Ultrasonic characterization using LabVIEW Technique

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***Abstract*— Ultrasonic is the science of acoustics and the technology of sound. The frequency range of ultrasonic waves is greater than 20 KHz up to several MHz, which is beyond the audible range or limit. Ultrasonics characterization allows for the measurement of velocity, viscosity, density, adiabatic compressibility, internal pressure, Gibb's energy, impedance and all the parameters of binary or ternary liquids. This ultrasonic characterization using pulse echo technique is discussed in this paper takes the principle of ultrasonic characterization and applied it to some binary liquid mixtures. A new instrumentation system using LabVIEW was designed to allow rapid data collection through varying liquid mixture and their characterization. The system is composed of pulse system and acquired data is then graphically shown using LabVIEW software. LabVIEW is a graphical development environment for creating test measurement and other control applications. Using LabVIEW, virtual instrumentation (VIs) is created to control or measure a process. In this application LabVIEW was used to create a virtual instrument that was laboratory to collect the data required for ultrasonic characterization of the binary systems, Acrolein + Methanol and Acrolein + Cyclohexane. Experiments were conducted to calibrated and validate the system for ultrasonic velocity, viscosity, density, adiabatic compressibility, internal pressure, impedance, free length, free volume, and Gibb's energy. Transducers are incorporated for sensing purpose. In this paper, the results of an ultrasonic velocity, density and viscosity to study the related acoustical parameters, for the binary systems of Acrolein + methanol and Acrolein + cyclohexane at the temperature 303K using Lab VIEW software have been reported. The behavior of these parameters with composition of the mixture has been discussed in terms of molecular interaction between the components of liquids.**

***Index Terms*— Molecular interaction, binary mixture, ultrasonic parameters, Acrolein, Methanol, Cyclohexane and Lab VIEW**

I. INTRODUCTION

Academic research and development usually encompasses discovery, innovation, experimentation and creation, however, in today's highly competitive and globalized economy, it also involves patents, licensing, technology transfer, and partnerships with industry. In other words, it is about creating "new knowledge" and building "new bridges" with industry while having a positive impact on the community and society in general. Due to the convergence of technologies and science, multidisciplinary research is required. This means that hardware and software tools must be adaptable to different disciplines. As technology evolves quickly, laboratories must be updated periodically as well as be able to extend the useful life of current and legacy equipment and software. New research may require custom instruments and application programs (software) that are not readily available on the market to be built using commercial off-the-shelf (COTS) technologies.

In recent years ultrasonic technique has become powerful tool in providing information regarding the behavior of liquids and solids owing to its ability of characterizing physiochemical behavior of the medium [1,2]. The study of miscibility and molecular interaction present in polymer like acrolein and solvent in a polymer solution is of great significance for engineering applications of polymers. They also provide substantial information on the process involving polymer production and their uses [3]. Further, polymer dissolution also plays a key role in many industrial applications in a variety of areas and an understanding of the dissolution process allows for the optimization of design and processing conditions as well as selection of suitable solvent[4,5]. Many researchers have undertaken these studies qualitatively through ultrasonic velocity, adiabatic compressibility and viscosity measurements [6-11]. However, there are very few studies on the quantitative study of the interactions in a polymer solution system. Acrolein is a versatile material and has been used on a wide range of fields and applications [12, 13]. In view of growing interest, in this paper, the results of an ultrasonic velocity, density and viscosity to study the related acoustical parameters, for the binary systems of acrolein + methanol and acrolein + cyclohexane at the temperature 303K using Lab VIEW software have been reported [14].

II. COMPUTATIONAL ASPECTS:

Scientists and researchers around the world have applied Lab VIEW and National Instrumentation products successfully for research and development in academia. This paper considers some of the advantages of applying national instruments platform, including Lab VIEW, to build virtual instrumentation and take an effective graphical system design approach that can effectively leverage the opportunities and take on the challenges of modern academic research and development. The study presented in this report describes a new laboratory ultrasonic data acquisition system for acquiring and processing ultrasonic characterization. The graphical representation of Ultrasonic characterization using LabVIEW of the two binary systems is shown in the Block diagram.

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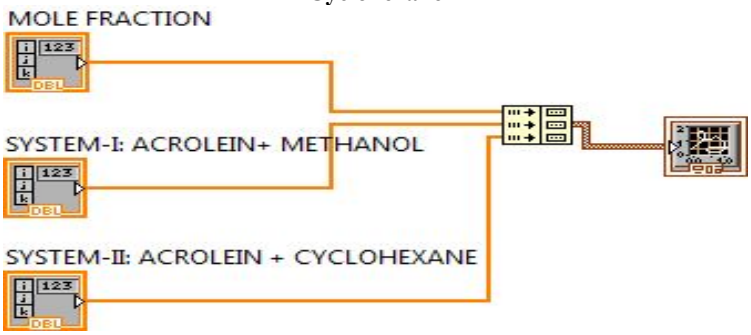
Graphical representation of ultrasonic characterization of two systems: Acrolein +Methanol and Acrolein + Cyclohexane



Block diagram of systems using Lab VIEW:

Table–1: *The experimental values of density (ρ), viscosity (η) and Ultrasonic Velocity (U) at 303K for the systems-I:* Acrolein + Methanol *and II:* Acrolein + Cyclohexane

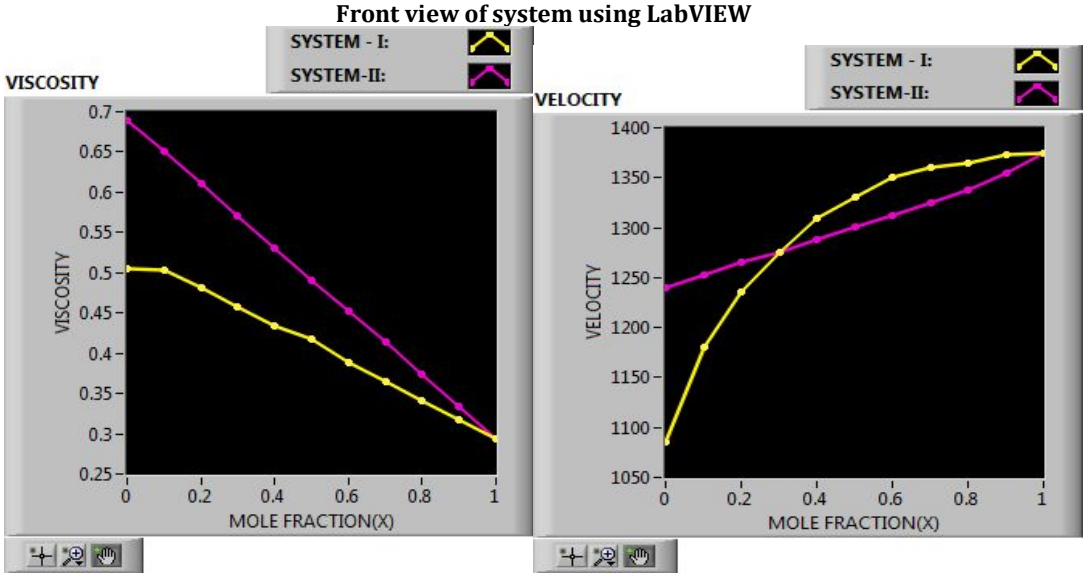
MOLE FRACTION		Density(ρ)	Viscosity(η)	Velocity(U)
X1	X2	(kg m^{-3})	(10^{-3} Nsm^{-2})	(ms^{-1})
	SYSTEM-I: ACROLEIN+METHANOL			
0	1	776.100	0.5050	1086.00
0.1	0.9	782.000	0.5040	1180.00
0.2	0.8	790.000	0.4810	1235.5.0
0.3	0.7	797.000	0.4577	1275.00
0.4	0.6	804.000	0.4344	1310.00
0.5	0.5	810.000	0.4171	1330.15
0.6	0.4	818.000	0.3878	1350.15
0.7	0.3	825.000	0.3645	1360.15
0.8	0.2	832.000	0.3412	1365.17
0.9	0.1	840.800	0.3175	1372.54
1	0	848.100	0.2946	1374.15
SYSTEMIII:ACROLEIN+CYCLOHEXANE				
0	1	772.300	0.6887	1240.00
0.1	0.9	779.850	0.6500	1253.00
0.2	0.8	787.410	0.6100	1265.00
0.3	0.7	794.930	0.5700	1275.00
0.4	0.6	802.450	0.5310	1288.00
0.5	0.5	809.990	0.4910	1301.00
0.6	0.4	817.500	0.4530	1312.00
0.7	0.3	825.050	0.4140	1325.00
0.8	0.2	832.600	0.3740	1338.00
0.9	0.1	840.160	0.3340	1355.00
1	0	848.100	0.2940	1374.00

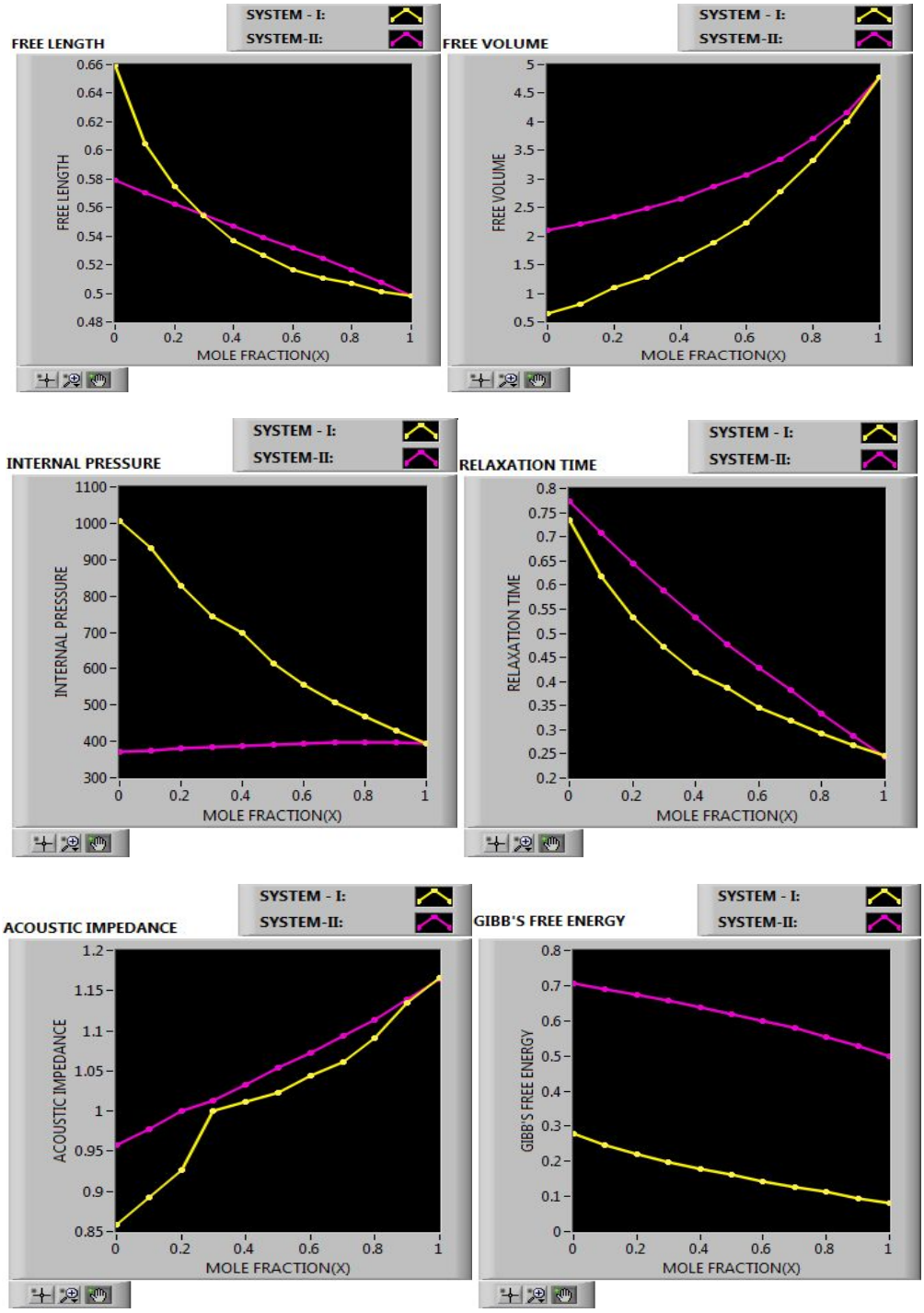
Table – 2: *The values of adiabatic compressibility (βa), free length (L_f). Free Volume (V_f), Internal pressure (π_i), Acoustic impedance (Z_a), Relaxation time (τ) and Gibb's Free energy (ΔG) at 303 K for the systems: I & II respectively.*

MOLE FRACTION		$\beta_a \times 10^{-10}$	$L_f \times 10^{-10}$	$V_f \times 10^{-7}$	$\pi_i \times 10^{6}$	$\tau \times 10^{-12}$	$Za \times 10^{6}$	$\Delta G \times 10^{-20}$
X1	X2	($m^2 N^{-1}$)	(m)	($m^3.mole^{-1}$)	(Pa S)	(S)	($Kgm^{-2}S^{-2}$)	
SYSTEM I - ACROLEIN + METHANOL								
0	1	10.9250	0.6594	0.64592	1050.229	0.73562	0.82844	0.27933
0.1	0.9	9.18390	0.60458	0.81779	931.6297	0.61716	0.92276	0.24739
0.2	0.8	8.29250	0.57449	1.10397	827.7686	0.53183	0.97604	0.22033
0.3	0.7	7.71820	0.55424	1.29098	742.7579	0.47102	0.10161	0.19825
0.4	0.6	7.24770	0.53708	1.58963	699.9686	0.41979	0.10532	0.17731
0.5	0.5	6.97770	0.52698	1.88003	613.2778	0.38805	0.10774	0.16302
0.6	0.4	6.70630	0.51663	2.32274	555.3212	0.34676	0.11044	0.14256
0.7	0.3	6.55190	0.51065	2.77983	508.6380	0.31842	0.11221	0.12705
0.8	0.2	6.44910	0.50663	3.31679	467.0810	0.29339	0.11358	0.11216
0.9	0.1	6.31330	0.50126	3.98986	428.9749	0.26726	0.1154	0.0952
1	0	6.24430	0.49852	4.77547	394.6721	0.24528	0.11654	0.07959
SYSTEM III - ACROLEIN + CYCLOHEXANE								
0	1	8.43113	0.57893	2.10659	371.5117	0.77420	0.95765	0.70736
0.1	0.9	8.16746	0.57014	2.21782	375.9866	0.70784	0.97715	0.69106
0.2	0.8	7.93630	0.56202	2.34753	380.1152	0.64548	0.99961	0.67429
0.3	0.7	7.73839	0.55496	2.48994	384.3173	0.58811	1.01353	0.65736
0.4	0.6	7.51191	0.54678	2.65666	388.1336	0.53184	1.03355	0.63907
0.5	0.5	7.29400	0.53879	2.85955	391.2126	0.47751	1.05379	0.61948
0.6	0.4	7.10632	0.53182	3.07333	394.9033	0.42922	1.07256	0.60009
0.7	0.3	6.90380	0.52418	3.34885	397.2577	0.38108	1.09319	0.57846
0.8	0.2	6.70890	0.51673	3.70192	398.1969	0.33455	1.11401	0.55477
0.9	0.1	6.48275	0.50795	4.16835	397.2246	0.28869	1.13841	0.52797
1	0	6.24568	0.49857	4.78931	394.2915	0.24483	1.16528	0.49799

Graphical representation:- Figures shown in the Front view of system using LabVIEW shows the variation of Viscosity(η), Velocity (U), free length (L_f) , Free Volume (V_f) , Internal pressure (πi) , Relaxation time (τ), Acoustic impedance (Za) & Gibb's energy (ΔG) Vs mole fraction(x) at 303K for , system –I: Acrolein + methanol , system- II : Acrolein + cyclohexane .

Front view of system using LabVIEW





3. Results and Discussion

Various acoustical and thermodynamical parameters were calculated from the measured data using the formulations, are as follows:

$\beta a = (U^2 \rho)^{-1}$ ….. (1),

$L_f = K_T \beta a^{1/2}$ ….. (2)

$V_f = (Meff\ U/\eta K)^{3/2}$ .. (3),

$J_i = bRT\ (K\eta/U)^{1/2}(\rho^{2/3}/Meff^{7/6})$ ….. (4)

$\tau = (4/3)\ \beta a^* \eta.$ ------ (5),

$Za = U^* \rho.$ ------- (6),

and $\Delta G = (K_B T) \log [(K_B T \tau)/h]$ ----- (7)

Where K_B is the Boltzmann's constant ($1.3806 \times 10\text{-}23 Jk^{-1}$), h is the plank's constant (6.63×10^{-34} JS), T is the absolute temperature and τ is the relaxation time, K_T is the temperature dependent constant having a value $207.712*10^{-8}$ at temperature 303K in MKS system, K is constant equal to $4.28*10^9$ in MKS system, b is a cubical packing fraction taken as 2 for all the liquids, R is the Universal gas constant, T is the experimental temperature, Meff =Σ ximi, where xi is the mole fraction and mi is the molecular weight of the component.

Experimental density, viscosity and ultrasonic velocity values for the two binary systems namely, system-I: Acrolein + methanol, and system-II: Acrolein + cyclohexane respectively at 303K are given in the Table-1. The thermodynamic

parameters such as adiabatic compressibility (βa), free length (L_f), free volume (V_f), acoustic impedance (Za), internal pressure (πi), relaxation time (τ) and Gibb's free energy (ΔG) at temperature 303K are listed in Table–2. The Front view of system using LabVIEW shows the variation of Viscosity(η), Velocity (U*),* free length (L_f) , Free Volume (V_f) , Internal pressure (πi) , Relaxation time (τ), Acoustic impedance (Za) & Gibb's energy (ΔG) Vs mole fraction(x) at 303K for , system –I: Acrolein + methanol , system- II : Acrolein + cyclohexane .

From the Table–2, it is noted that, the density (ρ) increases with increase in mole fraction, for the systems I i.e. for Acrolein + methanol. Ultrasonic velocity increases and viscosity decreases with increase in mole fraction of the solute in both the systems-I and II. It has been observed that for a given concentration, as the number of CH-group or Chain length changes the sound velocity. This may lead to the presence of specific molecular interaction between the molecules of the liquid mixture. The adiabatic compressibility and free length are the deciding factors of the ultrasonic velocity in the liquid systems. The internal pressure decrease and free volume increase with increasing mole fraction of the solute in both the systems. The internal pressure may gives information regarding the nature and strength of forces existing between the molecules. It represents the presence of weak interaction between the solute and solvent molecules. Acoustic impedance (Za) increases with increase in the mole fraction of the solute in the systems- I & II. The relaxation time (τ) decreases with increasing the mole concentration of the solute in both the systems. The dispersion of the ultrasonic velocity in the system may contain information about the characteristic time (τ) of the relaxation process that causes dispersion. The relaxation time which is in the order of 10^{-12} sec., is due to structural relaxation process and in such a situation, it is suggested that, the molecules get rearranged due to co-operative process. The Gibb's energy (ΔG) decreases with increasing mole fraction the solute in both the systems. This may be due to the intermediate compound formation between the binary liquids. It is observed that, generally, the decrease in Gibb's free energy favors the formation of product from reaction. This observation confirms the formation of hydrogen bonding in the binary mixture of Acrolein with methanol and cyclohexane.

CONCLUSION

The dependence of ultrasonic velocity and other derived parameters on composition of the mixtures is indication of the presence of molecular interactions. The interaction primarily of dipole-dipole and dipole–induce dipole type. The result indicates the existence of molecular interaction between the polymer and the solvent in their solutions. The result is also shows the presence of higher degree of molecular interaction between Acrolein and methanol in solution compared to Acrolein with cyclohexane in solutions. In view of growing interest, in this paper, the results of an ultrasonic velocity, density and viscosity to study the related acoustical parameters, for the binary systems of Acrolein + methanol and Acrolein + cyclohexane at the temperature 303K represented graphically using Lab VIEW software.

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