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°Ctemperature. 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.

Authors

Dr. Richa Saxena
Assistant Professor
School of Basic and Applied Sciences
Shri Guru Ram Rai University
Dehradun, India
saxena.richa23@gmail.com

Narender Singh
Department of Physics
School of Sciences
IFTM University,
Moradabad, India
nspal_physics@rediffmail.com

Jitendra Pal Singh
Department of Physics
School of Sciences
IFTM University,
Moradabad, India
paljitendra124@gmail.com

Swati Gupta
Department of Physics
School of Sciences
IFTM University,
Moradabad, India
2992swati@gmail.com

I. INTRODUCTION

For research related to Polymers field, for the molecular interactions and structural study ultrasonic study has become avery 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 solutionsin the textiles, chemicals, nuclear industries.Sound velocity, density and viscosity of PEG with acetonitrile and mixtures of water was studied bySyal et. al. [3].Sound velocity measurement studies in last fewyears, 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 volumetricmeasurement studies and theiracoustical 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]. Severalreporters[10-14] have studied the volumetric properties for PEG. The available literature for PEGhaving 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 ismixed with water in proper proportion, the solutions were prepared by mixing continuously to obtained desired solution. The range of concentration studied insolution is 1%, 0.8%, 0.6%, 0.5%,0.4% and 0.3% in the temperature45° Cat 1 MHz frequency. Variable path Ultrasonic interferometer is used to measure the velocity of sound with reliability ± 4 m/s at temperature of 30^0 C. By the circulation of water from the electronically operated digital constant temperature having an accuracy of ± 0.1^0 C, solution temperatureis 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 reliabilityin density is found to be0.5 kg/m^3. Viscosity was measured by Ostwald's viscometerwas 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 bywell known formulae[15-17].

III. RESULT AND DISCUSSION

In thisinvestigation the density, viscosity and velocity of ultrasound have been measured at different concentration of Polyethylene glycol at 45º C temperature, which is shown in Table 1, 2 and 3 respectively. By the useof 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 standardformulae and results are presented

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

Table -1 and Figure 1 represents the effect of density with concentration at temperature of 45ºC. Density decreases with concentration increment of PEG. Electro striction in solution may led 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 clearfrom 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 exists interaction with in the concerned molecules. Intermolecular free length being theimportant factoras itevaluates 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 group and this isalsopresent in thisinvestigation. 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 Fig5 that adiabatic compressibility decreases with increase of concentration of PEG. These results are in accordance with previousreports [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 electro striction forces they attract certain solvent,there is decrease in the incoming next solute because of thisobtainable 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 solventsby 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 bebeneficial for making and uses of Polyethylene glycol in industries and different fields.

REFERENCES

[1] Acree W E, Thermodynamics Properties of Non- Electrolytic solutions, 1st Edition, Academic Press, New York, Orlando, ISBN: 0120430207, 1984
[2] J M Prausnitz, B Linchenthalr and E G Azevedi, Molecular Thermodynamics of fluid-Phase Equlibria, 2nd Edition, Prentice Hall Inc., Prentice, 1986.
[3] V K Syal, Anita Chauhan and Suvarcha Chauhan, J of Pure and Applied Ultrasonics, 27, pp. 61-69, 2005.
[4] S J Kharat, J of Molecular liquids, 140, pp. 10-14, 2008.
[5] WiolettaZwirbla , Anna Sikorska and Bogumil B J Linde, 743, pp. 49-52, 2005.
[6] A Ali, A K Khan, Pranama J of Physics, 58, pp. 695-701, 2002.
[7] S W Mayer, G Meier, G Meier Hoffman anf I Alig, Physical Review E, 55(3), 1997.
[8] S Kalyanasundaram, S Sundaresan, J Hemalatha, Bulletin of Electrochemistry, 15, pp.501, 1999.
[9] S Kalyanasundaram, S Sundaresan, J Hemalatha, J of Polym. Material, 19, pp.211, 2001.

[10] S Grace Sahaya Sheba, R Omegala Priakumari, International J of Mathematical Computational Physical and Quantum Engineering no.2, 8, 2014.
[11] Poly (ethylene glycol) chemistry: Biotechnical and Biomedical application, Ed. , J M Haris, Plesum, NewYork, 1992.
[12] D S Soane, Polymer applications in Biotechnology, Pretice Hall Eagle Wood Cliffs, 1992.
[13] G D Smith, D Y Yoon, R L Jaffe, R H Colby, R Krishnsmoorti, L J Fetlers, J of Macromolecules, 122, pp. 15-20, 2005.
[14] S K Mehta, Rajni Jain, Shweta Sharma, nK K Bhasin, J of Molecular liquids, 122, pp. 15-20, 2005.
[15] S C Bhatt, H K Semwal, V Lingwal, K Singh and B S Semwal, J of Acoustical Society of India, 28, 275-278, 2000.
[16] S C Bhatt, H K Semwal, V Lingwal, K Singh and B S Semwal, J of Acoustical Society of India, 28, pp. 293-296, 2000.
[17] Y Marcue, Introduction to liquid state Chemistry, New York, Wiley, Int, 1977.
[18] V Y Syal, Uma Kumari, S Chauhan and M S Chauhan, Indian J of Pure and applied Physics, 30, pp. 719, 1992.

Table 1: Density ($x10^{3}Kgm^{-3}$) at 45º 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

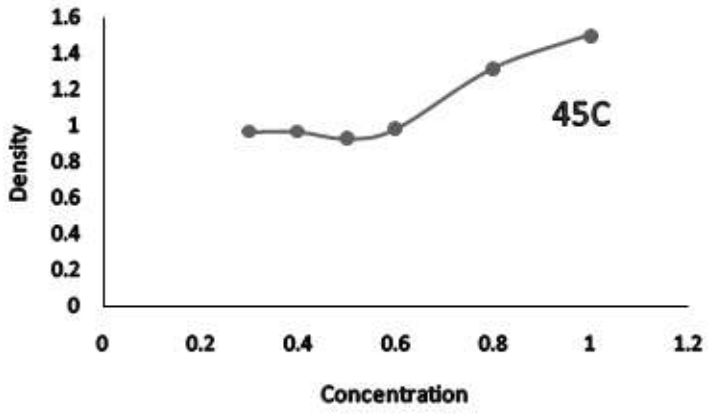

Figure 1: Variation of Density with Concentration at 45ºC

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

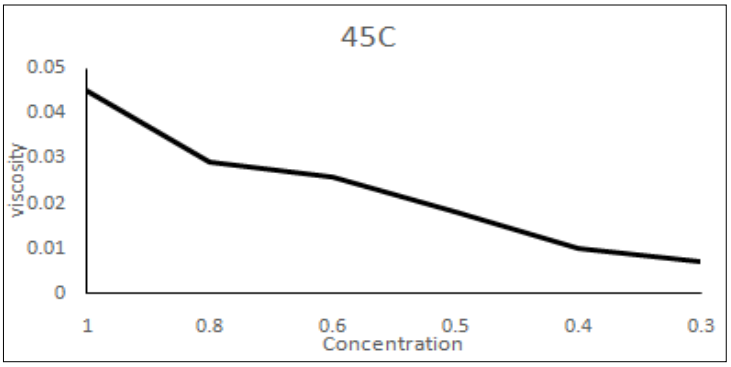

Figure 2: Variation of Viscosity with Concentration at 45ºC

Table 3: Ultrasonic Velocity (ms^{-1}) at 45^0C 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

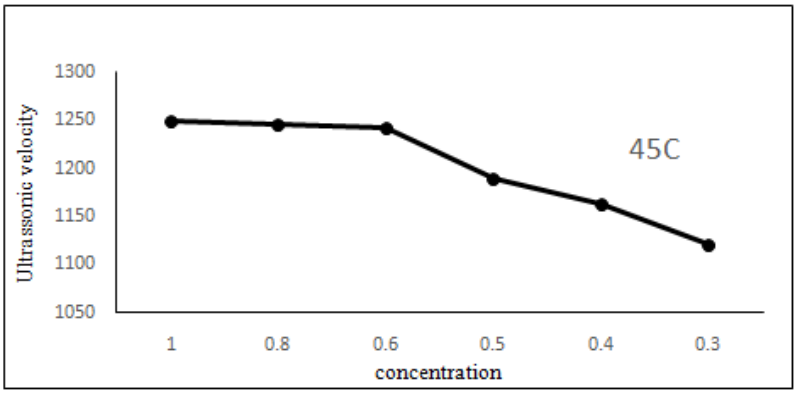

Figure 3: Variation of Ultrasonic Velocity with Concentration at 45ºC

Table 4: Intermolecular Free Length ($x10^{-10}$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

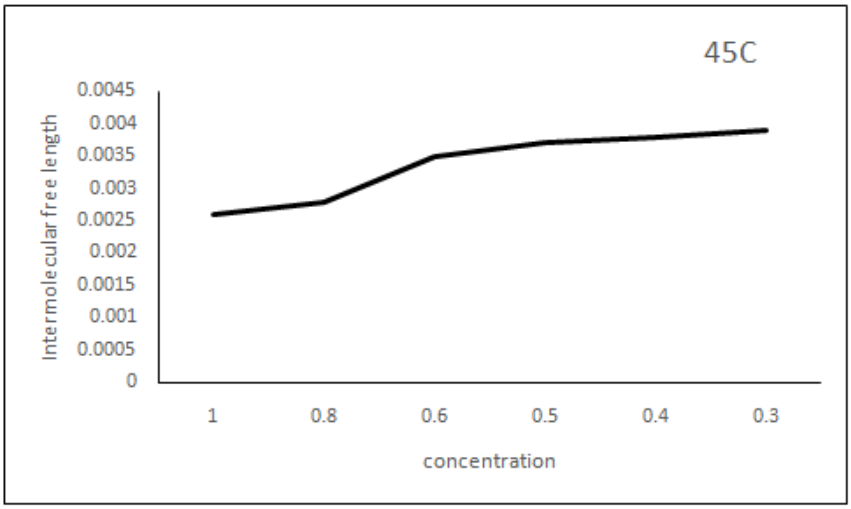

Figure 4: Variation of Intermolecular Free Length with Concentration at 45ºC

Table 5: Adiabatic Compressibility ($x10^{-10}Kg^{-1}ms^{2}$) 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**

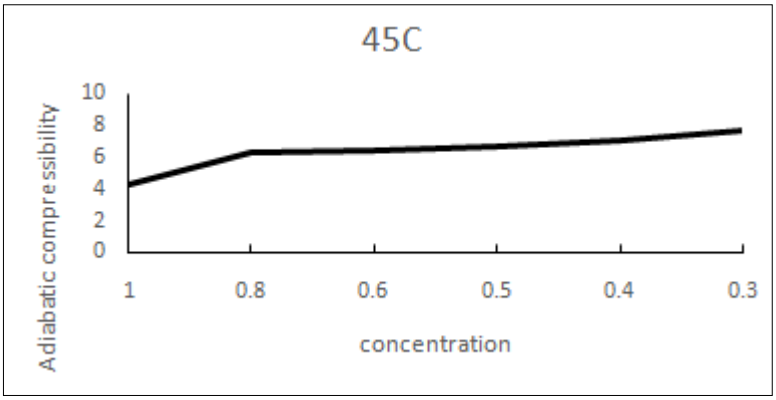

Figure 5: Variation of Adiabatic Compressibility with Concentration at 45ºC

Table 6: Relaxation Time ($x10^{-12}$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**

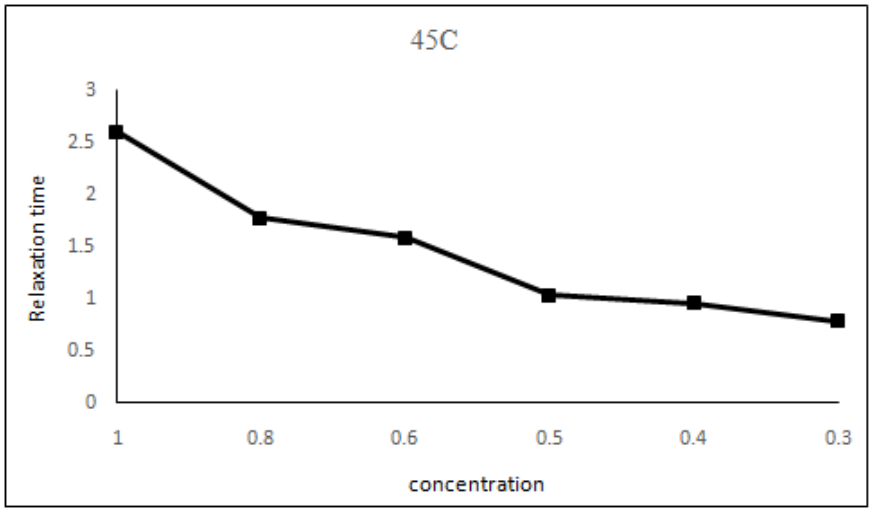

Figure 6: Variation of Relaxation Time with Concentration at 45ºC