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Ultrasonic Investigation of PEG200 and PEG300 in Cyclohexanone Solutions

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Abstract

The present study investigates the intermolecular interactions and structural behavior of PEG200 and PEG300 solutions in cyclohexanone using ultrasonic techniques. Acoustical, thermodynamical, and physicochemical parameters were evaluated at concentrations ranging from 0.25–1.0%. Experimental results showed that density, viscosity, ultrasonic velocity, absorption coefficient, acoustic impedance, internal pressure, Rao's constant, Wada's constant, and viscous relaxation time increased with concentration, whereas adiabatic compressibility and free volume decreased. These variations indicate strong intermolecular interactions between polyethylene glycol and cyclohexanone molecules, leading to enhanced molecular association and compact solution structures. The increase in ultrasonic velocity and acoustic impedance, together with the decrease in compressibility and free volume, confirms stronger cohesive forces and greater structural organization within the mixtures. Comparative analysis revealed that PEG300 exhibits stronger interaction effects than PEG200 due to its higher molecular weight and longer polymer chain. The observed interactions are mainly attributed to dipole–dipole and hydrogen-bond-assisted associations between PEG molecules and the carbonyl group of cyclohexanone. The study demonstrates that ultrasonic analysis is an effective and non-destructive method for understanding molecular interactions and the acoustical and thermodynamical behavior of PEG-cyclohexanone systems.

Keywords: Polyethylene Glycol, Cyclohexanone, Ultrasonic Velocity, Intermolecular Interactions, Adiabatic Compressibility, Acoustic Impedance and Thermodynamical Properties.

1. Introduction

The investigation of ultrasonic properties in liquid mixtures has received a great deal of interest in recent years as it has contributed to the knowledge of intermolecular interactions, molecular association and structural behaviour of complex fluid systems [1]. Ultrasonic techniques are well known and proven tools for the study of the physicochemical properties of liquid mixtures and are non-destructive and highly sensitive. Information about the nature and strength of molecular interaction that can exist in a solution system can be gained from the values of param-

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eters like ultrasonic velocity, density, viscosity, acoustic impedance, compressibility and free length [2]. The acoustical studies are of great importance in polymer science, pharmaceutical formulations, chemical engineering and industrial use of solvents where the behavior of molecular interactions directly affects the material performance and processing properties.

Polyethylene glycol (PEG) is one of the most extensively used polymeric compounds in scientific and industrial applications due to its remarkable physicochemical stability, non-toxic nature, high solubility and excellent compatibility with various organic solvents [3]. The PEGs are linear polyether compounds with repeating ethylene oxide units and come in various molecular weight ranges commercially. PEG200 and PEG300 are two low molecular weight liquid polymers with interesting solvent and interaction properties [4]. They are extensively used in medicine, cosmetics, lubricants, coatings and biomedical formulations owing to their attractive rheological and thermodynamic properties. The range of molecular weights between PEG200 and PEG300 affects the flexibility, association and hydrogen bonding capacity of their solutions, which in turn has an impact on the acoustical and transport properties of the solutions [5].

Cyclohexanone is an important cyclic ketone widely used as an industrial solvent and chemical intermediate in the production of nylon, resins, paints, adhesives, and pharmaceuticals. The carbonyl functional group is polar, which allows cyclohexanone to interact strongly with other polar molecules, such as polymeric molecules such as polyethylene glycols [6]. It is therefore necessary to understand the interaction between the PEG molecules and the cyclohexanone in order to gain insight into the manner in which molecules are organized and arranged within the solution medium. Such investigations can be used to develop better solvents, and to gain more understanding of solution chemistry and molecular dynamics [7].

Ultrasonic investigation of polymer-solvent systems is useful technique for the study of the degree of molecular interaction and association in liquid mixtures [8]. The velocity and absorption of ultrasonic waves in a medium is strongly affected by intermolecular forces, packing efficiency and relaxation processes in the structure. Changes in the acoustical parameters are usually associated with the presence of certain interactions like hydrogen-bonding, dipolar interaction and molecular aggregation [9]. The molecular structure and the compressibility behaviour may change because of the interaction between the ether oxygen atoms of PEG molecules and the carbonyl group of cyclohexanone in PEG-Cyclohexanone systems. Thus, in detail, ultrasonic analysis can give a great deal of information concerning the strength and nature of these interactions [10].

A few researchers have reported ultrasonic and acoustical studies of polymer solution and binary liquid mixtures to assess the molecular interactions and thermodynamic properties [11-14]. A previous study on a polyethylene glycol system has shown that ultrasonic methods are very efficient in characterizing the structural changes and interaction mechanism in solution media [15-17]. There is

however very little research available regarding the comparative ultrasonic behaviour of PEG200 and PEG300 solutions of cyclohexanone [18-19]. The present study, therefore, focuses on the study of the ultrasonic properties of PEG200 and PEG300 in cyclohexanone by measuring the various acoustical parameters and elucidating the intermolecular interactions of the system. The results of this work should be useful to the understanding of the molecular behavior, acoustic response, and physicochemical properties of PEG-based solvent systems, and eventually the understanding of polymer-solvent interactions in liquid solutions.

2. MATERIALS AND METHODS

Polyethylene glycol samples namely PEG200 and PEG300 used for the present investigation were of analytical reagent grade and were procured from Merck (India) Ltd., Mumbai. The solvent medium used is cyclohexanone, which was obtained from S.D. Fine-Chem Ltd., Mumbai and was not purified. The purity of all the chemicals employed in the study was high with a minimum error in experimental measurements of ultrasonic readings. Solutions were freshly prepared in the lab to ensure that contaminants and solvent evaporation effects were not present.

The amount of PEG200 needed was carefully measured with a digital electronic balance (Shimadzu Corporation, accuracy ±1 mg). Four different concentrations of PEG200 solution were prepared by dissolving 0.25 g, 0.50 g, 0.75 g and 1.00 g of the polymer in 100 ml of cyclohexanone to get 0.25%, 0.50%, 0.75% and 1.00% respectively. The same method was used to prepare PEG300 solutions of the same concentration. Stirring was continuous to assure uniform dissolution and homogeneity of the solutions.

Under controlled temperature, single-frequency ultrasonic interferometer was used to measure ultrasonic signals. The system was calibrated before measurements were taken, to assure the accuracy and reproducibility of the acoustical parameters obtained from the system.

3. RESULT AND DISCUSSION

3.1 Variation of Density, Viscosity and Ultrasonic Velocity in PEG200 and PEG300–Cyclohexanone Systems

The measured densities, viscosities, ultrasonic velocity and intermolecular free length (M_{eff}) of PEG200 and PEG300 in cyclohexanone at different concentrations are listed in Table 3.1 and the graphical variation are shown in Fig. 3.1.1, Fig. 3.1.2 and Fig. 3.1.3. This systematic variation of the aforementioned acoustical and physicochemical parameters is definitely evidence of a great molecular interaction between polyethylene glycol molecules and cyclohexanone solvent molecules.

It is clear from Fig. 3.1.1 that the density of both PEG200 and PEG300 solutions is increased with the increase of concentration [20]. In case of PEG200, the density increment is from 0.9443 g/cm^3 for pure cyclohexanone to 0.9470 g/cm^3 at 1.00 % whereas PEG300 shows a comparatively higher increase to 0.9485 g/cm^3 at the same concentration. This is believed to be due to the tighter packing of molecules and stronger cohesive forces in the solution system [21]. The relatively high densities measured for PEG300 have been attributed to its higher

molecular weight and chain length, which results in more intermolecular association with the cyclohexanone molecules [22]. This type of behaviour indicates dipole-dipole interactions and probable molecular aggregation by hydrogen bonding in the solution medium [23].

Table 3.1 Measured Properties of PEG in Cyclohexonone

SYSTEM	Concentration %	Density gm/cm^3	Viscosity cP	Velocity cm/sec	M_{eff} gm
PEG200	0.00	0.9443	1.7056	137100	98.15
	0.25	0.9455	1.7499	137233	98.28
	0.50	0.9463	1.7995	137333	98.41
	0.75	0.9468	1.8553	137409	98.55
	1.00	0.9470	1.9117	137467	98.68
PEG300	0.00	0.9443	1.7056	137100	98.15
	0.25	0.9464	1.7897	137317	98.32
	0.50	0.9477	1.8654	137447	98.50
	0.75	0.9482	1.9416	137533	98.67
	1.00	0.9485	2.0002	137600	98.85

As concentration increases, the viscosity increases as shown in Fig. 3.1.2. A gradual increase in viscosity is observed for both PEG systems with increasing polymer concentration. The viscosity of PEG200 solutions increases from 1.7056 cP to 1.9117 cP, and PEG300 solutions have a higher increase from 1.7056 cP to 2.0002 cP. This rise in viscosity is due to the increased viscosity after the increase in the strength of the interaction between the molecules of the solute and solvent, as well as the increased resistance to the flow of molecules [24]. The influence of the molecular size and chain entanglement effect is further confirmed by the higher viscosity values shown by PEG300. The higher the concentration, the more effectively the polymer chains interact with the cyclohexanone molecules and the more viscous the solution will become, as a result of which the molecules will not be able to move about as easily [25]. The non-linear increase in viscosity with concentration also shows that there are some kind of structured molecular organization in the liquid mixture [26].

The rate of change of ultrasonic velocity with concentration is shown in Fig. 3.1.3 for PEG200 and PEG300. In both, the velocity of sound rises regularly as the concentration increases, which means that the elasticity and compactness of the solution medium increases [27]. The velocity of PEG200 is increased from 137100 cm/s to 137467 cm/s while PEG300 has even higher increase up to 137600 cm/s. The higher value of ultrasonic velocity could be due to the rise in intermolecular cohesion and a corresponding decrease in compressibility of the solution [28]. The larger the velocity value, the more the constituent molecules interact, and the better the ultrasonic waves can be transmitted in the medium [29]. From the comparison of the velocities, it is evident that PEG300 solutions have a relatively higher velocity, thus indicating stronger molecular association caused by the larger size of PEG molecule and greater interaction between PEG molecules [30].

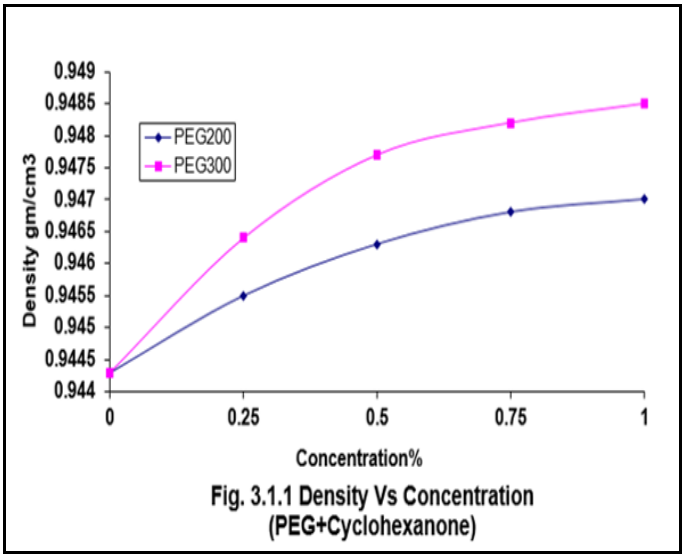

Fig. 3.1.1 Density Vs Concentration (PEG+Cyclohexanone)

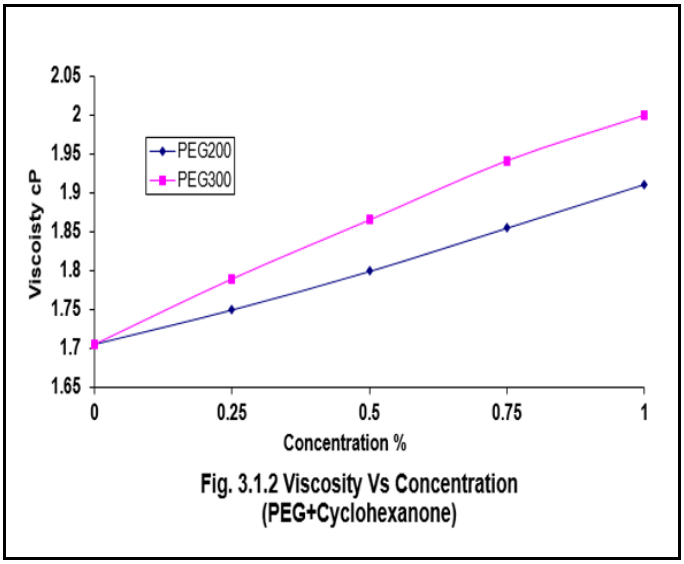

Fig. 3.1.2 Viscosity Vs Concentration (PEG+Cyclohexanone)

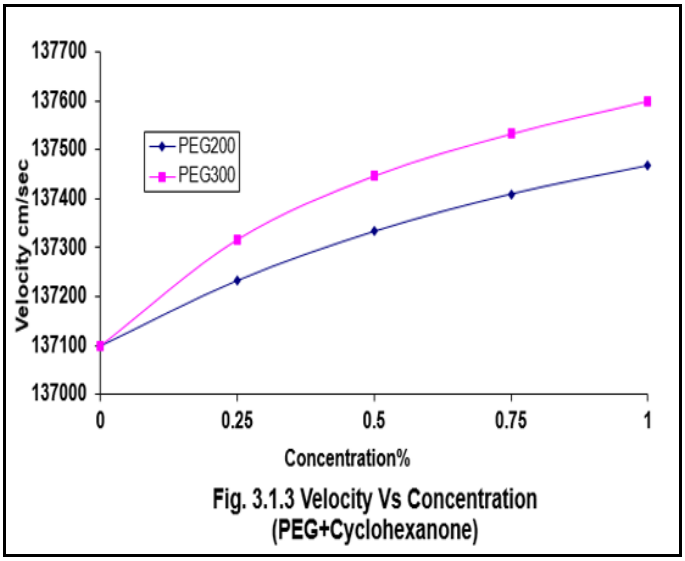

Fig. 3.1.3 Velocity Vs Concentration (PEG+Cyclohexanone)

The simultaneous determination of density, viscosity and ultrasonic velocity clearly indicates that PEG molecules have a strong effect on the structural-acoustical behaviour of the solvent system. The trend observed are in agreement with the presence of significant intermolecular forces between PEG and cyclohexanone molecules [31]. As the concentration increases, the acoustical parameters increase, which facilitates the formation of molecular structures associated with the mixture and the increase of cohesive forces between molecules [32]. Furthermore, PEG300 has higher interaction effects than PEG200, because of the relatively higher molecular weight and longer polymeric chain structure of PEG300 [33].

Therefore, it is evident from the present ultrasonic study that concentration and molecular weight are important parameters in the determination of the acoustical and the physicochemical behavior of PEG-Cyclohexanone systems [12]. The findings of this study are well in line with previous ultrasonic studies of polymer-solvent mixtures, and help shed light on the molecular interaction mechanism that exists in polyethylene glycol solutions.

3.2 Thermodynamical Parameters and Molecular Interaction Studies of PEG200 and PEG300 in Cyclohexanone

The thermodynamical parameters of the PEG200 solutions and the PEG300 solutions in cyclohexanone as a function of concentration are shown in Table 3.2 and in the figures in the following text, as absorption coefficient, free volume, internal pressure and viscous relaxation time respectively. These parameters are important for the understanding of

nature of intermolecular interactions, structure and dynamics of polymer-solvent systems. The difference in the measured parameters observed is a clear indication of strong solute-solvent interaction and modification of the solution medium [34].

The absorption coefficient of PEG200 and PEG300 solutions as a function of concentration is shown in Fig. 3.2.1. The absorption coefficient is observed to be increasing with increasing concentration for both systems. For PEG200, the absorption coefficient increases from 1.843 × 10^{-14} $cm^{-1}s^{-2}$ to 2.043 × 10^{-14} $cm^{-1}s^{-2}$, whereas PEG300 exhibits a comparatively higher increase up to 2.128 × 10^{-14} $cm^{-1}s^{-2}$. The higher value of absorption coefficient means that the ultrasonic energy is being absorbed more strongly, which could be attributed to stronger molecular interactions and energy dissipation in the material [29, 35]. It is assumed that the increase of cohesive forces and relaxation processes between molecules of polyethylene glycol and cyclohexanone solvent molecules is the reason for this behavior [36]. The relatively higher values of PEG300 indicate greater association between the molecules which may be due to increased molecular chain and higher molecular weight [37].

The effect of concentration on free volume is presented in Fig. 3.2.2. The free volume is found to be a decreasing function of concentration for both PEG systems. In PEG200 solutions, the free volume decreases from 7.914 × 10^{-5} ml/mol to 6.751 × 10^{-5} ml/mol, while PEG300 shows a sharper decrease reaching 6.333 × 10^{-5} ml/mol at 1.00% concentration. The reduction of free volume reveals the tendency of the molecules to pack closely together and restrict movement [38]. This behavior demonstrates that there is indeed more intermolecular attraction and more intermolecular association between the constituent molecules. The decrease in free volume also indicates that the PEG molecules cause a compact structural arrangement in the cyclohexanone medium [39]. The chain interactions and molecular entanglement effects are more significant in PEG300, which results in lower free volume values [40].

Figure 3.2.3 shows the change of internal pressure as a function of concentration. The internal pressure of both PEG200 and PEG300 systems is observed to increase with the increase in concentration. The internal pressure of PEG200 is changed from 46671 to 49130 atm while that of PEG300 shows an increase up to 50182 atm. The cohesive energy density and intermolecular attractive forces of the liquid system are directly related to its internal pressure [41]. An increase in internal pressure means that the interaction between solute and solvent molecules will be increased, which means that the stability of the solution's structure will be increased [42]. The cohesive interactions are comparatively larger in PEG300 solutions because of the larger molecular structure of PEG300 which is evident from the higher internal pressure values [43].

The viscous relaxation time is plotted as a function of concentration in Fig. 3.2.4. It is found that the viscous relaxation time of both PEG systems increases with increasing concentration. PEG200 shows an increase from

1.281 × 10^{-10} sec to 1.424 × 10^{-10} sec, while PEG300 reaches 1.485 × 10^{-10} sec at 1.00% concentration. This extended relaxation time implies a slowing down of molecular rearrangement and a strengthening of resistance to molecular motion in solution medium [44]. This behavior can be explained by increasing intermolecular interactions and the appearance of associated molecular structures that slow down the process of structural relaxation [45].

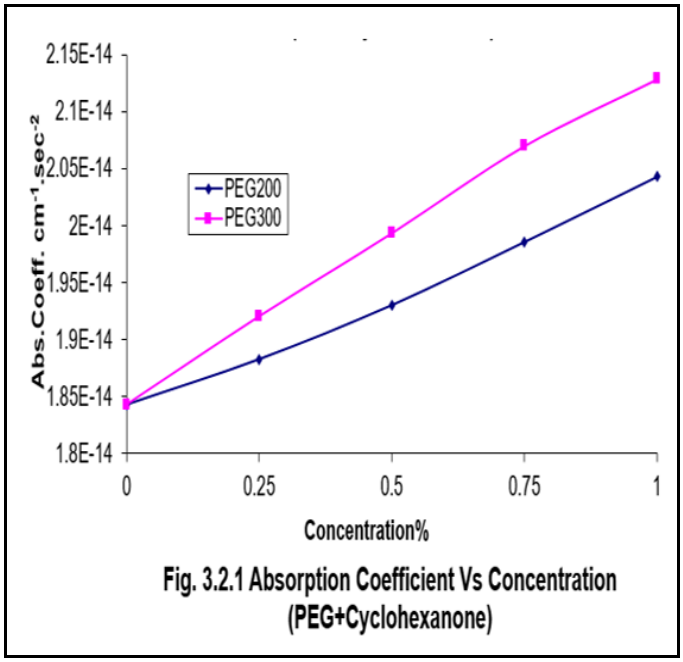

Fig. 3.2.1 Absorption Coefficient Vs Concentration (PEG+Cyclohexanone)

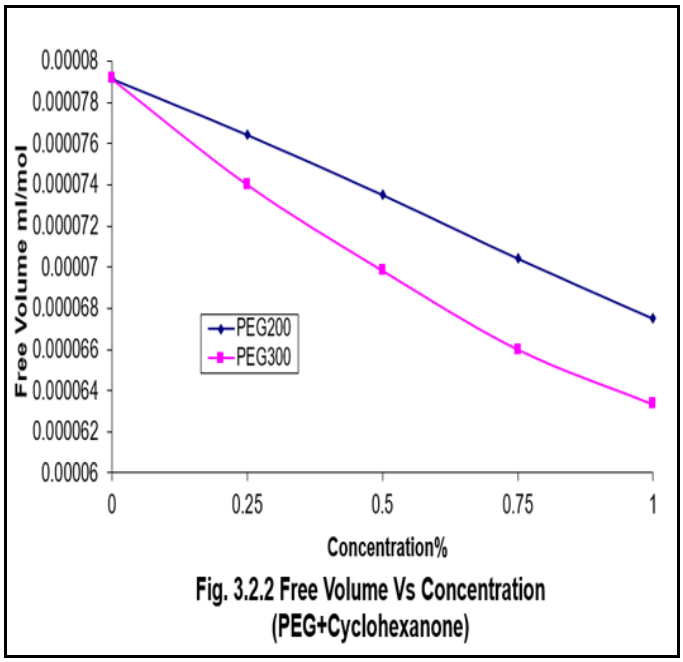

Fig. 3.2.2 Free Volume Vs Concentration (PEG+Cyclohexanone)

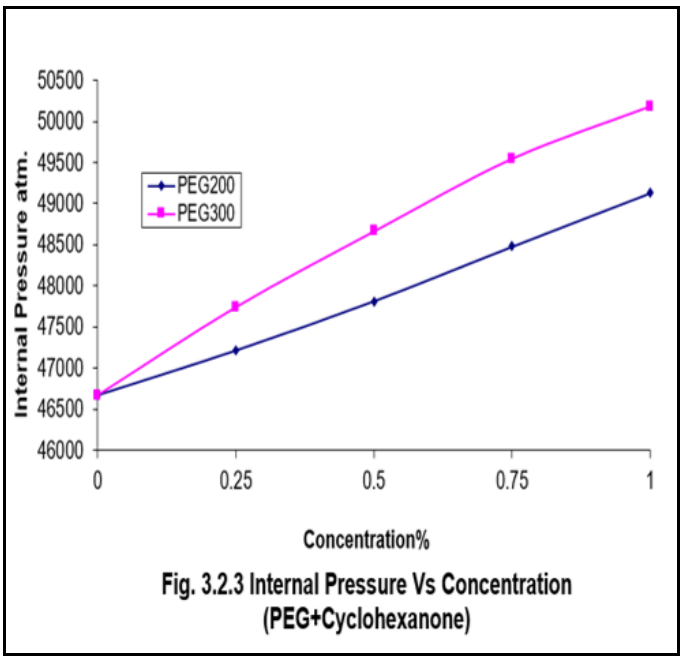

Fig. 3.2.3 Internal Pressure Vs Concentration (PEG+Cyclohexanone)

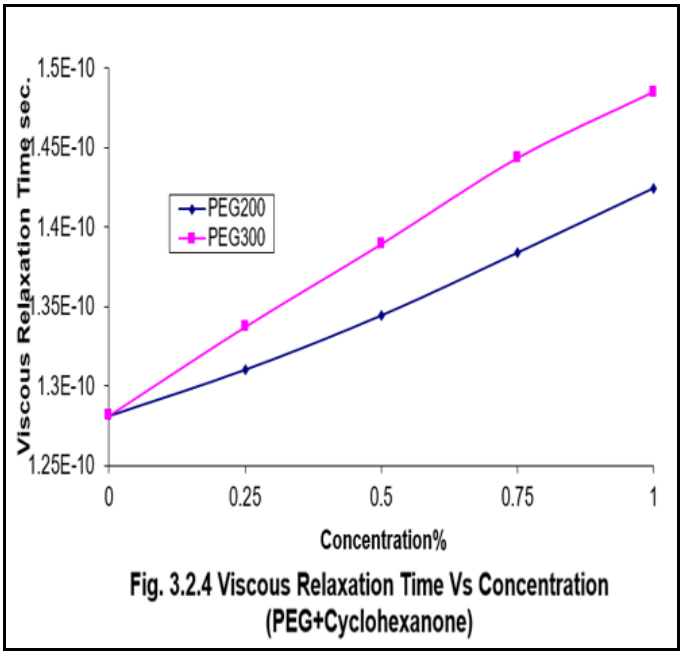

Fig. 3.2.4 Viscous Relaxation Time Vs Concentration (PEG+Cyclohexanone)

This overall analysis of thermodynamical parameters clearly shows that the interactions between PEG molecule and cyclohexanone are strong dipolar and hydrogen-bond interactions [46]. The absorption coefficient and the pressure of the solution, as well as the viscosity relaxation time, are observed to increase and the free volume decreases, which confirms that the system of molecules forms compact and highly associated molecular structures

in the solution [47]. Additionally, the interaction effects of PEG300 are more significant than PEG200 because PEG300 has a higher molecular weight and longer chain length. The results presented are in agreement with previous ultrasonic studies on polymer-solvent mixtures and are helpful to understand the acoustical and thermodynamical properties of polyethylene glycol solutions in a cyclohexanone medium.

Table 3.2 Thermodynamical Properties of PEG in Cyclohexanone

SYSTEM	Concentration %	Absorption Coefficient $\times 10^{-14}$ $cm^{-1}s^{-2}$	Free Volume $\times 10^{-5}$ ml/mol	Internal Pressure atm	Viscous Relaxation Time $\times 10^{-10}$ sec
PEG200	0.00	1.843	7.914	46671	1.281
	0.25	1.883	7.642	47215	1.310
	0.50	1.930	7.351	47815	1.344
	0.75	1.986	7.042	48478	1.384
	1.00	2.043	6.751	49130	1.424
PEG300	0.00	1.843	7.914	46671	1.281
	0.25	1.920	7.400	47741	1.337
	0.50	1.993	6.983	48661	1.389
	0.75	2.070	6.599	49545	1.443
	1.00	2.128	6.333	50182	1.485

3.3 Acoustical Parameters and Molecular Interaction Analysis of PEG200 and PEG300 in Cyclohexanone

The acoustical parameters like adiabatic compressibility, acoustic impedance, Rao's constant and Wada's constant of PEG200 and PEG300 solutions in cyclohexanone are given in Table 3.3; the concentration dependent variation of these parameters are shown in Fig. 3.3.1, Fig. 3.3.2, Fig. 3.3.3, and Fig. 3.3.4, respectively. The parameters are very sensitive to the nature of the interactions and modification of the structures involved in the formation of the liquid systems and hence are very useful for understanding nature of solute-solvent association in polymeric solution [8, 11 & 13].

TABLE 3.3 Ultrasonic Properties of PEG in Cyclohexanone

SYSTEM	Concentration %	Adiabatic Compressibility $\times 10^{-11}$ cm^2/dyne	Acoustic Impedance gm cm^{-2} s^{-1}	Rao Constant $cm^{-2}s^{-1}$	Wada Constant cm dyne
PEG200	0.00	5.634	129464	5359.52	3026.56
	0.25	5.616	129754	5361.66	3028.18
	0.50	5.603	129958	5365.62	3030.67
	0.75	5.594	130099	5370.94	3033.83
	1.00	5.588	130181	5377.70	3037.68
PEG300	0.00	5.634	129464	5359.52	3026.56
	0.25	5.604	129957	5359.97	3027.55
	0.50	5.585	130259	5363.81	3030.17
	0.75	5.576	130409	5371.57	3034.70
	1.00	5.568	130514	5380.20	3039.64

The variation of the adiabatic compressibility with concentration of PEG200 and PEG300 systems are shown in Fig. 3.3.1. Adiabatic compressibility is observed to be continuously decreasing with increase in concentration for both the polymer solutions. In PEG200 solutions, the compressibility decreases from 5.634×10^{-11} cm^2/dyne to 5.588×10^{-11} cm^2/dyne, whereas PEG300 exhibits a comparatively larger decrease reaching 5.568×10^{-11} cm^2/dyne at 1.00% concentration. With increasing polymer concentration the decrease in compressibility demonstrates a more restricted structure and increased incompressibility of the solution [48]. This can be

explained by the attraction between molecules and the packing of molecules in the PEG and the cyclohexanone solvent [31, 49]. This decrease in compressibility is a confirmation of the presence of the strong cohesive forces in the solution medium [50]. PEG300 has a higher molecular association and larger molecular size, which results in lower compressibility values.

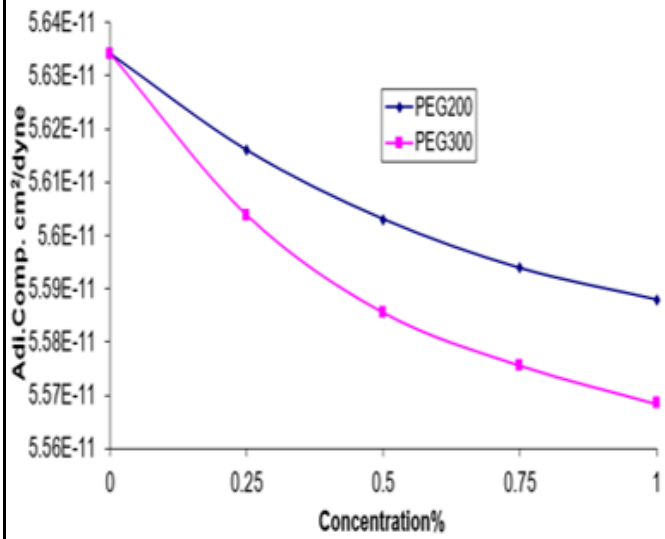

Fig. 3.3.1 Adiabatic Compressibility Vs Concentration (PEG+Cyclohexanone)

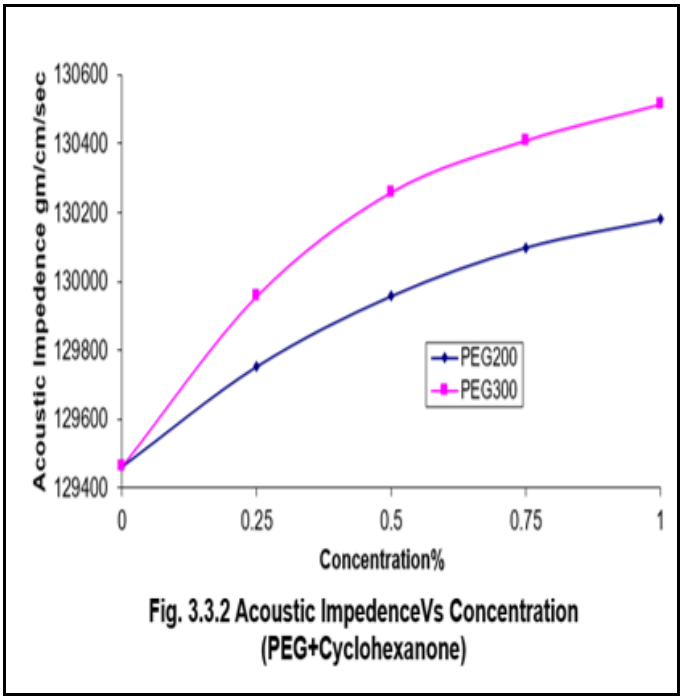

Fig. 3.3.2 Acoustic ImpedenceVs Concentration (PEG+Cyclohexanone)

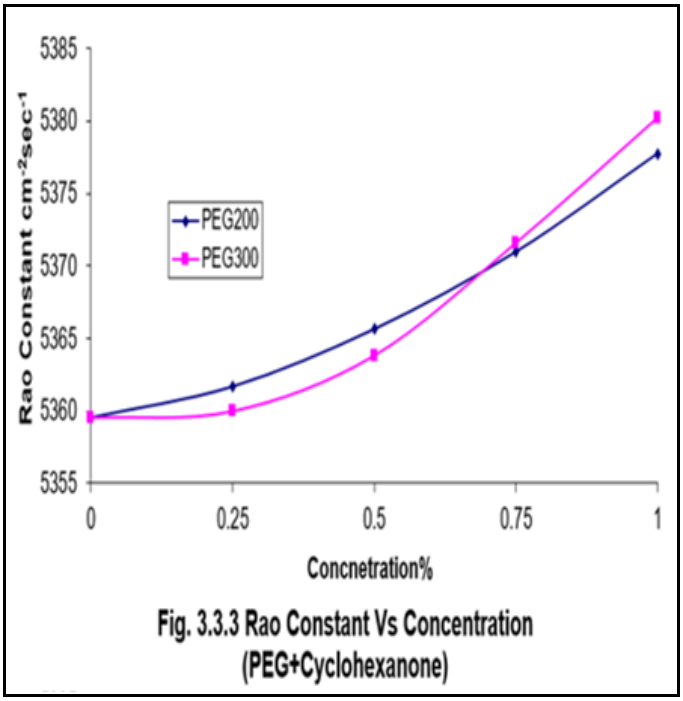

Fig. 3.3.3 Rao Constant Vs Concentration (PEG+Cyclohexanone)

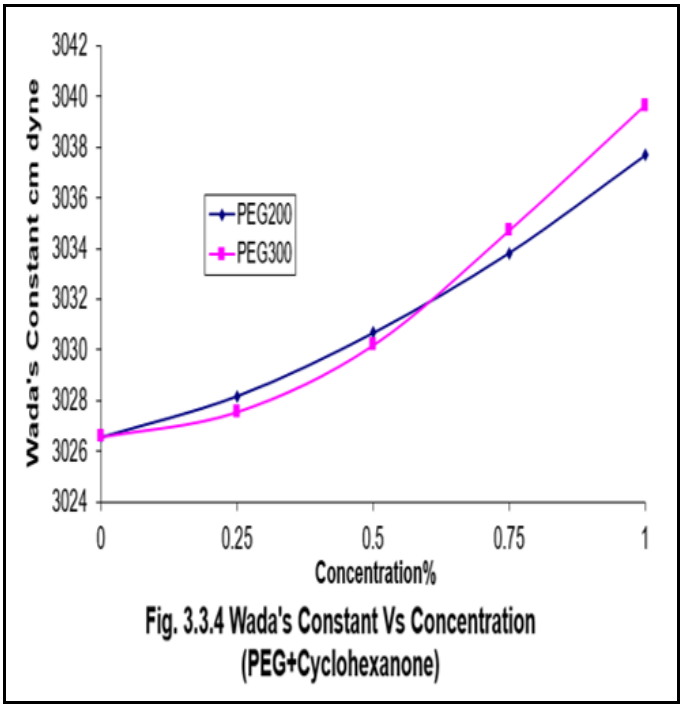

Fig. 3.3.4 Wada's Constant Vs Concentration (PEG+Cyclohexanone)

The results of the variation of acoustic impedance with concentration are shown in Fig. 3.3.2. It is found that both PEG systems have a linear positive dependence of the acoustic impedance on the concentration. For PEG200, the acoustic impedance increases from 12946 gm $cm^{-2}s^{-1}$ to 130181 gm $cm^{-2}s^{-1}$, while PEG300 exhibits higher values

increasing up to 130514 gm $cm^{-2}s^{-1}$. Acoustic Impedance is related to density and Ultrasonic velocity and it can be said to represent resistance of material against the propagation of ultrasonic waves [8]. This observed increase in interaction between constituent molecules and rigidity of the solution system [51]. The PEG300 solution with the higher impedance value has relatively higher cohesive interactions, which may be attributed to the longer chains and higher molecular weight of PEG300 molecules [52].

Rao's constant for PEG200 and PEG300 solution is plotted as a function of concentration in Fig. 3.3.3. The value of β gradually increases with increasing concentration for both the systems. PEG200 shows an increase from 5359.52 $cm^{-2}s^{-1}$ to 5377.70 $cm^{-2}s^{-1}$, whereas PEG300 reaches 5380.20 $cm^{-2}s^{-1}$ at 1.00% concentration. The molar sound velocity is related to the Rao's constant which is useful for the information of the effective molecular association in liquid mixtures [8, 53]. As the constant increases for Rao, it shows an improvement in the molecular interactions and molecular organization within the solution medium. The non-linear variation also indicates that polymer-polymer association is likely to have greater effect at higher concentrations because of the increased polymer-solution interaction [11, 54].

The change of Wada's constant with concentration is depicted in Fig. 3.3.4. As can be seen, Wada systematically increases with the concentration of the solutions both for PEG200 and PEG300. The 200 and 300 molecular weight PEGs show a relative increase from 3026.56 cm dyne to 3037.68 cm dyne and the molecular weight PEG300 shows a relatively higher increase from 3026.56 cm dyne to 3039.64 cm dyne respectively. The constant of Wada is a function of the molar compressibility of the liquid system and is often employed to explain the degree of packing and compactness of the molecules in the liquid system [8, 13 & 55]. The increase in Wada's constant indicates an increase in the intermolecular cohesive forces and associated molecular structure in the medium of cyclohexanone.

A comparison of the collective analysis of the adiabatic compressibility, the acoustic impedance, Rao's constant and Wada's constant clearly shows that there exist strong intermolecular interaction between PEG molecules and cyclohexanone [56-57]. The lower compressibility and the higher acoustic impedance and the molecular constants indicate the formation of low compressibility and highly associated structures in the solution [32, 58]. The interaction can be largely attributed to dipole-dipole attraction and association via the hydrogen bonding of the PEG ether oxygen atoms with the carbonyl group of cyclohexanone [43, 59]. In addition, the polymer interaction effects are also more pronounced for PEG300 than for PEG200 because of its higher molecular weight and longer polymeric chain structure. These results are consistent with those previously obtained by ultrasonic studies of polymer-solvent systems and suggest important data on the acoustical and structural properties of polyethylene glycol solutions in the cyclohexanone medium [2, 12 & 30].

4. CONCLUSIONS

In the present investigation, ultrasonic properties of PEG200 and PEG300 in cyclohexanone solutions have given valuable insights into the molecular interaction and the molecular structure of PEG-solution. The systematic change of the measured parameters in acoustical, thermodynamical and physicochemical properties clearly shows the strong intermolecular interaction between the molecules of polyethylene glycol and the molecules of the solvent, namely, cyclohexanone. The ultrasonic techniques used were found to be very successful in the assessment of the nature of molecular association and the changes in molecular structure of the solution medium.

From the experimental results, it has been found that in both systems (PEG200 and PEG300) the density, viscosity, ultrasonic velocity, absorption coefficient, acoustic impedance, internal pressure, viscous relaxation time, Rao's constant and Wada's constant have increased continuously with increasing concentration. Other parameters like adiabatic compressibility and free volume, on the other hand, gradually diminish with increasing polymer concentration. These differences clearly suggest better cohesive forces and better molecular packing and greater structural compactness of the solution system. The rise in ultrasonic velocity and acoustic impedance may indicate better transmission of ultrasonic waves in a more rigid and elastic medium and the fall in compressibility indicates the formation of tightly associated molecular structures. This increase in both viscosity and viscous relaxation time further illustrates the presence of stronger solute-solvent interactions and a decrease in molecular mobility of the solutions. Likewise, the increase in internal pressure reflects the increase in cohesive energy density due to intermolecular forces between PEG molecules and cyclohexanone. The reduction in free volume is observed which favours the formation of compact molecular arrangements as a result of the efficient interaction between the molecules. These interaction effects are likely to be dipole-dipole attraction and hydrogen bond associated association between the carbonyl group of cyclohexanone and the ether oxygen atoms of polyethylene glycol.

In comparison to PEG200, PEG300 has comparatively stronger interaction effects. The increased molecular association and ordering in the solution medium can be rationalized based on the higher molecular weight, longer polymeric chain length and increased interaction capability of PEG300 molecules. PEG300 has higher viscosity, ultrasonic velocity, internal pressure, acoustic impedance, Rao's constant and Wada's constant value, which further confirms this conclusion.

The overall conclusion of present ultrasonic investigation was that the role of concentration and molecular weight are significant in determining the acoustical and thermodynamical behaviour of polyethylene glycol solution in cyclohexanone. The obtained results are in good agreement with the previous studies related to polymer-solvent interaction and provide useful data for understanding the molecular dynamics and structural features of the PEG based liquid systems. Thus, the study

has demonstrated the suitability and applicability of ultrasonic analysis as a potent and trustworthy method to investigate intermolecular interactions in complex liquid mixtures as well as polymer solutions.

REFERENCES

[1] S. Panda, Recent Innov. Chem. Eng. 15 (2), (2022) 138–146.

[2] N. Das, M.K. Praharaj, S. Panda, Curr. Anal. Chem. 21 (4), (2025) 276–287.

[3] A.A. D'Souza, R. Shegokar, Expert Opin. Drug Deliv. 13 (9), (2016) 1257–1275.

[4] R.J. Sengwa, K. Kaur, R. Chaudhary, Polym. Int. 49 (6), (2000) 599–608.

[5] N. Chakraborty, K.C. Juglan, H. Kumar, J. Chem. Eng. Data 66 (6), (2021) 2391–2400.

[6] J. D'Souza, S.Z. Wong, R. Camargo, N. Yan, ACS Sustain. Chem. Eng. 4 (3), (2016) 851–861.

[7] V.A. Azov, K.S. Egorova, M.M. Seitkalieva, A.S. Kashin, V.P. Ananikov, Chem. Soc. Rev. 47 (4), (2018) 1250–1284.

[8] R. Panda, S. Panda, S.K. Biswal, Curr. Microw. Chem. 11 (1), (2024) 2–15.

[9] D.O. Abhishek, M.K. Kuldip, A.K. Kaushal, N.S. Kevil, S.R. Vishal, P.J. Tejas, Langmuir 42 (17), (2026) 11846–11860.

[10] V.F. Humphrey, Prog. Biophys. Mol. Biol. 93 (1–3), (2007) 195–211.

[11] M. Dhiman, K. Singh, J. Kaushal, A. Upmanyu, D.P. Singh, Acta Acust. United Acust. 105, (2019) 743–752.

[12] N. Das, S. Panda, M.K. Praharaj, Chem. Thermodyn. Therm. Anal. 18, (2025) 100169.

[13] N. Das, S. Panda, M.K. Praharaj, Recent Innov. Chem. Eng. 18 (4), (2025) 293–310.

[14] S. Ebrahimi, R. Sadeghi, J. Chem. Eng. Data 60 (11), (2015) 3132–3147.

[15] N. Das, S. Panda, M.K. Praharaj, J. Mol. Eng. Mater. 14 (1), (2026) 1.

[16] K. Kaur, K.C. Juglan, H. Kumar, J. Chem. Thermodyn. 127, (2018) 8–16.

[17] P.G. Nilsson, H. Wennerstroem, B. Lindman, J. Phys. Chem. 87 (8), (1983) 1377–1385.

[18] D. Sailaja, K.N. Raju, G.S.S. Devi, K. Subbarangaiah, Eur. Polym. J. 34 (7), (1998) 887–890.

[19] J. Li, Z. Du, H. Li, C. Zhang, Polymer 50 (6), (2009) 1526–1532.

[20] O.E.A. Adam, A.A. Hassan, Phys. Chem. Liq. 56 (1), (2018) 55–68.

[21] T. Lazaridis, Acc. Chem. Res. 34 (12), (2001) 931–937.

[22] F. Comelli, S. Ottani, D. Vitalini, R. Francesconi, Thermochim. Acta 407 (1–2), (2003) 85–92.

[23] A. Rajak, A. Das, ACS Polym. Au 2 (4), (2022) 254–263.

[24] P. Thakral, J.B. Ingle, R. Raina, D. Nehra, Resonance 27, (2022) 1789–1803.

[25] S. Rasouli, M.R. Moghbeli, S.J. Nikkhah, J. Mol. Model. 25, (2019) 195.

[26] V.K. Oikonomou, Symmetry 10 (9), (2018) 368.

[27] S. Singh, K. Dhal, M. Talukdar, Biointerface Res. Appl. Chem. 10 (5), (2020) 6377–6388.

[28] N.M. Abdel Jabbar, F.S. Mjalli, Phys. Chem. Liq. 57 (1), (2019) 1–18.

[29] A.G. Athanassiadis, Z. Ma, N. Moreno-Gomez, K. Melde, E. Choi, R. Goyal, P. Fischer, Chem. Rev. 122 (5), (2022) 5165–5208.

[30] V.K. Syal, A. Chauhan, S. Chauhan, J. Pure Appl. Ultrason. 27, (2005) 61–69.

[31] F. Zhang, Z. Wang, Y. Xu, P. Wen, M. Han, Y. Zhao, B. Zhao, S. Wang, Y. Liu, J. Lao, J. Yin, H. Wang, Y. Liu, S. Geng, Y. She, S. Liu, ACS Sustain. Chem. Eng. 13 (32), (2025) 13133–13147.

[32] K. Dhal, S. Singh, M. Talukdar, Russ. J. Phys. Chem. A 97, (2024) 3183–3200.

[33] S.A. Oelmeier, F. Dismer, J. Hubbuch, BMC Biophys. 5, (2012) 14.

[34] M.X. Du, Y.F. Yuan, J.M. Zhang, C.Y. Liu, Macromolecules 55 (11), (2022) 4578–4588.

[35] A.K.J. Rashid, E.D. Jawad, B.Y. Kadem, Eur. J. Sci. Res. 61 (2), (2011) 203–209.

[36] C. Jiang, Y. Hou, Macromol. Chem. Phys. 224 (13), (2023) 2300069.

[37] C.J. Neal, S. Das, S. Saraf, L. Tetard, S. Seal, ChemPlusChem 80 (11), (2015) 1680–1690.

[38] P.M. Budd, N.B. McKeown, D. Fritsch, J. Mater. Chem. 15 (20), (2005) 1977–1986.

[39] C. Zeng, M. Huang, H. Zhao, J. Zhou, J. Li, J. Appl. Polym. Sci. 123 (1), (2012) 124–134.

[40] S.Y. Kim, H.W. Meyer, K. Saalwächter, C.F. Zukoski, Macromolecules 45 (10), (2012) 4225–4237.

[41] Y. Marcus, Phys. Chem. Liq. 55 (4), (2017) 522–531.

[42] P.I. Nagy, Int. J. Mol. Sci. 15 (11), (2014) 19562–19633.

[43] D.B. Knowles, I.A. Shkel, N.M. Phan, M. Sternke, E. Lingeman, X. Cheng, L. Cheng, K. O'Connor, M.T. Record, Biochemistry 54 (22), (2015) 3528–3542.

[44] B.W. Peterson, Y. He, Y. Ren, A. Zerdoum, M.R. Libera, P.K. Sharma, A.J. van Winkelhoff, D. Neut, P. Stoodley, H.C. van der Mei, H.J. Busscher, FEMS Microbiol. Rev. 39, (2015) 234–245.

[45] C.J. Bhongale, C.W. Chang, C.S. Lee, E.W.G. Diau, C.S. Hsu, J. Phys. Chem. B 109 (28), (2005) 13472–13482.

[46] N.B. Haro Mares, S.C. Döller, T. Wissel, M. Hoffmann, M. Vogel, G. Buntkowsky, Molecules 29 (7), (2024) 1669.

[47] M. Sedlák, J. Phys. Chem. B 110 (28), (2006) 13976–13984.

[48] S. de Gennaro, G.G. Birch, S.A. Parke, B. Stancher, Food Chem. 68 (2), (2000) 179–183.

[49] Y. Tang, Y. Liu, D. Zhang, J. Zheng, Langmuir 40 (2), (2024) 1487–1502.

[50] K. Rajagopal, P. Sangeetha, R. Renganathan, Russ. J. Phys. Chem. A 93, (2019) 1065–1072.

[51] B.A. Ćavić, M. Thompson, G.L. Hayward, Analyst 124, (1999) 1405–1420.

[52] V.S. Kolosnitsyn, G.P. Dukhanin, S.A. Dumler, I.A. Novakov, Russ. J. Appl. Chem. 78, (2005) 1–18.

[53] K. Kaur, K.C. Juglan, Der Pharma Chem. 7 (2), (2015) 160–167.

[54] S. Panda, Recent Innov. Chem. Eng. 17 (1), (2024) 44–54.

[55] N. Grover, V. Pathania, S.K. Vermani, B.K. Vermani, S. Sharma, J. Chem. Eng. Data 69 (11), (2024) 3698–3717.

[56] N. Chakraborty, P. Thakur, K.C. Juglan, E3S Web Conf. 453, (2023) 01051.

[57] R. Abraham, M. Abdulkhadar, C.V. Asokan, J. Chem. Thermodyn. 32 (1), (2000) 1–16.

[58] I. Saxena, V. Kumar, A. Gupta, J. Solution Chem. 53, (2024) 182–202.

[59] S. Tang, G.A. Baker, H. Zhao, Chem. Soc. Rev. 41 (10), (2012) 4030–4066.