Density, Viscosity and Ultrasonic Velocity of Polyethylene Glycol

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Abstract: Ultrasonic velocity, density, and viscosity of polyethylene glycol have been measured for the solution in water at concentration range of 0.3% to 1% at temperature 50ºC. Ultrasonic velocity has been measured using ultrasonic interferometer at 1MHz frequency. By using the values of ultrasonic velocity, density, and viscosity, various acoustical parameters like adiabatic compressibility, acoustic impedance, intermolecular free length, and relaxation time have been calculated. The change in these acoustical parameters is explained in terms of solute-solvent interaction in a polymer solution.

Keywords: Density, Viscosity, Ultrasonic Velocity, Pplyethylene Glycol

Introduction

In recent years, ultrasonic velocity measurement has been employed in understanding the molecular interaction in pure liquids and liquid mixtures. The ultrasonic velocity measurements are very useful to provide information about strength of molecular interaction and physical nature of solute and solvents (Mehta and Chauhan 1997, Dewan et al 1991). Ultrasonic velocity of a liquid is fundamentally related to the binding forces between the atoms of the molecules and has been adequately employed in understanding the nature of molecular interaction in pure liquids(Tabhane 1983, Srinivasalu and Naidu Ranachandra 1991, Kannappan and Rajendran 1991).Polyethyleneglycol finds enormous use in the field of microbiology, biochemistry, drug delivery, gas chromatography and pharmaceutical industry (Nagara and Yamamoto 2008, Pittini et al 2008). Polymer dissolution also plays a key role in many industrial applications in variety of areas and an understanding of the dissolution process allows for the optimization of design and processing conditions as well as selection of suitable solvents. Aqueous solutions play a vital role for many geological processes in various environments, such as geothermal and magmatic hydrothermal settings. Subramanian Ravichandran et al. (2011) studied the ultrasonic studies on molecular interactions in the binary mixture of ammonium chloride in Polyethylene glycol solution. They reported the theoretical values of ultrasonic velocity in binary liquid mixture. Syal et al (2005) studied the ultrasonic velocity, density and ultrasonic velocity of Polyethylene glycols(PEG-800,PEG-20,000) in acetonitrile and water mixtures at 25^{O}C and they concluded that acetonitrile acts as a structure breaker in AN+ H2O solvent system releasing more water dipoles to interact at oxygen sites of PEG chains. Some of the researchers studied the ultrasonic characteristics of aqueous solution of Polyehtlene glycol (Venkata Ramana 2005, Kalyana and Hemalatha 1999, Lalitha et al 1996).Very few studies are available on aqueous solution of Polyethyleneglycol. Because of wide use of this liquid is chosen in present investigations[13]

Experimental details

In the present investigation polyethyleneglycol of molecular weight approximately (200 Da) in liquid form is used. The solutions were prepared by adding known weight of polyethyleneglycol in fixed volume of water and stirring, until a clear solution was formed. The concentration studied have been done with solution of concentration 1.0%, 0.8%, 0.6%, 0.5%, 0.4%, 0.3% (v/v). Acoustical parameters like adiabatic compressibility, acoustic impedance, intermolecular free length, and relaxation time have been calculated at 50^{0}C temperature and at 1.0%,0.8%,0.6%,0.5%,0.4%,0.3% concentration at 1MHz frequency. The ultrasonic velocity is measured by using ultrasonic interferometer with accuracy of ±0.4m/s at 35^{o}C. The temperature of the solution has been kept constant. The density at different temperature is also measured. The accuracy in density measurements was about 0.5 kg/m^3. The viscosity of the mixtures was also determined at constant temperature. The accuracy in the viscosity measurements is within ±0.5%. These parameters are calculated by using standard relations (Saxena and Bhatt 2010, Saxena et al 2020, Saxena and Bhatt 2018).

Result and Discussion

In present investigation density, viscosity and ultrasonic velocity have been measured at 1.0%,0.8%,0.6%,0.5%,0.4%,0.3% (v/v) at 50^{0}C concentration at 1 MHz frequency. Using these values different acoustical parameters adiabatic compressibility, acoustic impedance, intermolecular free length and relaxation time has been calculated for aqueous solution of Polyethylene glycol at 1.0%, 0.8%, 0.6%, 0.5%, 0.4%, 0.3% concentration and at 50^{0}C temperature have been presented in Table 1, 2, 3,4,5,6 and 7 respectively. Table-1 and Fig 1 represents the variation of density of polyethylene glycol with concentration at 50^{0}C. It is clear from Fig 1 that density increases with increase in concentration. The results are in good agreement with previous reports (Selvakumar and Krishna 2008). Viscosity is one of the important property of liquid. It is dependent on its molecular size, shape and intermolecular interaction. Some acoustical parameters also depend on

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viscosity. Table-2 and Fig-2 shows that viscosity increases with increase in concentration of PEG-200 this may be due to shrinkage in the volume because of presence of solute molecules. This results in more frictional force that is developed between the layers of the solution. The increasing trend of viscosity with concentration revealed that the addition of a polymer increases the effective molecular area. The trends are in agreement with the results of earlier researchers (Fabio et al 2000). Ultrasonic velocity increases with increase in concentration of PEG in the solution (Table3, Figure 3). Velocity studies show that as the polymer concentration increases a more rigid molecular structure is formed perhaps by bonding between the large polymer molecules. The variation of ultrasonic velocity in a mixture depends upon increase or decrease of intermolecular free length after mixing components. On the basis of a model, for sound propogation proposed by Eyring and Kincaid (Erything and Kincaid 1938), ultrasonic velocity should decrease, if the intermolecular free length increase and vice-versa. This is in fact observed in the present investigation. It is observed that with increase in concentration of polyethylene glycol in solution, the adiabatic compressibility decreases (Table 4 and Fig 4). This shows the enhancement of the bond strength with concentration. Similar results are reported in earlier reported data (Jayakumar et al 2015). Variation of acoustic impedance with temperature is shown in (Table 5 and Fig.5). It is noticed that the acoustic impedance increases with increasing concentration. These results also support the conclusions drawn from the behaviour of variation in ultrasonic velocity. This is in agreement with the requirement as both ultrasonic velocity and density increase with increase in concentration of the solute and also effective due to solute-solvent interactions (Syal et al 2005). Change of intermolecular free length with concentration is presented in Table - 6 and Fig. 6 which shows that with increase in concentration of PEG in solution, it decreases. This is also in accordance with the expected molecular interaction between the solute-solvent, increases in compressibility. The results are in good agreement with earlier reported data (Thirumaran et al 2013).Table 7 and Fig. 7 show the variation of relaxation time with concentration. It is clearly seen that relaxation time decreases with increase in concentration of Polyethylene glycol. This may be due to structural relaxation process.

Conclusion

The present study shows that there exist a strong interaction between solute and solvent. It is also concluded that association between Polyethylene glycol and water is responsible for increase in ultrasonic velocity. This in turn affects other acoustical parameters. It may be due to Polymer molecules come to the solvent molecules leaving sufficient space around them. The result also indicate the existence of positive interactions between polymer and molecules

Table: 1- Density($x10^3 kg/m^3$) of polyethylene glycol (PEG) at different concentration and at 50^0C temperature at 1 MHz frequency-

Concentration	*Density*
1 %	1.506
0.8%	1.412
0.6%	0.966
0.5%	0.915
0.4%	0.970
0.3%	0.969

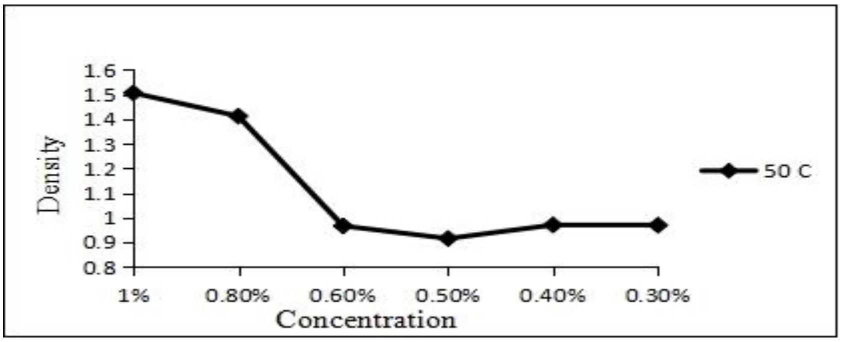

Fig.-1: Variation of density with concentration at 50^0C temperature

Table: 2-Viscosity($x10^{-1}$Pa.sec) of polyethylene glycol (PEG) at different concentration and at 50^0C temperature at 1MHz frequency-

Concentration	*Viscosity*
1 %	0.3928
0.8%	0.2160
0.6%	0.1560
0.5%	0.0899
0.4%	0.0860
0.3%	0.0690

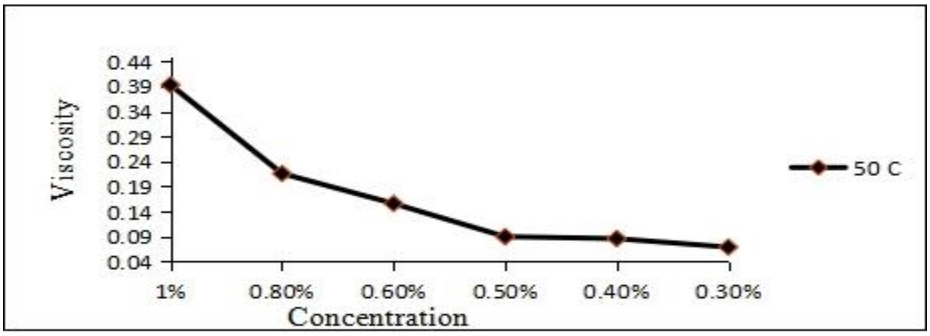

Fig.-2: Variation of viscosity with concentration at 50^0C temperature

Table: 3-Ultransonic velocity (m/s) of polyethylene glycol (PEG) at different concentration and at 50^0C temperature 1MHz frequency

Concentration	*Ultrasonic velocity*
1 %	1605.8
0.8%	1595.4
0.6%	1585.9
0.5%	1574.9
0.4%	1563.6
0.3%	1562.7

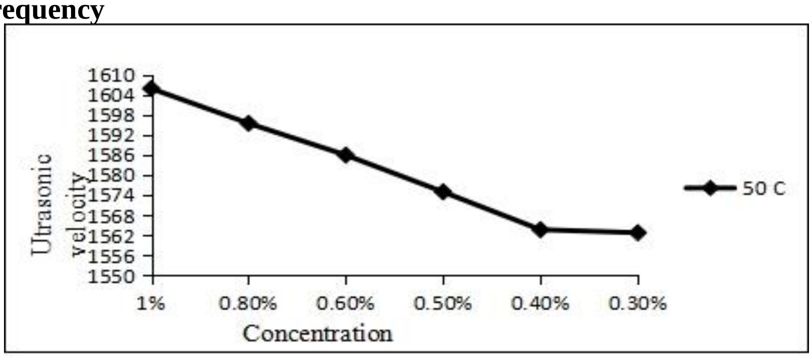

Fig.-3: Variation of ultrasonic velocity with concentration at 50^0C temperature

Table: 4- Adiabatic compressibility($x10^{-10}kg^{-1}ms^2$) at different concentration and at 50^0C temperature at 1MHz for polyethylene glycol (PEG)-

Concentration	*Adiabatic compressibility*
1 %	2.574
0.8%	2.783
0.6%	4.116
0.5%	4.407
0.4%	4.215
0.3%	4.226

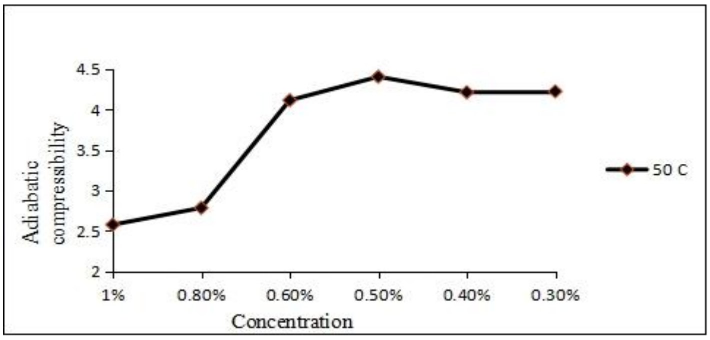

Fig.-4: Variation of adiabatic compressibility with concentration at 50^0C temperature

Table: 5- Acoustic impedance ($x10^3kgm^2s^{-1}$) at different concentration at 50^0C temperature at 1MHz for polyethylene glycol (PEG)-

Concentration	*Acoustic Impedance*
1 %	2419
0.8%	2252.2
0.6%	1531.8
0.5%	1440.7
0.4%	1517.2
0.3%	1514.3

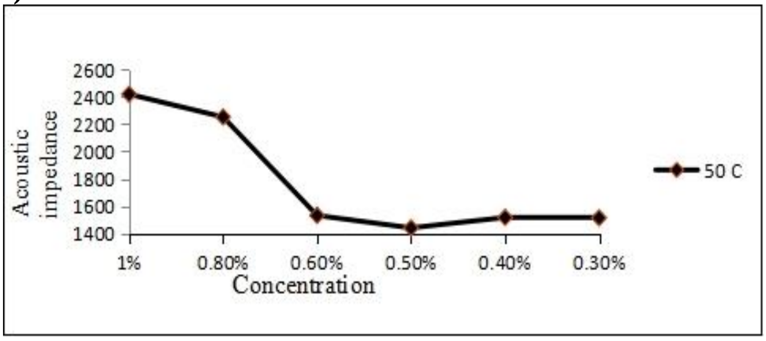

Fig.- 5: Variation of Acoustic Impedance with concentration at 50^0 C temperature

Table: 6- Intermolecular Free Length ($x10^{-13}m$) at different concentration a 50^0C temperature at 1MHz for polyethylene glycol (PEG)-

Concentration	*Intermolecular free length*
1 %	2.172
0.8%	2.258
0.6%	2.746
0.5%	2.841
0.4%	2.79
0.3%	2.782

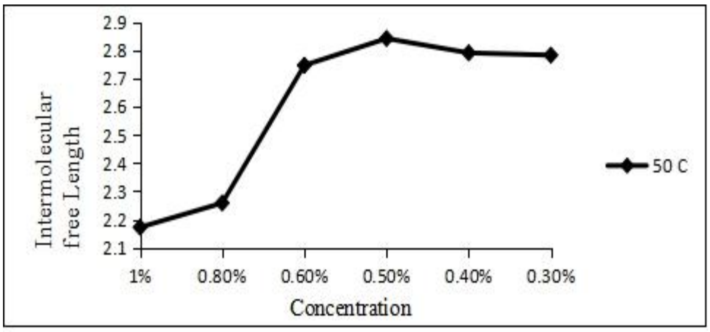

Fig.- 6: Variation of Intermolecular free Length with concentration at 50^0 C temperature

Table: 7 - Relaxation time (x10^{-12}s) at different concentration at 50^0C temperature at 1MHz for polyethylene glycol (PEG)–

Concentration	*Relaxation Time*
1 %	1.35
0.8%	0.868
0.6%	0.856
0.5%	0.528
0.4%	0.483
0.3%	0.389

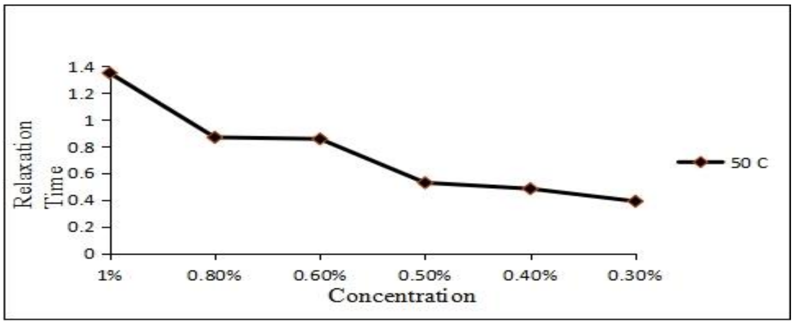

Fig.- 7: Variation of Relaxation time with concentration at 50^0 C temperature

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