

MOLECULAR INTERACTION STUDY OF POLYETHYLENE GLYCOL WITH WATER

Abstract

Sound velocity, viscosity and density are experimentally measured of binary mixture of Polyethylene glycol with water at frequency of 1MHz. Experimental values have been calculated at different range of concentration and at 45°C temperature. Different parameters are calculated like adiabatic compressibility, intermolecular free length and relaxation time of PEG solutions. These values are used to understand the behaviour of intermolecular interaction of solute and solvent.

Keywords: Sound velocity, adiabatic compressibility, intermolecular free length.

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I. INTRODUCTION

For research related to Polymers field, for the molecular interactions and structural study ultrasonic study has become a very interesting tool for multicomponent systems. Polyethylene glycol has wide applications in textiles, leather industry, is widely used in rubber, textiles and in field of pharmaceuticals. Acree [1] and Praunitz et al. [2] explained the wide applications of liquid, liquid mixtures and solutions in the textiles, chemicals, nuclear industries. Sound velocity, density and viscosity of PEG with acetonitrile and mixtures of water was studied by Syal et. al. [3]. Sound velocity measurement studies in last few years, are widely used in the investigation of behaviour of solute- solvent systems and to understand the solute and solvent nature in mixtures of liquids. To understand the molecular interaction between solute and solvent for mixtures of binary and ternary liquids. [4-7] literature survey reveals that adiabatic compressibility and sound velocity are found useful. Ultrasonic properties of solutions of polymers have shown that volumetric measurement studies and their acoustical parameters provides much useful information on solute-solvent interaction, these are found to be production of polymer and their uses in industries and other areas [8]. Using Shio model, ultrasonic study of hydration of Polyethylene glycol was made by S Kalyanasundaram et. al. [9]. Several reporters [10-14] have studied the volumetric properties for PEG. The available literature for PEG having molecular weight approximately 200 is not much. In our recent study investigation Polyethylene glycol of 200 molecular weight is used to elaborate the study.

II. EXPERIMENTAL DETAIL

In present study polyethylene glycol (of approximate molecular weight ≈ 200 Da) in the form of liquid is used with water. Fixed volume of polyethylene glycol is mixed with water in proper proportion, the solutions were prepared by mixing continuously to obtain desired solution. The range of concentration studied in solution is 1%, 0.8%, 0.6%, 0.5%, 0.4% and 0.3% in the temperature 45°C at 1 MHz frequency. Variable path Ultrasonic interferometer is used to measure the velocity of sound with reliability ± 4 m/s at temperature of 30°C . By the circulation of water from the electronically operated digital constant temperature having an accuracy of $\pm 0.1^\circ\text{C}$, solution temperature is kept constant by the outer jacket of measuring cell having double wall experimental liquid. The densities of the solutions at various temperatures are measured by using specific gravity bottle of 10 ml and single pan micro balance. The reliability in density is found to be 0.5 kg/m^3 . Viscosity was measured by Ostwald's viscometer was placed inside a jacket with double wall, in which water was circulated by thermostat water bath. For providing the thermal equilibrium, inner cylinder of this double wall glass jacket was filled with water of required temperature. The calculation of intermolecular interaction parameters is done by well known formulae [15-17].

III. RESULT AND DISCUSSION

In this investigation the density, viscosity and velocity of ultrasound have been measured at different concentration of Polyethylene glycol at 45°C temperature, which is shown in Table 1, 2 and 3 respectively. By the use of these experimental values for PEG-200 different acoustical parameters like intermolecular free length, relaxation time and adiabatic compressibility have been calculated by the use of standard formulae and results are presented

in Table 4, 5 and 6 respectively. The variation of these properties with concentration is shown in Figure 1-Figure 6 respectively.

Table -1 and Figure 1 represents the effect of density with concentration at temperature of 45°C. Density decreases with concentration increment of PEG. Electrostriction in solution may lead to decrease in density. The volume decreases due to this electrostriction and results in the increases in the density as a solute molecules number increases the electrostriction and density. It is clear from Table -2 and Fig.2 that, there is decrease in viscosity with increase of the concentration of PEG – 200. The plot of sound velocity with concentration is shown in Table-3 and Figure 3. The value of ultrasonic velocity decreases by the increase in PEG concentration. S K Syal V K et. al. [3] also reports the same results of increase in velocity with concentration increase. This shows the interaction of PEG with solvent molecules. There may exist interaction with in the concerned molecules. Intermolecular free length being the important factor as it evaluates the ultrasonic velocity in the fluid and condensed state. As the concentration of solute increases this leads to reduce the gap in between the two groups and this is also present in this investigation. It is reported from Fig. 4 and Table-4 that intermolecular free length decreases with concentration increase (Fig 4) of PEG. It is found to be in similar trend of the reports by previous researchers [18]. It is clearly seen from Table-5 and Fig 5 that adiabatic compressibility decreases with increase of concentration of PEG. These results are in accordance with previous reports [9]. This may be because of the movement of solute molecules towards each other by wrenching the molecules from bulk of the solvent, because of electrostriction forces they attract certain solvent, there is decrease in the incoming next solute because of this obtainable molecule of solvent. Table-6 and Figure 6 shows the variation of relaxation time with concentration. With increase in concentration of PEG relaxation time also increases. This may be because of the kinetic theory of fluid.

IV. CONCLUSION

In the present investigation it is clear that there is strong interaction between polyethylene glycol and water. The increase in the value of ultrasonic velocity and that led to effect the other acoustical parameters is due to molecular interaction between solvent and solute. This is because of the reason that molecules of polymer come near to molecules of solvents by departing with enough space round them. This study depicts the behaviour of PEG at different concentration in terms of the molecular interactions. This study is found to be beneficial for making and uses of Polyethylene glycol in industries and different fields.

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Table 1: Density ($\times 10^3 \text{Kgm}^{-3}$) at 45° C and at Different Concentration at MHz foe PEG

Concentration (%)	Density
1.0	1.506
0.8	1.321
0.6	0.986
0.5	0.932
0.4	0.971
0.3	0.970

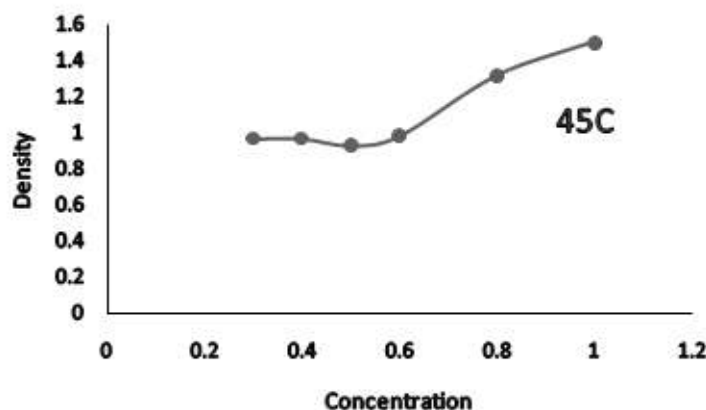


Figure 1: Variation of Density with Concentration at 45°C

Table 2: Viscosity (Pa.s) at 45°C Temperature and Concentration at 1MHz for PEG

Concentration (%)	Viscosity
1.0	.045
0.8	0.029
0.6	0.026
0.5	0.018
0.4	0.010
0.3	0.007

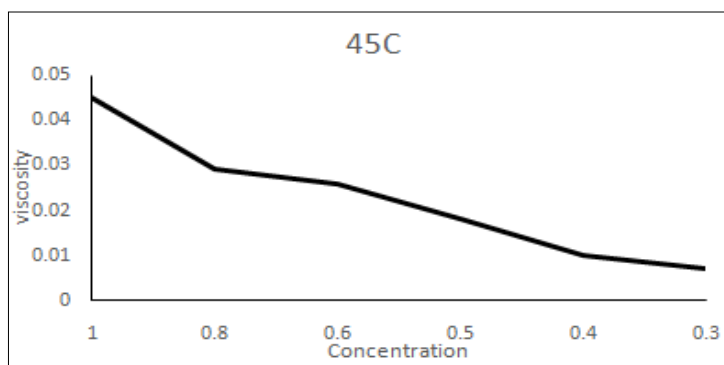


Figure 2: Variation of Viscosity with Concentration at 45°C

Table 3: Ultrasonic Velocity (ms^{-1}) at 45°C Temperature and Concentration at 1MHz for PEG

Concentration (%)	Ultrasonic velocity
1.0	1249.6
0.8	1245.2
0.6	1241.9
0.5	1189.6
0.4	1162.4
0.3	1120.4

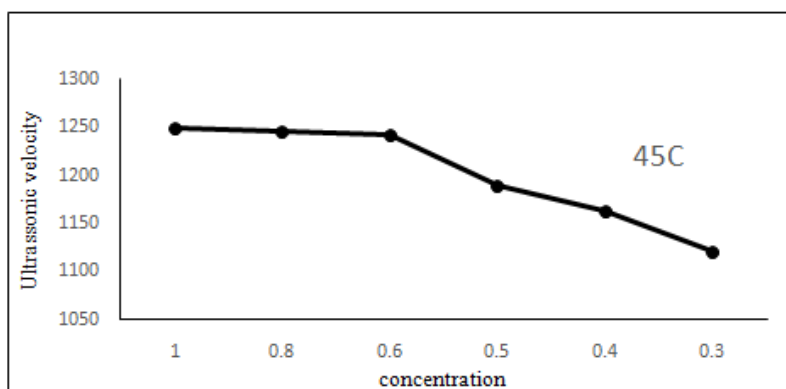


Figure 3: Variation of Ultrasonic Velocity with Concentration at 45°C

Table 4: Intermolecular Free Length ($\times 10^{-10}$ m) at Different Temperature and Concentration at 1MHz for PEG

Concentration (%)	Intermolecular Free length
1.0	0.0026
0.8	0.0028
0.6	0.0035
0.5	0.0037
0.4	0.0038
0.3	0.0039

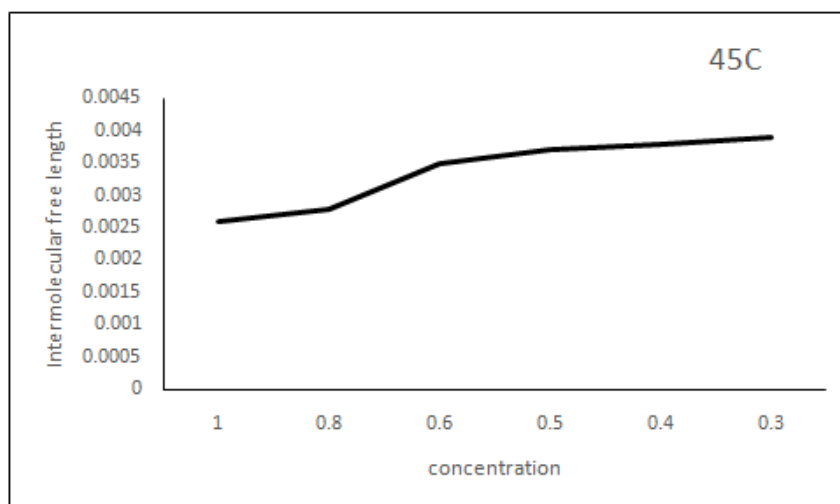


Figure 4: Variation of Intermolecular Free Length with Concentration at 45°C

Table 5: Adiabatic Compressibility ($\times 10^{-10} \text{Kg}^{-1} \text{ms}^2$) at Different Temperature and Concentration at 1MHz for PEG

Concentration (%)	Intermolecular Free length
1.0	4.25
0.8	6.32
0.6	6.45
0.5	6.72
0.4	7.08
0.3	7.75

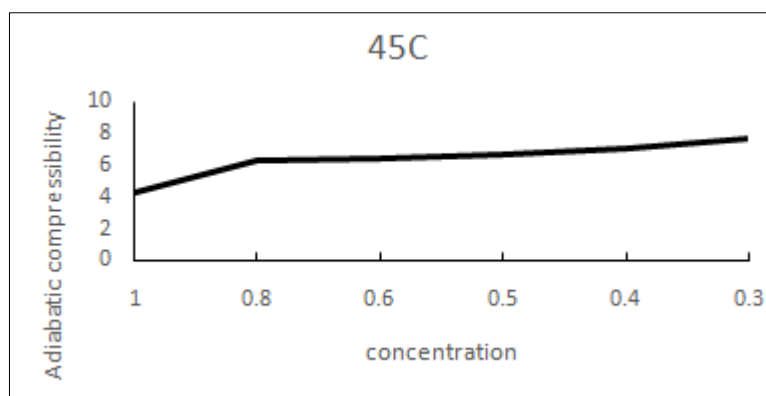
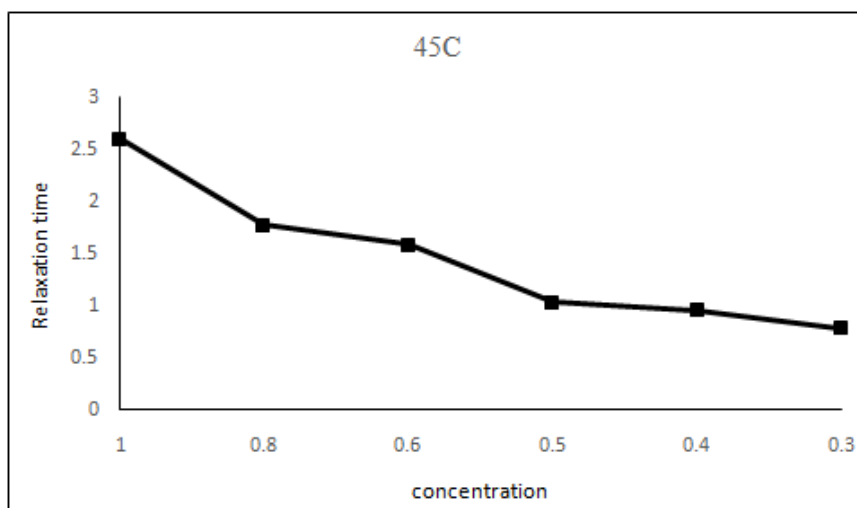


Figure 5: Variation of Adiabatic Compressibility with Concentration at 45°C

Table 6: Relaxation Time ($\times 10^{-12}$ s) at Different Temperature and Concentration at 1MHz for PEG

Concentration (%)	Relaxation time
1.0	2.61
0.8	1.78
0.6	1.59
0.5	1.04
0.4	0.97
0.3	0.79

**Figure 6: Variation of Relaxation Time with Concentration at 45°C**