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Molecular Interactions of Aqueous Solution of Polyethylene Glycol

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Abstract: The speed of ultrasonic waves has been measured in aqueous solution of polyethylene glycol at 1 MHz frequency. Measurements were carried out in temperature range 30°C to 65°C at different concentration range 0.3% to 1.0%. Different acoustical parameters have been calculated like intermolecular free length, relaxation time and adiabatic compressibility by using measured values of ultrasonic speed, density and viscosity. By using these values intermolecular interactions are discussed.

Keywords: ultrasonic velocity, intermolecular free length, relaxation time and adiabatic compressibility

1. Introduction

For investigating the structure and molecular interactions in multi component systems, ultrasonic study has become an interesting research tool in the field of polymers. Polyethylene glycol is widely applicable in rubber, textiles, pharmaceuticals and leather industries. Liquids, Liquid mixtures and solutions have found wide applications in chemical, textile, leather and nuclear industries, which is well explained by Acree[1]and Praunitz et al.[2] V. K. Syal et.al.[3] studied the ultrasonic velocity, viscosity and density of polyethylene glycols in acetonitrile and water mixture. In recent years the measurements of ultrasonic velocity have been adequately used to study the nature of molecular systems and physio- chemical behaviour in liquid mixtures. A survey of literature of binary and ternary mixtures[4-7] shows that studies of ultrasonic velocity and adiabatic compressibility are useful in understanding the molecular interactions. Acoustical properties of polymer solutions have shown that ultrasonic velocity and its derived parameters provide much information on molecular interactions, which are of utmost importance for processes involving polymer production and their uses[8]. S. Kalyanasundaram et al.[9] studied ultrasonic study on hydration of polyethylene glycol using shiio model. Many researchers [10-14] have calculated the ultrasonic parameters of polyethylene glycol. But for polyethylene glycol of molecular weight 200, available literatures are very few. Therefore in present investigation PEG of molecular weight 200 is taken.

2. Experimental Details-

In the present investigation liquid polyethylene glycol of molecular weight approximately 200 is used. The solutions were prepared by adding known volume of polyethylene glycol to fixed volume of water and stirring under reflex, until a clear solution was obtained. The concentration range studied in the solution is 0.3%- 1.0% (v/v). Different acoustical parameters like, intermolecular free length, adiabatic compressibility and relaxation time were calculated at different concentration like 1.0%, 0.8%, 0.6%,

0.5%, 0.4% and 0.3% and at different temperatures 30°, 35°, 40°, 45°, 50°, 55°, 60° and 65°C at 1MHz frequency by using variable path ultrasonic interferometer with reproducibility of ± 0.4 m/s at 25^oC. The temperature of the solution has been kept constant by circulating water from the thermostatically controlled $(\pm 0.1^{\circ}C)$ water bath. The densities at different temperatures were measured using 10ml specific gravity bottle and single pan macro balance. The uncertainty in density measurements was found to be about 0.5kg/m³. The viscosity of the mixtures was determined by using Ostwald's viscometer, which was kept inside a double-walled -jacket, in which water from thermostat water bath was circulated. The inner cylinder of this double-wall-glass jacket was filled with water of desired temperature so as to establish and maintain the thermal equilibrium. The accuracy in the viscosity measurements is within $\pm 0.5\%$. These parameters are calculated by using standard relations [15,16,17].

Ultrasonic velocity $v = f \lambda$ (1) Adiabatic compressibility $\beta = 1 / v^2 \rho$... (2) Intermolecular free length Lf = K $\sqrt{\beta}$ (3) Relaxation time $\tau = 4 \eta / 3 \rho v^2$ (4)

Where

- ρ , is density of the medium.
- $\boldsymbol{\upsilon},$ is the ultrasonic velocity in the medium.
- η , is viscosity of the medium.
- f, is frequency.
- λ , is wavelength
- K, is Jacobson's constant,

Temperature	1							
Concentration	30^{0} C	35 ⁰ C	40^{0} C	$45^{0}C$	50 ⁰ C	55 ⁰ C	60 ⁰ C	65^{0} C
(v/v)	50 C	55 C	70 C	чJ С	50 C	55 C	00 C	05 C
*								
1.0%	1.509	1.508	1.507	1.507	1.506	1.506	1.503	1.502
0.80%	1.435	1.430	1.426	1.421	1.412	1.398	1.383	1.368
0.60%	1.018	1.009	0.999	0.989	0.966	0.946	0.946	0.938
0.50%	0.970	0.958	0.943	0.936	0.915	0.905	0.883	0.868
0.40%	0.985	0.982	0.979	0.975	0.970	0.947	0.908	0.906
0.30%	0.982	0.978	0.976	0.972	0.969	0.941	0.901	0.889

Table 1: Density (x10³Kgm⁻³) at different temperature and concentration at 1MHz for PEG

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Temperature			_			_	_	
Concentration(v/v)	$30^{\circ}C$	$35^{\circ}C$	$40^{\circ}C$	$45^{\circ}C$	$50^{\circ}C$	$55^{\circ}C$	$60^{\circ}C$	$65^{\circ}C$
↓								
1.0%	.064	.060	.053	.046	.039	.034	.024	.020
0.80%	0.066	0.035	0.032	0.029	0.022	0.019	0.016	0.016
0.60%	0.049	0.035	0.020	0.018	0.016	0.014	0.013	0.011
0.50%	0.029	0.023	0.011	0.010	0.011	0.009	0.009	0.009
0.40%	0.026	0.015	0.011	0.010	0.009	0.008	0.007	0.005
0.30%	0.012	0.009	0.008	0.007	0.007	0.006	0.006	0.005

Table 2: Viscosity (Pa.s) at different temperature and concentration at 1MHz for PEG

Table 3: Ultrasonic velocity (ms⁻¹) at different temperature and concentration at 1MHz for PEG

Temperature — Concentration (v/v) ↓	► 30 ⁰ C	35 ⁰ C	40^{0} C	45 ⁰ C	50 ⁰ C	55 ⁰ C	60 ⁰ C	65 ⁰ C
1.0%	1264.8	1260.6	1253.3	1249.6	1246.5	1239.8	1236.4	1230.5
0.80%	1262.8	1258.4	1250.4	1245.2	1241.8	1236.8	1230.9	1225.7
0.60%	1257.6	1252.8	1246.8	1241.9	1237.9	1233.8	1228.7	1219.7
0.50%	1234.7	1220.4	1195.8	1189.6	1185.7	1181.9	1176.1	1174.8
0.40%	1187.6	1177.6	1167.2	1162.4	1157.6	1155.3	1151.2	1140
0.30%	1155.1	1142.5	1133.7	1120.4	1114.6	1098.1	1095.7	1087.2

Table 4: Intermolecular Free Length (x10⁻¹⁰m) at different temperature and concentration at 1MHz for PEG

Temperature → Concentration(v/v)	30 ⁰ C	35 ⁰ C	40 ⁰ C	45°C	50 ⁰ C	55°C	60 ⁰ C	65 ⁰ C
1.0%	0.0028	0.0027	0.0028	0.0028	0.0029	0.0028	0.0028	0.0028
0.80%	0.0028	0.0028	0.0029	0.0029	0.0029	0.0029	0.0030	0.0029
0.60%	0.0034	0.0034	0.00344	0.0035	0.0035	0.0036	0.0036	0.0036
0.50%	0.0035	0.0036	0.0037	0.0037	0.0038	0.0038	0.0039	0.0039
0.40%	0.0036	0.0037	0.0037	0.0037	0.0038	0.0038	0.0039	0.0039
0.30%	0.0037	0.0038	0.0038	0.0039	0.0039	0.0040	0.0041	0.0042

Temperatu re ► Concentration(v/v)	30 ⁰ C	35 ⁰ C	40 ⁰ C	45 ⁰ C	50 ⁰ C	55 ⁰ C	60 ⁰ C	65 ⁰ C
1.0%	4.14	4.17	4.22	4.25	4.27	4.32	4.35	4.40
0.80%	6.19	6.23	6.28	6.32	6.38	6.52	6.67	6.79
0.60%	6.24	6.28	6.38	6.45	6.51	6.63	6.81	6.9
0.50%	6.38	6.53	6.65	6.72	6.85	6.94	7.12	7.39
0.40%	6.63	6.72	6.94	7.08	7.25	7.34	7.54	7.78
0.30%	7.24	7.33	7.75	7.75	8.07	8.23	8.67	8.88

Table 6: Relaxation time $(x10^{-12}s)$ at different temperature and concentration at 1MHz for PVA

Temperature Concentration	30 ⁰ C	35°C	40°C	45°C	50°C	55°C	60°C	65°C
1.0%	3.54	3.34	2.98	2.61	2.24	1.99	1.41	1.17
0.80%	3.93	2.05	1.93	1.78	1.32	1.20	1.02	1.02
0.60%	4.09	2.95	1.72	1.59	1.41	1.32	1.20	1.02
0.50%	2.33	2.13	1.06	1.04	0.93	0.94	0.91	0.91
0.40%	2.45	1.45	1.08	0.97	0.88	0.82	0.77	0.59
0.30%	1.19	0.97	0.85	0.79	0.76	0.74	0.68	0.67

3. Result and Discussion

In the present work density, viscosity and ultrasonic velocity have been measured at different temperature and concentration of polyethylene glycol, which is shown in Table-1, 2, and 3 respectively. By using these values for PEG-200, intermolecular free length, relaxation time and adiabatic compressibility have been calculated by using well known relations and the results have been presented in Table-4, 5 and 6, respectively. The variations of these parameters with temperature and concentration have been shown in Fig.1-Fig.6 respectively.

Table-1 and Fig.1& 2 represent the variation of density with temperature and concentration respectively. Density decreases with increase in temperature and increases with increase in concentration. It may be due to electro striction in that solution. This electro striction decreases the volume

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and hence increases the density as a number of solute molecules increase the electro striction and density. It is evident from Table-2 and Fig.3 & 4 that, viscosity decreases with increase in temperature and increases with increase in concentration of PEG-200. The variations of ultrasonic velocity with temperature and concentration have been shown in Table-3 and Fig. 5 & 6. Ultrasonic velocity decreases with increase in temperature and increases with increase in concentration of PEG. Similar increase in velocity with increase in concentration has also been reported by Sval V.K. et al[3]. This indicates interactions between PEG and solvent molecules. The increase or decrease in value of ultrasonic velocity and intermolecular free length with composition indicates interactions between contributing molecules. Intermolecular free length is a predominant factor as it determines the sound velocity in the condensed and fluid state. The increase in the solute concentration leads to the decrease in the gap between two species and this is ideally observed in present work. It is clear from Fig.7 and Table-4 that intermolecular free length increases with increase in temperature and decreases with increase in concentration (Fig.8). It is similar trend reported by earlier workers[18]. It is clear from Table-5, and Fig.9, that adiabatic compressibility increases with increase in temperature and Fig.10 shows the variation of adiabatic compressibility with concentration. It decreases with increase in concentration. These results are in agreement with earlier workers[9]. It may be due to that when solute molecules are added to the solvent, they attract certain solvent molecules towards themselves by wrenching the molecule from bulk of solvent due to the forces of electro striction because of this available solvent molecule for the next incoming solute gets decreased. Table -6, Fig. 11 & Fig. 12 show the variation of relaxation time with temperature and concentration. Relaxation time decreases with increase in temperature and increases with increase in concentration. This may be due to as per kinetic theory of fluid.

4. Conclusion

From above study it is concluded that there is association between polyethylene glycol and water because of interaction between solvent and solute may be responsible for increase in ultrasonic velocity, and in turns affects other parameters. It may be because of polymer molecules come close to the solvent molecules leaving sufficient space round them. It also shows the nature of polymer in solvent at different concentration and temperature and to study intermolecular interactions. Those in turns are useful for production and uses of polymers in pharmaceuticals and industry.

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