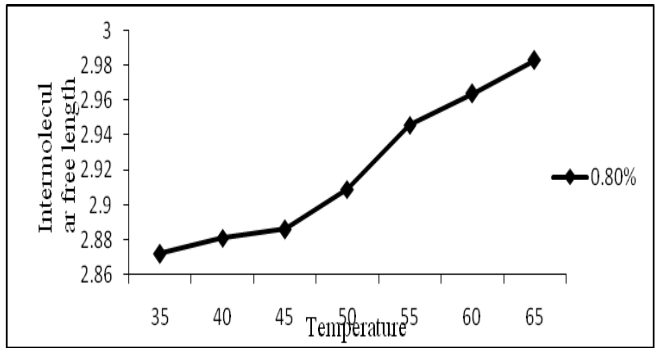

Fig.-6: Variation of intermolecular free Length with temperature at 0.8% Concentration

Table: 7 - Relaxation time (x10^{-12}s) of polyvinyl alcohol with temperature at 0.8% concentration at 1MHz frequency

TEMPERATURE (°C)	RELAXATION TIME
35	1.709
40	1.255
45	1.336
50	0.992
55	0.902
60	0.764
65	0.759

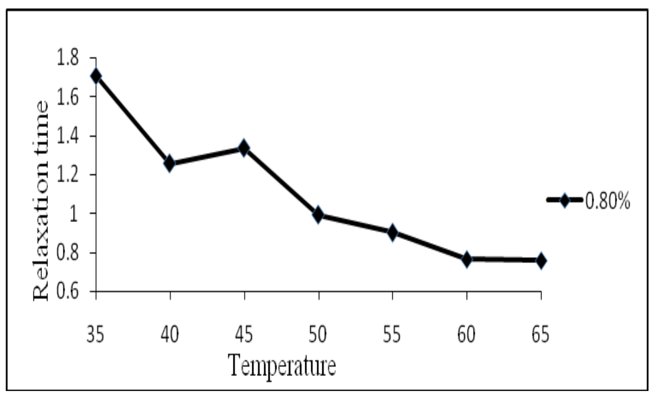

Fig.-7: Variation of relaxation time with temperature at 0.8% Concentration

Conclusion

The ultrasonic velocity measurement technique is a effective and powerful tool to investigate properties of polymer solution and nature of polymer chain in ultrasonic field. Densities, viscosity, ultrasonic velocities of the aqueous solution of Polyvinyl alcohol have been experimentally determined at 35^0C,40^0C,45^0C,50^0C, 55^0C, 60^0C, 65^0C. The values of density and viscosity decrease with increase temperature. This may be due to decrease in an inner molecular forces and increasing thermal energy. The increase of the temperature increases the thermal energy that in turn decrease the ultrasonic velocity. Free length shows molecular interaction between surfaces of molecules so it increase the molecular free energy. The variation in the acoustical parameters suggests that there are strong solute solvent interactions.

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