Ultrasonic Study of the Binary Liquid Mixture Containing Propanol and Acetone at 312.15 °K

SARWADE M. P[1]., Miss. Rokade[2] V. R., Miss.Thite[2] M. M.

Department of Physics, D. S. M. College, Parbhani - 431401, Maharashtra (India)

ABSTRACT:

Density (ρ), viscosity (η) and Ultrasonic velocity (U) of the binary mixture of Propanol and Acetone were measured over entire composition range. These measurements were done at constant temperature 312.15 K and at frequency 1MHZ. These were used to evaluate various acoustic parameters such as classical absorption coefficient ($\alpha/f2$), internal pressure (π_i), refractive index, relaxation time (τ), relative association (RA), molar volume (Vm) and Gibb's free energy (ΔG). These parameters have been interpreted in terms of intermolecular interactions at frequency 1MHZ and at constant temperature 312.15K.

KEY WORDS: Propanol, internal pressure, relative association, molar volume, refractive index

INTRODUCTION:

Thermodynamic property is one which serves to describe a system. Fundamental variables of thermodynamic properties includes volume, pressure, temperature, energy etc. and of course, the amount of substance. The ultrasonic study of liquid and liquid mixtures is useful in understanding the nature of molecular interactions in pure liquids and in liquid mixtures. Ultrasonic waves are high frequency mechanical waves [1]. Ultrasonic wave propagation affects the physical properties of the medium and hence can provide information about molecular interactions of the pure liquids and liquid mixtures. The measured ultrasonic parameters are being extensively useful to study intermolecular processes in liquid systems [2]. The sign and magnitude of the non-linear deviations from ideal values of velocities and adiabatic compressibilities of liquid mixtures with composition are related to the difference in molecular size and strength of interaction between unlike molecules. In the present study the chemicals used are Propanol and Acetone.

Acetone is an organic compound with chemical formula (CH3)2CO.This is clear, mobile easy to burn liquid. It is the simplest example of ketones. It can be mixed with water. It is an important solvent. It is commonly used to clean things in laboratory. It is commonly used at homes as active ingredient in nail polish remover and as paint thinner. It is common building block in organic chemistry. It has Pungent, irritating, floral, cucumber like odor. It is miscible in water. It is also miscible in benzene, diethyl ether, ethanol, methanol and chloroform. It has dipole moment 2.91.

Propanol is a primary alcohol with the formula $CH_3CH_2CH_2OH$. It is a colorless liquid. It is prepared naturally in small amounts during many fermentation processes and is used as solvent in pharmaceutical industries, generally for resins and cellulose esters and sometimes as disinfectant agent. It is thought to be similar to ethanol in its effects on the human body. It is 2 to 4 times more potent. It has high octane number and is suitable for engine fuel usage. However, it is too expensive to use as a motor fuel. It is miscible in water. It has mild alcohol like odor. Its dipole moment is 1.68. Propanol belongs to a group of medicines called beta-blockers. It helps to decrease anxiety and relieve tremors. It is also used to help prevent migraine, heart-related chest pain (angina), and bleeding in the stomach caused by high blood pressure in the liver (portal hypertension).It is Used in making cosmetics, skin and hair preparations, pharmaceuticals, perfumes, lacquer formulations, dye solutions, antifreezes, rubbing alcohols, soaps, window cleaners. It is polar liquid. It has relative polarity 0.617.

In the present work, density, viscosity and ultrasonic velocity of Propanol and Acetone binary mixture have been measured and used to compute various acoustic parameters such as classical absorption coefficient ($\alpha/f2$), internal pressure (π_i), refractive index, relaxation time (τ), relative association (RA), molar volume (Vm) and Gibb's free energy (ΔG). These parameters have been interpreted in terms of intermolecular interactions at frequency 1MHZ and at constant temperature 312.15K. Behavior of these parameters has been used to interpret the intermolecular interaction in this binary mixture for entire mole fraction range.

EXPERIMENTAL:

Chemicals used were Propanol and Acetone. Acetone is obtained from Thermo Fisher Scientific Corporation India private limited Mumbai. Propanol is obtained from Thermo Fisher Scientific Corporation India private limited Mumbai. Density of the pure components and their mixtures were measured by using 10 ml specific gravity bottle up to the accuracy (0.001 g) [3]. The Abbe's refractometer is very popular and owes its popularity to its convenience, its wide range (n_D = 1.3 to 1.7), and to the minimal sample is needed [4]. The accuracy of the instrument is about ±0.0002; its precision is half this figure. The improvement in accuracy is obtained by replacing the compensator with a monochromatic source and by using larger and more precise prism mounts. The former provides a much sharper critical boundary and the latter allows a more accurate determination of the prism position.

The viscosity of pure liquids and their mixtures [5] were measured using Ostwald's viscometer with an accuracy of ± 0.001 Nsm^{-2}. Ultrasonic sound velocities were measured using multifrequency ultrasonic interferometer MX–3 (H. C. Memorial Scientific Corporation, Ambala Cantonment) with working frequencies 1MHZ, 3MHZ & 5MHZ. From the measured values of Density (ρ), viscosity (η) and Ultrasonic velocity various acoustic parameters such as classical absorption coefficient ($\alpha/f2$), internal pressure (π_i), refractive index, relaxation time (τ), relative association (RA), molar volume (Vm) and Gibb's free energy (ΔG) were evaluated. These parameters have been interpreted in terms of intermolecular interactions at frequency 1MHZ and at constant temperature 312.15K.

THEORATICAL APPROACH:

For the measurement of ultrasonic absorption by interferometer technique, the experimental liquid is placed in the cell of the ultrasonic interferometer. Then the distance between the crystal and the reflector is slowly varied by the micrometer screw. The current in the anode circuit of the oscillator undergoes cyclic variation giving rise to alternate maxima and minima. The distance between consecutive alternate maxima and minima corresponds to half wavelength in the liquid medium. The ultrasonic velocity is found using the average values of minima and maxima. The standard equations utilized for computation of different thermo-acoustic parameters are explained below.

1. ULTRASONIC VELOCITY: It is the velocity of the sound waves propagating through the binary liquid mixture. λ is the wavelength of the sound waves inside the binary or ternary liquid mixture.

$$U = n\lambda \quad m/s \qquad (1)$$

2. CLASSICAL ABSORPTION: it is also known as attenuation coefficient. It is measure of spatial rate of decrease in intensity level of the ultrasonic wave.

$$(\alpha/f^2) = (8\pi^2\eta) / 3\rho U^3 \quad NPS^2m^{-1} \qquad (2)$$

η is the viscosity of the binary mixture, U is the velocity of the ultrasonic wave and ρ is the density of the binary mixture

3. INTERNAL PRESSURE : It is also known as molar compressibility of the given liquid mixture. This is very large pressure. It gives idea about the solubility characteristics.

$$\pi_i = bRT \left(\frac{k\eta}{u}\right)^{1/2} \left(\frac{\rho^{2/3}}{M_{eff}^{7/6}}\right) \quad Pa \qquad (3)$$

$b = 2$, R= 8.314 J/ mol. °K, k is a constant equal to 4.28×10^9

U is the velocity of the ultrasonic wave and ρ is the density of the binary mixture

Where b=2, R= 8.314 J/mol°K, K is a constant equal to 4.28×10^9

4. RELATIVE ASSOCIATION: it is a parameter used to assess the association in any solution relative to association existing in water at 0 °C. it is influenced by two factors 1)the breaking up of solvent molecules on addition of electrolyte to it & 2)the salvation of ions that is simultaneously present.

$$R_A = \frac{ds}{do}\left[\frac{Uo}{Us}\right]^{1/3} \qquad (4)$$

Uo & Us are ultrasonic velocities in solvent & solution respectively and ds & do respective densities.

5. RELAXATION TIME: The general formula is

$$\tau = (4/3)\,\beta_{ad}\,\eta \quad \text{second} \qquad (5)$$

It is closely related with viscosity and classical absorption ultrasonic energy. Increase in relaxation time increases the ultrasonic absorption and vice versa. The dispersion of sound

velocity in a binary mixture reveals information about the characteristic time of relaxation process.

6. MOLAR VOLUME: The general relation for molar volume is

Vm = Meff /(density of mixture) (m^3/mol) (6)

If Vm varies non-linearly with mol fraction, this behavior is attributed to solute-solvent interaction which is different from ideal mixture behavior. Its value increases with increase in concentration may be due to molecular weight. It is also function of temperature. This increases with increase in temperature.

RESULTS AND DISCUSSION:

The experimentally measured values of density (ρ) and ultrasonic velocity (U) & viscosity are used to evaluate other thermo-acoustic parameters. Evaluation of all these parameters is done at constant temperature 312.15 K and at fixed ultrasonic frequency 1MHz. These parameters play very important role in explaining the nature and degree of association or dissociation among the constituents of the binary mixture Propanol and Acetone. The discussion of the results obtained from these parameters is made below.

Table I: The acoustic parameters density, viscosity, refractive index and internal pressure are shown in table I. The variation of the above mentioned parameters with rise in mole fraction of Propanol in Acetone is illustrated in figures 1 to 4 as shown below.

Mole fraction of Propanol in Acetone	ρ (Kg/m^3)	η	R I	πi
T=312.15°K and Frequency = 1MHZ				
0	784.5	0.00295	1.3588	1219244128
0.099095	786.4	0.003609	1.361515	1348356174
0.19839	788.3	0.004417	1.364236	1496233321
0.297885	790.2	0.005408	1.366962	1685537112
0.397581	792.1	0.006624	1.369694	1941671195
0.497477	794	0.008116	1.372431	2127402823
0.597576	795.9	0.009949	1.375174	2358652564
0.697877	797.8	0.012201	1.377922	2615644095
0.79838	799.7	0.014969	1.380676	2901336765
0.899088	801.6	0.018373	1.383435	3325400399
1	803.5	0.02256	1.3862	3714114551

The variation of density of the binary mixture with rise in mole fraction of Propanol in Acetone is depicted in figure 1. Perusal of figure 1 illustrates that the density is increasing with increase in concentration of Propanol in Acetone. The density rise is due to shrinkage in volume and increase in cohesive forces in the binary system. It means that there is contraction in volume of the binary system with increase in concentration of Propanol in

Acetone. It indicates strong molecular interaction between the unlike molecules of the system [10].

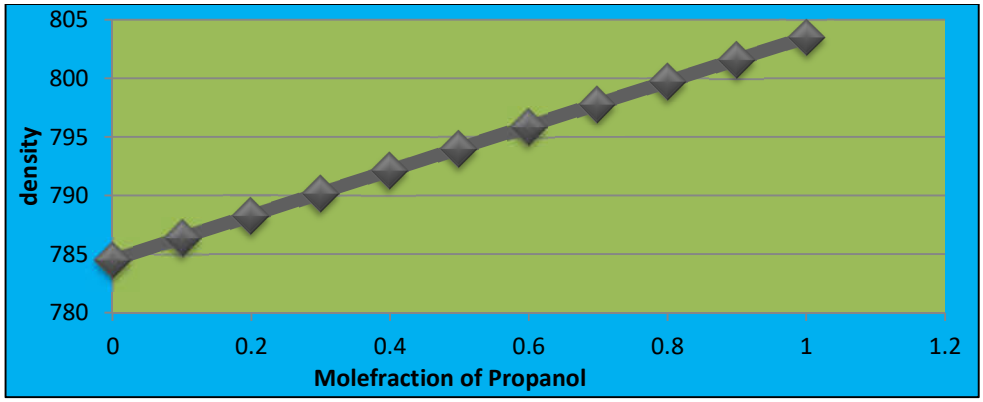

Fig 1 Graph between mole fraction of Propanol in Acetone and the density of the binary mixture at constant temperature and fixed ultrasonic frequency

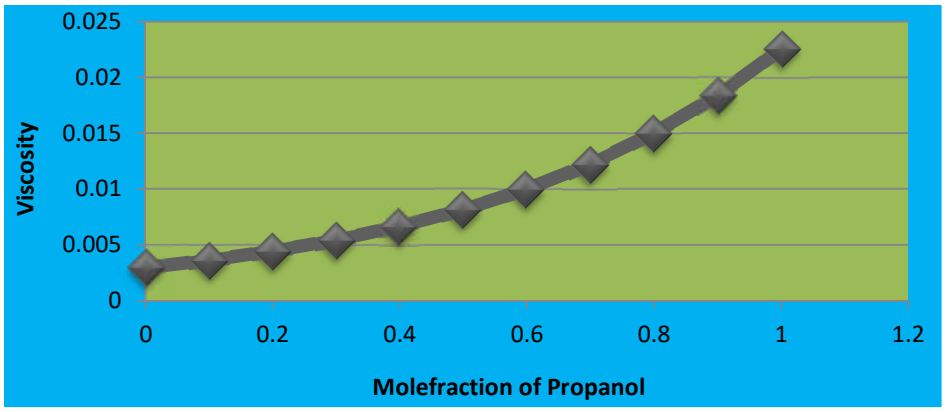

Fig 2 Graph between mole fraction of Propanol in Acetone and the viscosity of the binary mixture at constant temperature and fixed ultrasonic frequency

The variation of viscosity of the binary mixture with rise in mole fraction of Propanol in Acetone is shown in figure 2. Perusal of figure 2 illustrates that the viscosity is increasing with increase in concentration of Propanol in Acetone. The increase in viscosity with increase in concentration of Propanol in Acetone indicates the presence of strong molecular interaction between the constituents of the binary mixture [7].

The variation in refractive index with rise of mole fraction of Propanol in Acetone is shown in figure 3. Observation of figure 3 illustrates that the refractive index is increasing linearly with increase concentration of Propanol in Acetone. It is the physical property of the binary mixture. It is function of temperature. As refractive index of the binary mixture is increasing linearly with increase in concentration of the solute Propanol in Acetone, it means that the thickness of binary mixture is increasing due to contraction in the volume of the

mixture [8]. It means that strong forces of attraction exists between the unlike molecules of the binary mixture.

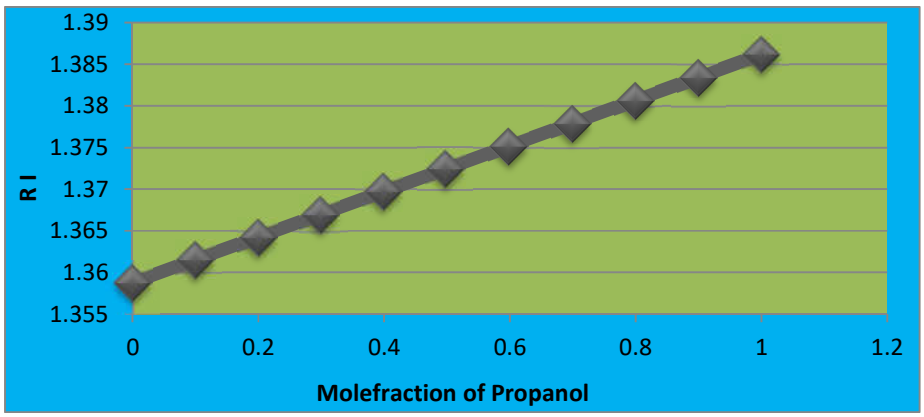

Fig 3 Graph between mole fraction of Propanol in Acetone and the refractive index of the binary mixture at constant temperature and fixed ultrasonic frequency

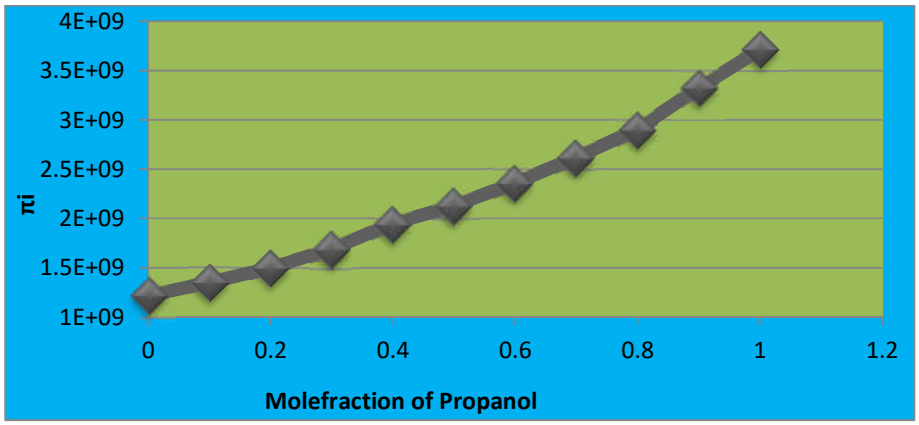

Fig 4 Graph between mole fraction of Propanol in Acetone and internal pressure of the binary mixture at constant temperature and fixed ultrasonic frequency

The variation of internal pressure of the binary mixture with rise in mole fraction of Propanol in Acetone is shown in figure 6. Perusal of figure 6 illustrates that the internal pressure is increasing somewhat non-linearly with increase in concentration of Propanol in Acetone. This behavior of the internal pressure may be attributed to possibility of strong interaction due to dipole-dipole or H-bonding or complex formation. This suggests strong molecular interaction with increase in concentration of Propanol in Acetone between the unlike constituents of the binary mixture [9].

The variation in classical absorption with increase in concentration of Propanol in Acetone is illustrated in figure 5. Perusal of fig. 5 indicates that the classical absorption coefficient is varying non-linearly with concentration of Propanol in this binary mixture. It is also known as attenuation coefficient. It is measure of spatial rate of decrease in intensity

level of ultrasonic wave. This spatial rate of decrease in intensity level of ultrasonic wave is varying non-linearly with the non-linear variation of the classical absorption coefficient. This non-linear behavior of the classical absorption coefficient with increase in concentration of Propanol in Acetone strongly supports the molecular interaction between the constituents of this binary system [10].

Table II: The evaluated thermo-acoustic parameters classical absorption coefficient, relative association, relaxation time are illustrated in table II. The variation in these parameters with rise in mole fraction of Propanol in Acetone is represented in figures 5 to 7 respectively.

Mole fraction of Propanol in Acetone	α/f2	RA	τ
T=312.15°K and Frequency = 1MHZ			
0	4.86353E-14	1	3.12173E-12
0.099095	6.01569E-14	1.003919	3.84402E-12
0.19839	7.58838E-14	1.010003	4.79646E-12
0.297885	1.04694E-13	1.026236	6.35415E-12
0.397581	1.65018E-13	1.058219	9.20046E-12
0.497477	1.92399E-13	1.055195	1.08976E-11
0.597576	2.40633E-13	1.060363	1.3528E-11
0.697877	3.01129E-13	1.065566	1.68019E-11
0.79838	3.77066E-13	1.070813	2.08796E-11
0.899088	5.74219E-13	1.099684	2.95673E-11
1	7.48117E-13	1.109864	3.12173E-12

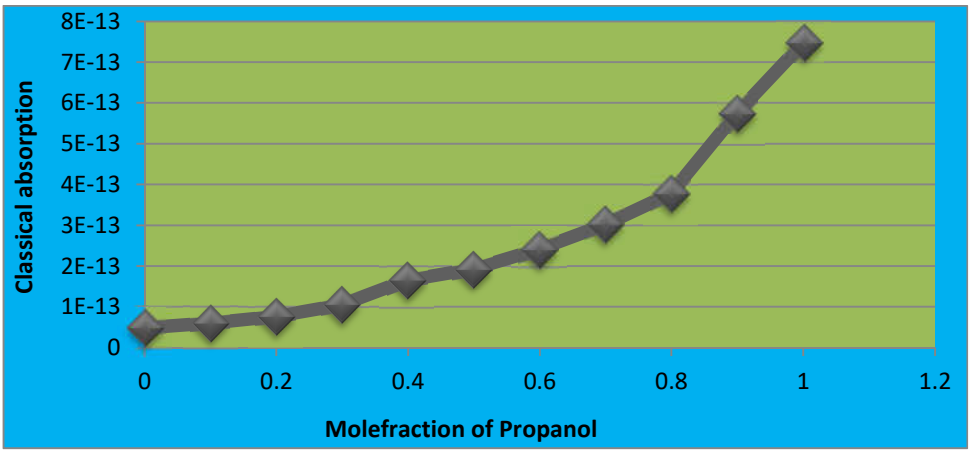

Fig 5 Graph between mole fraction of Propanol in Acetone and classical absorption coefficient of the binary mixture at constant temperature and fixed ultrasonic frequency

The variations in relative association with increase in concentration of Propanol in Acetone are illustrated in figure 6. Observation of figure 6 reveals that the relative association

in the binary mixture is increasing non-linearly with increase in concentration of Propanol in Acetone. The increasing nature of relative association [11] represents association. Thus, there may be strong significant interaction in the binary mixture with increase in concentration of Propanol in Acetone. The non-linear increasing values of relative association indicate complex formation and association between the components of the binary mixture. This is quite clear from figure 6.

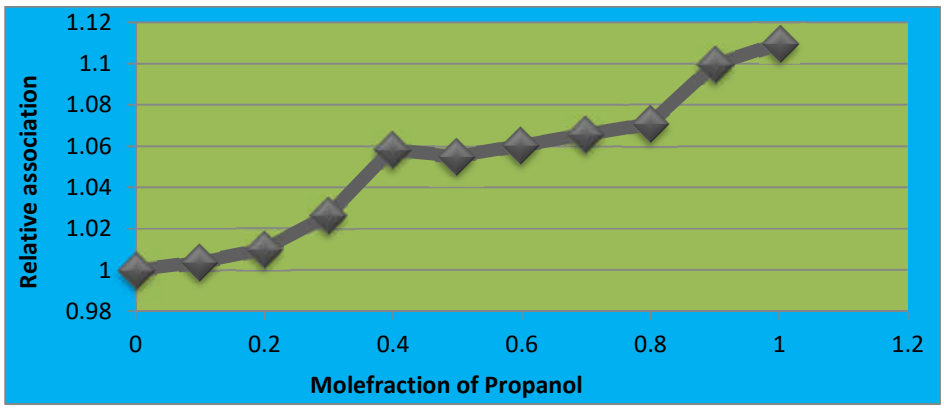

Fig 6 Graph between mole fraction of Propanol in Acetone and the relative association of the binary mixture at constant temperature and fixed ultrasonic frequency

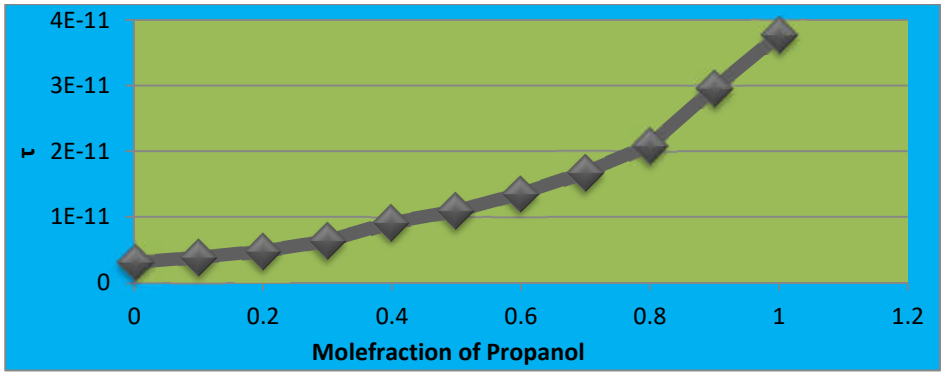

Fig 7 Graph between mole fraction of Propanol in Acetone and relaxation time of the binary mixture at constant temperature and fixed ultrasonic frequency

The variation in relaxation time with increase in concentration of Propanol in Acetone is illustrated in figure 7. Examination of figure 7 indicates that the relaxation time is varying non-linearly with concentration of Propanol in this binary mixture. The non-linear behavior of the relaxation time with increase in concentration of Propanol in Acetone strongly suggest interaction between the unlike molecules of the binary mixture. Strictly speaking the interaction is changing with the variation of the concentration of Propanol in Acetone. Therefore, there is existence of molecular interaction between the constituents of the binary system. Relaxation time is the time taken for the excitation energy to appear as translational

energy and it depends on temperature and impurities. In the present case, relaxation time increases with increase in concentration of Propanol in Acetone and it indicates the presence of molecular interaction in the mixture [12].

Table III. The thermo-acoustic parameters molar volume and Gibb's free energy are depicted in table III. The variation of these parameters with rise of mole fraction of Propanol in Acetone is shown in figures 8 and 9 respectively.

Mole fraction of Propanol in Acetone	Vm	ΔG
T=312.15°K and Frequency = 1MHZ		
0	7.40344E-05	1.91828E-19
0.099095	7.41088E-05	1.90931E-19
0.19839	7.41834E-05	1.89977E-19
0.297885	7.42581E-05	1.88765E-19
0.397581	7.4333E-05	1.8717E-19
0.497477	7.4408E-05	1.8644E-19
0.597576	7.44831E-05	1.85508E-19
0.697877	7.45585E-05	1.84574E-19
0.79838	7.46339E-05	1.83638E-19
0.899088	7.47095E-05	1.82138E-19
1	7.47853E-05	1.81087E-19

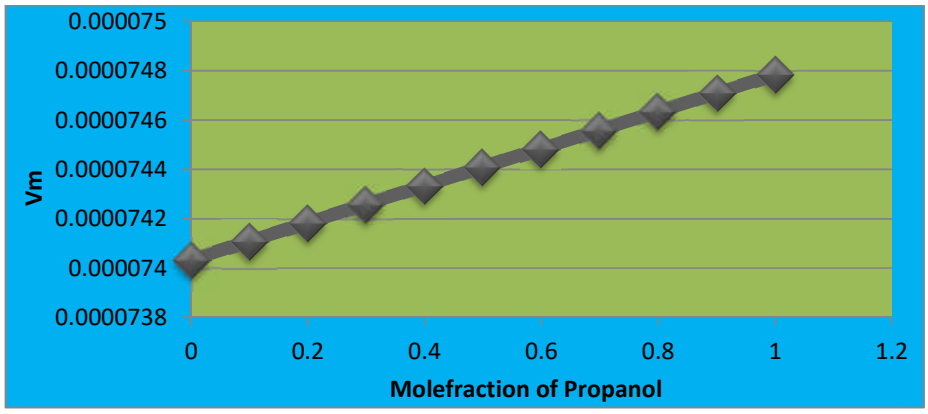

Fig 8 Graph between mole fraction of Propanol in Acetone and the molar volume of the binary mixture at constant temperature and fixed ultrasonic frequency

The variations in molar volume with increase in concentration of Propanol in Acetone are illustrated in figure 8. Examination of figure 8 indicates that the molar volume of the binary mixture is increasing linearly with increase in concentration of Propanol in Acetone.

This is generally proportional to molecular weight of the solution. Rise in temperature also increases the values of molar volume. In this figure there is increase in molar volume with increase in concentration of Propanol in Acetone. This suggests strong [13] interaction between the constituents of this binary mixture. This fact can be seen in this binary mixture.

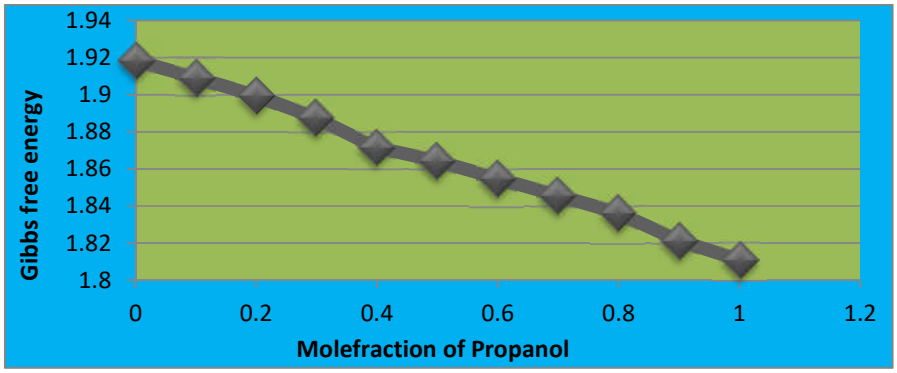

Fig 9 Graph between mole fraction of Propanol in Acetone and the Gibb's free energy of the binary mixture at constant temperature and fixed ultrasonic frequency

The variation of Gibb's free energy of the binary mixture with rise in mol fraction of Propanol in Acetone is shown in figure 9. Observation of figure 9 illustrates that Gibb's free energy is decreasing almost linearly with the concentration of Propanol in Acetone. Gibb's free energy is measured which is useful in the accurate determination of physico chemical properties and which is highly sensitive to molecular interactions in liquid mixtures. Figure 9 shows variation in Gibb's free energy with concentration Propanol in Acetone. Gibb's free energy decreases with increase in concentration which confirms the hydrogen bonding formation in binary liquid mixtures [14]. The Gibb's Free energy decreases with increasing mole fraction of this system. This may be due to the intermediate compound formation between binary liquids. It is observed that generally Gibb's free energy decrease favors the formation of products from reaction. This observation confirms the formation of hydrogen bonding in binary mixtures.

CONCLUSION:

In the present investigation, we have studied important thermo-acoustic parameters of Propanol in Acetone. Density and Viscosity show linear increase with concentration of Propanol in Acetone. Refractive index and internal pressure also show almost linear increase with increase in concentration of Propanol in Acetone. Classical absorption coefficient shows non-linear increase with increase in concentration of Propanol in Acetone. Relative association and relaxation time also show non-linear increase with increase in concentration of Propanol in Acetone. Molar volume shows linear increase with increase in concentration of Propanol in Acetone. Gibb's free energy shows almost linear non-linear decrease with increase in concentration of Propanol in Acetone. This investigation supports strong molecular interaction and so contraction in the volume of the mixture with increase of concentration of Propanol in Acetone.

Thus, it can be concluded that there exist strong molecular interaction between the constituents of Propanol in Acetone with increase in concentration of Propanol in the binary liquid mixture.

REFERENCES:

[1]. M. Gowrisankar • P. Venkateswarlu • K. Sivakumar • S. Sivarambabu, J Solution Chem ***(2013)*** *42:916–935*

[2]. Palaniappan L. and Karthikeyan V., Indian J. Phys., 2005, 79(2), 155.

[3]. John A. Dean, "Handbook of organic chemistry", McGraw Hill.

[4]. Smith, Warren. Modern Optical Engineering Boston: McGraw Hill, ***2008.***

[5]. Jerry March, "Advanced Organic Chemistry", 4th Edn, Wiley Publications, ***2008.***

[6]. Asole A. W; Journal of Pure Applied and Industrial Physics, Vol.6 (4), 50-56, ***April 2016.***

[7]. A. MaryGirija, Dr. M. M. Armstrong Arasu, D. Devi; IRJET Volume: 04 Special Issue: ***09 | Sep -2017.***

[8]. Giner B, Lafuente C, Villares A, Haro M, Lopez M C, J Chem Thermodyn 39(1) 148-157 ***(2007).***

[9]. B. Hemalatha, P. Vasantharani; Archives of Applied Science Research, ***2013****, 5 (3):31-37.*

[10]. D. Anbananthan, J. Acoust. Soc Ind. ***1979-*** *7 -123.*

[11]. P.B. Agarwal, M.L. Narwade, Indian J. Chem. A 42, ***(2003)*** *1047–1049.*

[12]. *M. K. Praharaj, P. R. Mishra, S. Mishra, A. Satapathy Archives of Physics Research,* ***2012,*** *3 (3):192-200.*

*[13]. Dash Ashok Kumar and Paikaray Rita; Research Journal of Physical Sciences Vol. 1(3), 12-20, April (****2013****).*

[14]. Eyring H and Kincaid JF, Ind. J. Phys., ***1938****; 6: 620*