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RESEARCH ARTICLE

ACOUSTICAL STUDY OF TERNARY LIQUID MIXTURE OF WATER, FORMIC ACID AND BUTYRIC ACID

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ABSTRACT

The ultrasonic wave velocity in different composition of ternary liquid mixtures of water formic acid and butyric acid at different frequencies, at room temperature has been measured with the help of ultrasonic interferometer and for whole composition range isentropic compressibility (Ks), acoustic impedance (z) and relaxation time (Ʈ) have been calculated for these ternary mixtures.

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INTRODUCTION

Ultrasonic waves propagating in a material carry valuable information about its microstructure and mechanical properties. Various ultrasonic parameters such as velocity, attenuation, and spectral analysis of ultrasonic signals can be used to extract this information of the material. The use of ultrasonic measurements during fabrication and heat treatment ensure the absence of unacceptable discontinuities and presence of desired microstructure with acceptable properties. Ultrasonic in-service inspection is carried out to detect any unacceptable degradation in microstructure formation and extension of defects during the operation of components (D.R. Godhani et al., 2001). Measurements of ultrasonic velocities and other acoustical properties have been done to study physio – chemical behavior and molecular interaction in a number of binary system (Feng, Prog, 1980; Eggers *et al.,* 1968; Arumugam *et al.,* 1997). Flory's statistical theory (Yoon and Katz, 1976; Yoon *et al.,* 1976) has been used for predicting theoretically the ultrasonic velocities in liquid mixtures (Lang et al., 1970; Brown and Mayor, 1976; Lakes and Saha, 1978; Yoon *et al.,* 1981). Flory's statistical theory has been extended to evaluate the characteristic parameters of three ternary liquid systems; benzene-n-hexane-pentane (I), benzene-n-Hexane-Carbon tetrachloride (II}, and Benzene-n-Hexane-cyclohexane (III), at 298 Kelvin which are used to predict the surface tension of ternary mixtures.

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Measurement of ultrasonic velocity (Ana B. López *et al.,* 2013; Papari *et al.,* 2013; Rathnam *et al.,* 2012; Sahin *et al.,* 2011; Bhatt *et al.,* 2000; Semwal *et al.,* 2003) has been adequately employed in understanding the molecular interactions in pure, binary, and higher order multi-component liquid mixtures. The propagation of ultrasonic velocity in a medium is a thermodynamic property and has come to be recognized as a very specific and unique tool for predicting and estimating various physio-chemical properties of the systems under consideration (Ranjan Dey *et al.,* 2014).

Acoustical Parameters

The ultrasonic velocity measurements are extensively used to study physio – chemical behavior of liquids. With the help of measured ultrasonic velocity, density and viscosity using following formulae, some acoustic parameters like Ultrasonic velocity, isentropic compressibility, Acoustic impedance and relaxation time have been determined and results are tabulated and discussed.

1. Ultrasonic velocity (U) calculated from the ultrasonic wavelength.
   $U = n\lambda$
2. Isentropic compressibility
   $Ks = U^{-2} \rho^{-1}$
3. Acoustic impedance
   $Z = \rho X U$
4. The Relaxation time is related to the viscosity &frequency and ultrasonic of waves as Relaxation time $\tau = 4\eta/3\rho U^2$

Where –

τ = relaxation time
η = viscosity
ρ = density of liquid mixture
U = ultrasonic velocity of waves
ρ = density of liquid mixture

RESULT AND DISCUSSION

Ultrasonic velocity has been measured by variable path interferometer at different frequencies from 1MHZ to 7MHZ at room temperature in ternary liquid mixture of a Water+ Formic acid+ Butyric acid. Ultrasonic velocity in ternary liquid mixtures (Water+ Formic acid+ Butyric acid) presented in Table-1. From the table it is observed that in ternary liquid mixture ultrasonic velocity is increases with increasing frequency while with composition the ultrasonic velocity changes depend upon the composition percentage of particular liquid in the ternary liquid mixture. Isentropic compressibility of ternary liquid mixture have been calculated using formula $Ks=U^{-2}\rho^{-1}$and acoustic impedance is calculated by the equation $Z=\rho x U$. From the Table-2 the isentropic compressibility of ternary liquid mixture is decreasing with increasing frequency.

It is also changing with composition and depends upon the composition percentage of particular liquid in liquid mixture. Table-3 shows that acoustic impedance slightly increases with increasing frequency while it changes with composition and depends upon the composition percentage of particular liquid in liquid mixture.

Table 1. Ultrasonic velocity for ternary liquid mixture (Water+ Formic acid+ Butyric acid) at different frequencies and composition at room temperature

Ternary liquid mixture composition (volume)			Density	Ultrasonic velocity(m/s) at different frequencies						
Water %	Formic acid %	Butyric acid %	(g/cc)	1MHZ	2MHZ	3MHZ	4MHZ	5MHZ	6MHZ	7MHZ
10	20	70	.9350	1695	1697	1698	1700	1701	1701	1703
20	30	50	.9380	1746	1748	1749	1750	1751	1752	1753
30	40	30	.9608	1768	1769	1769	1770	1772	1773	1775
40	50	10	.9608	1836	1838	1839	1840	1841	1841	1842
20	10	70	.9140	1595	1595	1597	1600	1601	1602	1602
30	20	50	.9250	1704	1706	1706	1707	1708	1710	1711
40	30	30	.9587	1710	1710	1711	1712	1713	1713	1715
50	40	10	.9474	1108	1109	1110	1110	1111	1113	1114
70	10	20	.9608	1897	1898	1899	1900	1902	1903	1904
50	20	30	.9290	1809	1810	1810	1811	1812	1813	1813
30	30	40	.9446	1818	1819	1819	1820	1821	1822	1822
10	40	50	.93407	1758	1759	1759	1760	1761	1762	1762

Table 2. Isentropic compressibility for ternary liquid mixture (Water+ Formic acid+ Butyric acid) at different frequencies and composition at room temperature

Ternary liquid mixture composition (volume)			Isentropic compressibility($Kg^{-1}ms^{-2}$) at different frequencies($x10^{-3}$)						
Water %	Formic acid %	Butyric acid %	1MHZ	2MHZ	3MHZ	4MHZ	5MHZ	6MHZ	7MHZ
10	20	70	.372	.371	.370	.370	.369	.369	.368
20	30	50	.349	.348	.348	.348	.347	.347	.346
30	40	30	.332	.332	.332	.332	.331	.331	.330
40	50	10	.308	.308	.307	.305	.307	.307	.307
20	10	70	.430	.430	.428	.428	.426	.426	.426
30	20	50	.372	.371	.371	.371	.370	.369	.369
40	30	30	.356	.356	.356	.356	.355	.355	.354
50	40	10	.859	.858	.856	.856	.855	.852	.850
70	10	20	.289	.288	.288	.288	.287	.287	.303
50	20	30	.328	.328	.328	.328	.327	.327	.327
30	30	40	.320	.320	.319	.319	.319	.318	.318
10	40	50	.346	.346	.346	.345	.345	.344	.344

Table 3. Acoustic impedance for ternary liquid mixture (Water+ Formic acid+ Butyric acid) at different frequencies and composition

Ternary liquid mixture composition (volume)			Acoustic impedance(Kgm-2s-1) at different frequencies						
Water %	Formic acid %	Butyric acid %	1MHZ	2MHZ	3MHZ	4MHZ	5MHZ	6MHZ	7MHZ
10	20	70	1.577	1.586	1.587	1.589	1.590	1.590	1.592
20	30	50	1.637	1.639	1.640	1.641	1.642	1.643	1.644
30	40	30	1.698	1.699	1.699	1.706	1.702	1.703	1.705
40	50	10	1.764	1.765	1.766	1.767	1.768	1.768	1.769
20	10	70	1.457	1.457	1.459	1.462	1.463	1.464	1.464
30	20	50	1.576	1.578	1.578	1.578	1.579	1.581	1.582
40	30	30	1.639	1.639	1.640	1.641	1.642	1.642	1.641
50	40	10	1.049	1.060	1.051	1.051	1.052	1.054	1.054
70	10	20	1.822	1.823	1.824	1.825	1.827	1.828	1.829
50	20	30	1.822	1.680	1.681	1.681	1.683	1.684	1.684
30	30	40	1.717	1.717	1.712	1.719	1.720	1.721	1.721
10	40	50	1.642	1.642	1.643	1.643	1.644	1.645	1.645

Table 4. Relaxation time for ternary liquid mixture (Water+ Formic acid+ Butyric acid) at different frequencies and composition (room temperature)

Ternary liquid mixture composition (volume)			Relaxation time(Second) at different frequencies						
Water %	Formic acid %	Butyric acid %	1MHZ	2MHZ	3MHZ	4MHZ	5MHZ	6MHZ	7MHZ
10	20	70	.513	.512	.511	.510	.510	.510	.508
20	30	50	.526	.525	.525	.524	.523	.523	.522
30	40	30	.497	.496	.496	.496	.495	.494	.493
40	50	10	.422	.421	.421	.420	.420	.420	.419
20	10	70	.688	.688	.680	.679	.676	.676	.676
30	20	50	.579	.578	.578	.577	.577	.575	.575
40	30	30	.620	.620	.619	.618	.617	.617	.616
50	40	10	.129	.129	.128	.128	.128	.128	.128
70	10	20	.431	.431	.431	.430	.429	.429	.428
50	20	30	.459	.458	.458	.458	.457	.457	.457
30	30	40	.485	.485	.485	.484	.320	.483	.483
10	40	50	.528	.528	.527	.526	.526	.525	.525

The relaxation time is also calculated using formula $\tau=4\eta/3\rho U^2$.The values of relaxation time are also shown in table-4. It is observed that relaxation time in ternary liquid mixture (Water+ Formic acid+ Butyric acid) slightly decreases with increasing frequency while relaxation time changes with composition and depends upon the composition percentage of particular liquid in ternary liquid mixture.

Conclusion

It is concluded that value of ultrasonic velocity in liquid mixtures is increasing with increase in frequency while compositional changes of ultrasonic velocity depend on the percentage of particular liquid in liquid mixture. From the table-2 it is revealed that the isentropic compressibility of liquid mixtures decreases with increasing ultrasonic velocity, it means that there is a significant interaction between the molecules due to which structural arrangement is affected of the constituent ion. From the result and discussion it is also observed that the acoustic impedance slightly increases with increasing frequency, which shows that the constituent ions of structural arrangement are considerably affected in solute-solvent molecules.

From the Table 4 it is concluded that the relaxation time increases with decreasing frequency while it decreases with increasing frequency in liquid mixtures.

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