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## INVESTIGATION OF THERMO-ACOUSTIC PROPERTIES OF ETHANOL-n-HEXANE BINARY MIXTURE AT DIFFERENT TEMPERATURES

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## ABSTRACT

Ultrasonic velocity, density and viscosity have been measured using Anton Paar DSA 5000 M in the binary mixtures of n-Hexane with Ethanol at various mole fractions from 0.1 to 0.9 with temperature ranging from 288K to 318K. Various derived parameters like adiabatic compressibility, acoustic impedance, free length and relaxation time have been calculated using standard formulae. Non covalent interaction taking place in the liquid mixture has been discussed on the basis of the values obtained from experimental parameters and derived parameters.

**Keywords:** adiabatic compressibility, acoustic impedance, relaxation time, free length, intermolecular non-covalent interactions.

## 1. INTRODUCTION

The knowledge of structure and molecular interactions of liquid mixtures is very important from fundamental and engineering point of view. Fundamental thermodynamic and thermo-acoustic properties are essential sources of information necessary for a better understanding of the non-ideal behavior of complex systems because of physical and chemical effects, which are caused by molecular interactions, intermolecular forces, etc. of unlike molecules. From a practical point of view, these properties are necessary for development of thermodynamic models required in adequate and optimized processes of the chemical, petrochemical, pharmaceutical, food processing, drugs industries, paint industries, fluid mechanics etc. [1,2]. The compositional dependence of thermodynamic properties has proved to be very useful tool in understanding the nature and extent of pattern of molecular aggregation which results from intermolecular interaction between components. Molecular interaction in liquid mixtures has been extensively studied using ultrasonic technique by many workers. The thermodynamic and acoustic properties are very essential for understanding the physicochemical behavior of the binary and multi-component liquid mixtures [3].

behavior of multi-component liquid mixtures rather than the single component because of their widespread range of applications. Thermodynamic properties which are derived from the measurement of ultrasonic velocities, densities and viscosities for binary liquid mixtures are useful in understanding the nature and type of intermolecular interactions taking place in between the constituent molecules. In chemical process industries, materials are normally handled in liquid form and thus the physical, chemical and transport properties of liquids, assume importance. Thus, data on some of the properties associated with the liquids and liquid mixtures like ultrasonic velocity, viscosity and density invention has extensive application in solution theory models and molecular dynamics [4, 5]. Ultrasonic velocity of sound waves in a medium is fundamentally related to the binding forces between the molecules. Ultrasonic velocities of the liquid mixtures consisting of polar and non-polar components are of considerable importance in understanding inter-

molecular interaction between components molecules and find application in several industrial and technological processes [6, 7]. Acoustical and thermo dynamical study of liquid mixtures provide enough knowledge about the association of molecular packing, molecular motion and strength of intermolecular

In the recent years, importance has been given to the

interactions. Thermodynamic and acoustical properties such as adiabatic compressibility, intermolecular free length, internal pressure, acoustic impedance, relaxation time, molar volume, classical absorption and surface tension can be calculated from measured ultrasonic velocity, density and viscosity for binary mixtures and are very much helpful to interpret nature and type of intermolecular interactions between the component molecules [8-10].

Using the measured values of sound velocity (u) and density  $(\rho)$ , the thermodynamic parameters such as isentropic compressibility (KS) and intermolecular free length (Lf) can be computed. Intermolecular free length (Lf) is an important physical property of liquid mixtures which mainly affects the sound velocity [11, 12]. Thus, data on some of the properties associated with the liquids and liquid mixtures like density, viscosity and ultrasonic velocity can be used to find extensive application in solution theory and molecular dynamics. Such results are necessary for interpretation of data obtained from thermo chemical, electrochemical, biochemical and kinetic studies [13, 14].

#### 2. MATERIAL AND METHODS

The chemical n-Hexane used in present work was procured from Loba Chemie Pvt. Ltd., Palghar (INDIA) with assay of 99.9% and Ethanol used was procured from Merck KGaA, Darmstadt, Germany with assay of 99.9%. Both chemicals were of AR (HPLC) grade and used without further purification. The instrument used for measurements of density, viscosity and ultrasonic velocity was Anton Paar DSA 5000 M having range, up to 3g/cc with 0.000007 g/cc accuracy for density, 1000 to 2000 m/s with 0.01 m/s accuracy for ultrasonic velocity, 0.2 to 30,000 mm<sup>2</sup>/s range for viscosity with 0.1% accuracy and temperature range from 0°C to

100°C with repeatability of 0.001°C.

Literature survey showed that measurements have been previously reported for the Ethanol-n-Hexane binary mixture at limited range of temperature. The objective of the present investigation was to find out the density  $(\rho)$ , viscosity  $(\eta)$  and ultrasonic velocity (U) for the binary system constituted by these components at 288K, 293K, 298K, 303K, 308K, 313K and 318K over the concentration range of 0.1 to 0.9 mole fraction. The experimental values were used to calculate adiabatic compressibility ( $\beta$ a), acoustic impedance (Z), relaxation time ( $\tau$ ) and free length (Lf) over the entire concen-tration range for the binary mixtures. The results are discussed in terms of the molecular interactions.

#### 3. MATERIAL AND METHODS

The various acoustical parameters computed from experimental parameters using the following relations,

Adiabatic compressibility (βa)	$\beta a = 1/(U^2 \rho)$
Acoustic Impedance (Z)	Ζ = ρU
Relaxation Time (Sec) $(\tau)$	$\tau = (4/3)\eta\beta a$
Free Length (Lf)	$Lf = K*\sqrt{\beta a}$ ,
Whore K is the temperature independent	nt Iacobson's

Where, K is the temperature independent Jacobson's constant

The evaluation of theoretical values of ultrasonic velocity, viscosity and density in binary mixture those obtained experimentally in the binary mixture is expected to interpret the nature of interaction between components of the mixture. Such theoretical study is useful in the wide-ranging theoretical modeling for the liquid mixtures [3].

### 4. OBSERVATIONS

Table 1: Density (Kg/m <sup>3</sup> )								
	288K	293K	298K	303K	308K	313K	318K	
0.1	769.3006	765.0885	761.5778	758.4628	755.0457	751.7279	747.0065	
0.2	750.568	745.6509	741.4352	737.5145	733.191	728.2618	722.3318	
0.3	726.5983	721.3719	716.4584	711.6384	705.0921	693.7101	679.3995	
0.4	713.5056	709.0921	704.9771	701.9628	699.0493	696.0336	691.8158	
0.5	703.4343	698.92	694.7043	690.8915	688.7765	685.9623	682.7516	
0.6	691.7516	687.8416	683.0216	677.4967	673.166	666.8268	660.9762	
0.7	675.7382	670.3033	664.2747	659.3505	655.0305	650.5113	646.4949	
0.8	676.6446	671.9289	667.5118	662.8933	659.8719	655.9498	650.9263	
0.9	668.084	664.174	660.0591	655.1384	651.412	646.4828	640.9557	

# Table 2: Viscosity (Kg/m<sup>3</sup>)

	288K	293K	298K	303K	308K	313K	318K
0.1	0.001119744006	0.001011680346	0.000920767082	0.000848071424	0.000776374167	0.000707900077	0.000649780816
0.2	0.000867955710	0.000797219087	0.000734247851	0.000683685023	0.000630625977	0.000578598799	0.000534689381
0.3	0.000867466349	0.000783279970	0.000709678034	0.000633407883	0.000556685790	0.000483557259	0.000420360573
0.4	0.000700619775	0.000642917430	0.000604293659	0.000559358968	0.000537744547	0.000517582219	0.000505441240
0.5	0.000691636587	0.000638887123	0.000600723499	0.000564447186	0.000530870906	0.000511113333	0.000499756628
0.6	0.000558917639	0.000514623160	0.000479776251	0.000448564836	0.000422374870	0.000399263776	0.000383487079
0.7	0.000485118417	0.000449366318	0.000417678437	0.000392175634	0.000372699536	0.000354833220	0.000345191444
0.8	0.000431808793	0.000405437115	0.000382448066	0.000361868667	0.000346064341	0.000335359662	0.000325427288
0.9	0.000384851477	0.000361107935	0.000341568570	0.000321871788	0.000306286831	0.000296456627	0.000286723715

# Table 3: Sound Velocity (m/s)

	288K	293K	298K	303K	308K	313K	318K
0.1	1162.2	1145.0	1125.8	1107.2	1090.4	1070.6	1051.3
0.2	1136.2	1118.4	1099.4	1078.8	1060.2	1041.2	1021.4
0.3	1118.4	1100.2	1081.8	1061.4	1042.2	1022.8	1002.6
0.4	1110.2	1091.8	1072.2	1051.6	1032.2	1011.8	990.4
0.5	1105.6	1086.2	1064.6	1043.6	1023.2	1002.4	980.8
0.6	1102.2	1083.1	1060.4	1039.2	1018.2	997.4	976.0
0.7	1100.4	1079.8	1057.2	1035.8	1014.2	993.4	972.1
0.8	1103.6	1082.6	1059.2	1036.8	1014.8	993.8	972.6
0.9	1108.8	1087.2	1064.3	1041.6	1019.4	998.6	976.2

# Table 4: Adiabatic Compressibility

	288K	293K	298K	303K	308K	313K	318K
0.1	9.623702446E-10	9.969591244E-10	1.036008302E-09	1.075507791E-09	1.113922755E-09	1.160606110E-09	1.211217928E-09
0.2	1.032049162E-09	1.072186011E-09	1.115874451E-09	1.165058040E-09	1.213409176E-09	1.266613612E-09	1.327001941E-09
0.3	1.100300489E-09	1.145242609E-09	1.192655642E-09	1.247333133E-09	1.305725884E-09	1.377972478E-09	1.464263971E-09
0.4	1.137103949E-09	1.183071992E-09	1.233881306E-09	1.288204309E-09	1.342655160E-09	1.403396680E-09	1.473629342E-09
0.5	1.163001832E-09	1.212698764E-09	1.270068337E-09	1.328990907E-09	1.386757795E-09	1.450833705E-09	1.522566812E-09
0.6	1.189950825E-09	1.239294295E-09	1.302045389E-09	1.366767174E-09	1.432886008E-09	1.507468432E-09	1.588234197E-09
0.7	1.222138332E-09	1.279505026E-09	1.346908145E-09	1.413617285E-09	1.484196029E-09	1.557746713E-09	1.636865558E-09
0.8	1.213433543E-09	1.269815529E-09	1.335319246E-09	1.403351275E-09	1.471564994E-09	1.543588062E-09	1.624050952E-09
0.9	1.217481847E-09	1.273794126E-09	1.337485409E-09	1.406905741E-09	1.477253361E-09	1.551171804E-09	1.637172267E-09

# **Table 5: Acoustic Impedance**

	288K	293K	298K	303K	308K	313K	318K
0.1	894081.157	876026.333	857384.287	839770.012	823301.831	804799.890	785327.933
0.2	852795.362	833935.967	815133.859	795630.643	777329.098	758266.186	737789.701
0.3	812627.539	793653.364	775064.697	755332.998	734846.987	709526.690	681165.939
0.4	792133.917	774186.755	755876.447	738184.080	721558.687	704246.796	685174.368
0.5	777716.962	759166.904	739582.198	721014.369	704756.115	687608.610	669642.769
0.6	762448.614	745001.237	724276.105	704054.571	685417.621	665093.050	645112.771
0.7	743582.315	723793.503	702271.213	682955.248	664331.933	646217.925	628457.692
0.8	746744.981	727430.227	707028.499	687287.773	669638.004	651882.911	633090.919
0.9	740771.539	722089.973	702500.900	682392.157	664049.393	645577.724	625700.954

	288K	293K	298K	303K	308K	313K	318K
0.1	1.703267017E-12	1.600185859E-12	1.511467045E-12	1.429392875E-12	1.351871508E-12	1.289820257E-12	1.236055970E-12
0.2	1.540841151E-12	1.446279353E-12	1.369947283E-12	1.317403241E-12	1.256079384E-12	1.195514498E-12	1.149680539E-12
0.3	1.273349456E-12	1.217345690E-12	1.167606456E-12	1.137043976E-12	1.097899548E-12	1.063057628E-12	1.043901862E-12
0.4	1.315199215E-12	1.235568793E-12	1.167544613E-12	1.087945019E-12	9.965827313E-13	9.048302025E-13	8.259408995E-13
0.5	1.086429442E-12	1.039553564E-12	1.023325657E-12	9.911773096E-13	9.942952564E-13	1.001234305E-12	1.026090743E-12
0.6	1.097351370E-12	1.055692222E-12	1.042892349E-12	1.028623847E-12	1.014236658E-12	1.027316286E-12	1.058307422E-12
0.7	9.107662281E-13	8.779505596E-13	8.616193870E-13	8.454653408E-13	8.358494731E-13	8.292691129E-13	8.369557221E-13
0.8	7.848786127E-13	7.608164384E-13	7.436454074E-13	7.338135680E-13	7.312687873E-13	7.302884299E-13	7.474779910E-13
0.9	7.009591558E-13	6.885912207E-13	6.820249440E-13	6.788201401E-13	6.816329478E-13	6.936006025E-13	7.103740411E-13

## **Table 6: Relaxation Time**

### 5. RESULTS AND DISCUSSION

Density is defined as mass per unit volume. In present system, density decreases with increase in concentration of n-hexane. It indicates ethanol has greater density than n-hexane. Initially ethanol has higher concentration and having compact structure than n-Hexane due to strong hydrogen bonding. At higher concentration of n-hexane, concentration of ethanol diminishes and n-hexane shows the predominance in the solution. It has smaller dipole moment compared to ethanol and also has long carbon chain. Hence density decreases with increase in composition of n-hexane.

As the temperature increases the translational, rotational and vibrational energy of components in the liquid mixture increases. Due to increase in energy, the compactness of the solution decreases and more volume is occupied by the same number of molecules in given mixture. Hence, density of the system decreases with increase in temperature. Above system shows same variation with temperature [15, 16]. Slightly unusual behavior is found in case of solutions having 0.3 and 0.7 mole fraction. A deep in density curve is obtained at these concentrations which is more intense in 0.3 mole fraction solution. This indicates that weakening effects in interaction forces are more pronounced at

# these concentrations.

Viscosity depends on compactness of structure of the medium. If there is a strong interaction of Van der Waal forces and hydrogen bonding, system has greater viscosity and vice versa. In present system, viscosity decreases with increase in concentration of n-hexane. As ethanol forms strong hydrogen bonding, its viscosity is greater than n-hexane.

The variation of viscosity is a consequence of the variation in surface area, relative velocity and the structure (shape, size and geometry) of the molecules of the medium. The decrease in viscosity of solution indicates lesser association among the molecules of solution. The weak association in Ethanol-n-Hexane solution is due to weak intermolecular hydrogen bonding between the components. Abnormal behavior is shown by 0.3M concentration solution, which is again an indication of pronounced weakening in interaction forces.

As the temperature increases the translational, rotational and vibrational energy of components in the given mixture increases resulting in weakening of Van der Waal forces and hydrogen bonding. Hence, viscosity of the system decreases with increase in temperature. Above system shows same variation with temperature at constant concentration [17, 18].

	0						
	288K	293K	298K	303K	308K	313K	318K
0.1	5.9945541113E-11	6.1557956219E-11	6.3307163892E-11	6.5068431421E-11	6.6796019590E-11	6.8768997796E-11	7.0852784331E-11
0.2	6.2077752383E-11	6.3838192864E-11	6.5702048000E-11	6.7723179244E-11	6.9715072438E-11	7.1840995945E-11	7.4162020840E-11
0.3	6.4097552166E-11	6.5977258396E-11	6.7924863386E-11	7.0073657554E-11	7.2318440494E-11	7.4932554926E-11	7.7903229987E-11
0.4	6.5160720140E-11	6.7058078160E-11	6.9088844995E-11	7.1212450547E-11	7.3333985470E-11	7.5620664848E-11	7.8151965792E-11
0.5	6.5898570063E-11	6.7892528559E-11	7.0094635980E-11	7.2331015398E-11	7.4528666964E-11	7.6888092564E-11	7.9439034271E-11
0.6	6.6657696056E-11	6.8632961876E-11	7.0971551937E-11	7.3351808677E-11	7.5758063781E-11	7.8374427610E-11	8.1134029890E-11
0.7	6.7553207466E-11	6.9737522456E-11	7.2183881218E-11	7.4598394468E-11	7.7102538736E-11	7.9670710587E-11	8.2366816677E-11
0.8	6.7312200686E-11	6.9472964813E-11	7.1872672584E-11	7.4327025638E-11	7.6773752734E-11	7.9307813105E-11	8.2043768693E-11
0.9	6.7424391976E-11	6.9581716342E-11	7.1930945104E-11	7.4421095388E-11	7.6921994933E-11	7.9502396452E-11	8.2374533090E-11

Table	e 7:	Free	Length
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Ultrasonic velocity depends on stiffness of the medium. Stiffness of the medium not only depends on strong interaction of Van der Waal forces and hydrogen bonding but also on the compact structure of medium. As the stiffness of the system increases, ultrasonic velocity also increases. In present system, ultrasonic velocity decreases with increase in concentration of nhexane. n-Hexane, due to its bigger size, will not form compact structure as like in ethanol. Hence ultrasonic velocity decreases with increase in concentration of nhexane indicating lesser association among the components of the liquid mixture.

As the temperature increases the translational, rotational and vibrational energy of components in the given mixture increases resulting in weakening of Van der Waal forces and hydrogen bonding leading to reduce the stiffness of the medium. Hence, ultrasonic velocity of the system decreases with increase in temperature [19-21].

Adiabatic compressibility of gases is higher than liquids

and liquids has greater compressibility than solids. Compressibility is directly proportional to the compactness of the medium.

In present system, adiabatic compressibility increases with increase in concentration of n-hexane. This increase in adiabatic compressibility implies the diminished molecular association in this system upon increment of n-Hexane. The new complex structure formed due to lesser molecular association become less compact and more compressible. This suggests that the compressibility of the solution is more than that of solvent. Hence, Adiabatic compressibility increases with increase in concentration of n-hexane.

As the temperature increases the kinetic energy of components in the given mixture increases which leads to weakening of Van der Waal forces and hydrogen bonding and reduces the compactness of the structure of the medium. Hence, adiabatic compressibility of the system increases with increase in temperature [22-24].



Fig. 4: Concentration Vs Adiabatic Compressibility



Fig. 5: Concentration Vs Acoustic Impedance

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Acoustic impedance depends on density and ultrasonic velocity of the medium. Density depends on molecular arrangement per unit volume and sound velocity depends on stiffness of the medium. As the concentration of n-hexane increases, acoustic impedance decreases indicating decrease in rigidity of the medium as well as decrease in interaction between ethanol and nhexane.

As the temperature increases the kinetic energy of components in the given mixture increases which leads to decrease in Van der Waal forces and hydrogen bonding and reduces the compactness of the structure of the medium. Hence, acoustic impedance of the system decreases with increase in temperature [25, 26].

Relaxation time depends mostly on close packing and viscosity of the medium. In present system, viscosity

decreases with increase in concentration of n-hexane. Hence relaxation time also decreases in accordance with concentration of n-hexane suggesting the formation of complex clusters between Ethanol and n-Hexane molecules.

The agitation in the system increases with increase in temperature resulting in the decrease in viscosity of the medium and hence the relaxation time [27, 28].

Free length depends on adiabatic compressibility and is directly proportional to its square root. So, in our present system free length is following the same order with increase in temperature and concentration of 1propanol as the adiabatic compressibility does, indicating lack of compact structure as well as lesser interaction in the system at higher concentrations and at high temperatures [29].



### Fig. 6: Concentration Vs Relaxation Time



Fig. 7: Concentration Vs Free Length

### 6. CONCLUSION

It has been observed that the inter molecular interactions depends not only on Van-der-Waal forces and hydrogen bonding but also on the size of the molecules.

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#### Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

#### 8. REFERENCES

- Djordjević BD, Radovic IR, Kijevcanin MLJ, Tasic AZ, Serbanovic SP. J Serb Chem Soc, 2009; 74 (5):477-491.
- Dandwate SR, Deshmukh SB. Int J Universal Print, 2018; 4(4):196-201.
- Kumar D, Parshad D. Int J Res in Pharm and Chem, 2014; 4(4):825-828.
- Siddharthan N, Jayakumar S. Int J Chem Sci, 2016; 14(4):2981-2996.
- Reddy GS, Reddy MM, Chowdary VS. Int J Chem and Phys Sci, 2014; 3(2):32-44.
- Thennarasu J, Meenakshi G, Rasayan J Chem, 2011; 4(4):904-909.
- Alisha SB, Nafeesabanu S, Rao KSVK, Subha MCS, Rao KC. Ind J Advances in Chem Sci, 2017; 5(3):142-147.
- Anuradha S, Prema S, Rajagopal K. J Pure Appl Ultrason, 2005; 27:49-54.
- Ubagaramary D, Neeraja P. Int Refereed J Engg and Sci, 2012; 1(4):54-77.
- 10. Rathina K. Int J Engg and Adv Tech, 2019; 8(6S):151-159.
- 11. Natarajan R, Ramesh P. J Pure App and Ind Phys, 2011; 1(4):252-258.

- Ghosh AM, Ramteke JN. Der Chemica Sinica, 2017; 8(2):291-297
- 13. Lakshmi V. IJCR, 2014; 6(5):6814-6820
- 14. Girija AM, Arasu MMA, Devi D. Int J Sci Res in Sci and Tech, 2017; 3(11):89-96
- George CD, Thomas PM, Joseph CD. Physical and Theoretical Chemistry. New Delhi: S. Chand and Comp. Ltd.; 1986.
- 16. Nithiyanantham S, Palaniappan L. Arab J Chem, 2012; 5:25-30
- Rao CNR. University General Chemistry-An Introduction to Chemical Science. Chennai: Macmillan Pub. India Ltd.; 1973.
- Jahagirdar DV, Arbad BR, Mirgane SR, Lande MK, Shankarwar AG. J Mol Liq, 1998; 75:33-43.
- Rao NP, Ronald, Verrall E. Can J Chem, 1987;
   65:810-816.
- 20. Raman MS, Amirthaganesan G. Indian J Phys, 2004; 78:1329-1335.
- Povey MJ. Ultrasonic Techniques for Fluid Characterisation. London: London Academic Press; 1997.
- 22. Ravichandran S, Ramanathan K. Polymer-Plastics Technology and Engineering, 2008; 47:169-173.
- 23. Gekko K, Noguchi H. J Phys Chem, 1979; 83:2706-2727.
- Raman MS, Kesavan M, Senthilkumar K, Ponnuswamy V. J Mol Liq, 2015; 202:115-124.
- Mehra N, Sanjnami H. Ind J Pure & App Phys, 2000; 38:760-375.
- 26. Palani R, Balkrishnan S. Arch Phys Res, 2010; 1:111-118.
- Raman M, Ponnuswamy V, Kolandaivel P, Perumal K. J Mol Liq, 2010; 151:97-106.
- Syal VK, Chauhan A, Chauhan S. J Pure Appl Ultrason, 2005; 27:61-69.
- B. Jacobson. Acta Chemica Scandinavica, 1952;
   6:1485-1498.