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A Study of Acoustical parameters of Sodium Acetate with Amides in Ethanol at Different Temperatures

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Abstract

The ultrasonic velocity, density and viscosity have been measured for the ternary mixtures Sodium acetate with secondary and tertiary amides in Ethanol at 303K, 313K and 323K. The experimental data have been used to calculate the acoustical parameters namely adiabatic compressibility (β), free length (L_f), free volume (V_f), internal pressure (π_i), Viscous relaxation time (τ) and Acoustic impedance (Z). From the obtained values, molecular interactions have been determined through hydrogen bonding between solute and solvent liquid mixtures.

Keywords: Sodium Acetate, Amides, Acoustical Parameters, Molecular interactions, Hydrogen bonding 2-6
Keywords are required (10pt Times New Roman, Justified).

Introduction

In many industrial applications liquid mixtures, rather than single component liquid system, are used in processing and product formulations [1, 2]. Liquid mixtures consisting of polar and non-polar components are of considerable importance in industries such as petrochemical, pharmaceutical and dye. The ethanol is selected as a solvent in the present work since it finds a variety of applications. The ultrasonic study of liquids is very important in understanding the nature and strength of molecular interactions. The biological activity of drug molecules and the activation energy of the metabolic process [3, 4] basically depend on the type and strength of the intermolecular interactions.

Thermodynamic and transport properties of liquid mixtures have been extensively used to study the departure of a real liquid mixture behavior from ideality [5, 6]. The ultrasonic velocity (U), density (ρ) and viscosity (η) can be used to study the physicochemical behavior and molecular interactions such as ion-solvent interaction and solvent-solvent in pure liquids, liquid mixtures and solutions. The degree of molecular interactions in different solutions are changes depending upon the nature of solvent, the structure of solute molecule and extent of solution taking place in the solution [7, 8].

In view of growing interest, the result of an ultrasonic velocity, density and viscosity to study the related acoustical parameters for the ternary system of Sodium acetate with secondary and tertiary amides

(N, Methyl formamide, N, Methyl acetamide, N, N-Methyl formamide and N, N-Dimethyl acetamide) in Ethanol at 303K, 313K and 323K. The experimental data have been used to calculate the acoustical parameters namely adiabatic compressibility (β), free length (L_f), free volume (V_f), internal pressure (π_i), Viscous relaxation time (τ) and Acoustic impedance (Z). The variations of these properties with composition at the temperature 303K, 313K and 323K are studied in terms of molecular interactions between unlike molecules. Further, these properties have been widely used to study the intermolecular interactions between the various species present in the mixture.

Materials and methods

The liquid mixtures of various concentrations in mole fraction were prepared by taking Analytic reagent grade chemicals. All the three Ternary liquids for different compositions can be prepared in terms of mole fraction. In all the mixtures the mole fraction of the components Ethanol with Sodium acetate in fixed concentration (0.01M) and secondary and tertiary amides (N, Methyl formamide, N, Methyl acetamide, N, N-Methyl formamide and N, N-Dimethyl acetamide) were mixed and concentration ration was varied between odd numbers. The ultrasonic velocity was measured by a single crystal interferometer with a high degree of accuracy operating at a frequency of 2MHz (manufactured by Mittal enterprises, New

Delhi) at 303K, 313K and 323K. The viscosity was measured by Ostwald's viscometer. An electronically operated constant temperature water bath is used to circulate water through the double walled measuring cell made up of steel containing the experimental solution at the desired temperature. Densities of the mixtures have been found by specific gravity bottle with 10ml capacity.

Theory and Calculation

Using the measured data, the following acoustical parameters have been calculated

Adiabatic compressibility (β)

$$\beta = \frac{1}{U^2 \rho} \dots \dots N^{-1} m^2$$

Where,

U is the velocity in m/s and ρ is the density in kg/m^3 .

Free length (L_f)

$$L_f = K_T \sqrt{\beta} \dots \dots (m)$$

Where,

K_T is a temperature dependent constant.

Free volume (V_f)

$$V_f = \left(\frac{M_{eff} U}{K \eta} \right)^{\frac{2}{3}} \dots \dots (m^3 mol^{-1})$$

Where,

M_{eff} is the effective molecular weight ($M_{eff} = \sum m_i x_i$), in which m_i and x_i are the molecular weight and the mole fraction of the individual constituents respectively.

K is a temperature independent constant which is equal to 4.28×10^9 for all liquids.

Internal pressure (π_i)

$$\pi_i = bRT(K\eta/U)^{1/2} (\rho^{2/3}/M_{eff}^{7/6}) \dots (Pa)$$

Where,

K is a constant, T is the absolute temperature, other symbols have their own significance.

Viscous relaxation time (τ)

$$\tau = \frac{4}{3} \eta \beta \dots \dots (S)$$

Acoustic impedance (Z)

$$Z = U \rho \dots \dots (Kg/m^2) sec^{-1}$$

Where,

U is the velocity in m/s and ρ is the density in kg/m^3 .

Results and discussion

The experiments values of density, viscosity and ultrasonic velocity are used to calculate the derived acoustical parameter values like adiabatic compressibility, free length, free volume internal pressure, acoustic impedance and viscous relaxation time for the ternary systems of systems of Sodium acetate with amides (N, Methyl formamide, N, Methyl acetamide, N, N-Methyl formamide and N, N-Dimethyl acetamide) in ethanol at different temperatures are presented in Tables 1-3.

From the Table-1 the density and ultrasonic velocity decreases with increase in mole fraction of amides in all the systems studied. Viscosity increases in system, suggesting thereby more association between solute and solvent molecules [9-10]. From the Table-2, the adiabatic compressibility and free length increases with increase of mole fraction of the amides. This may lead to the presence of specific molecular interaction between the molecules of the liquid mixture. Increase in intermolecular free length in system leads to negative deviation in sound velocity and positive deviation in compressibility. In Table-2-3, the acoustic impedance (Z) (which is the product of ultrasonic velocity and density of the solution) decrease with increase in concentration of amides. The increase in L_f and increase in Z with the concentration of amides, suggest the presence of intermolecular interactions in the system.

From table 2-3 the internal pressure increasing with increase mole fraction of the solute in system. The internal pressure may give information regarding the nature and strength of forces existing between the molecules. The decrease in free volume in system show that the strength of interaction decreases gradually with the increase in amide concentration. It represents that there is weak interaction between the Sodium acetate amides molecules.

From table-3, the relaxation time (τ) increase with increasing concentration for all the three systems. The dispersion of the ultrasonic velocity in the system should 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 [3] and in such a situation it is suggested that the molecules get rearranged due to co-operative process [11].

Table 1. The values of Density (ρ), Viscosity (η) and Velocity (U) at 303K, 313K and 323K

Mole fraction of X_2	Ultrasonic Velocity(U) (m/sec)			Density(ρ), gm/mol			Viscosity(η) $\eta \times 10^3 / \text{Nsm}^{-2}$		
	303K	313K	323K	303K	313K	323K	303K	313K	323K
Sodium acetate with N, Methyl formamide in ethanol									
0.0132	1457	1357	1307	1057	1053	1049	0.9153	0.8849	0.7181
0.0342	1326	1287	1254	1060	1051	1046	0.9180	0.8688	0.7226
0.0512	1299	1255	1227	1051	1042	1031	0.9963	0.8909	0.8762
0.0732	1275	1226	1199	1042	1039	1032	1.0862	0.9393	0.8196
0.0943	1242	1201	1172	1039	1035	1027	1.0632	0.9486	0.8212
0.1134	1246	1206	1177	1035	1026	1020	1.2394	1.0544	0.8890
0.1332	1249	1209	1180	1026	1053	1049	1.2748	1.0895	0.8725
0.1543	1276	1242	1198	1017	1051	1046	1.3221	1.1842	0.9982
Sodium acetate with N, Methyl acetamide in ethanol									
0.0143	1559	1389	1347	1065	1061	1058	0.9954	0.8992	0.7347
0.0311	1339	1288	1256	1062	1057	1050	1.1202	0.9024	0.7809
0.0521	1312	1256	1229	1061	1055	1048	2.0165	1.0702	0.7854
0.0714	1284	1227	1206	1059	1043	1045	2.0987	1.0987	0.9674
0.0923	1255	1203	1183	1055	1049	1041	2.1812	2.0716	1.0501
0.1122	1260	1208	1186	1052	1046	1038	2.2463	2.1367	2.0152
0.1341	1263	1211	1204	1047	1043	1035	2.3452	2.2189	2.0974
0.1542	1288	1243	1347	1042	1036	1029	2.4477	2.3214	2.1999
Sodium acetate with N, N-Methyl foramide in ethanol									
0.0132	1607	1457	1411	1071	1069	1065	1.0002	0.9130	0.7976
0.0322	1635	1558	1462	1067	1062	1054	1.0199	1.0175	0.8334
0.0521	1445	1398	1323	1055	1060	1052	1.1838	1.1000	0.7930
0.0731	1380	1332	1257	1034	1056	1049	1.2853	1.2066	0.9827
0.0923	1320	1272	1197	1020	1052	1044	1.4112	1.4112	1.0558
0.1132	1368	1320	1245	1018	1051	1042	1.5472	1.5472	1.1371
0.1342	1393	1363	1339	1014	1046	1037	1.5568	1.6468	1.2065
0.1543	1335	1320	1296	1009	1042	1035	1.7317	1.7317	1.3107
Sodium acetate with N, N-Dimethyl acetamide in ethanol									
0.0144	1757	1657	1511	1091	1079	1069	1.1202	0.9630	0.8976
0.0324	1785	1758	1562	1081	1062	1052	1.1199	1.0675	0.9334
0.0521	1595	1598	1423	1075	1050	1042	1.2818	1.1500	0.9930
0.0752	1530	1532	1357	1064	1056	1039	1.3853	1.2566	1.0827
0.0932	1470	1472	1297	1060	1062	1024	1.5112	1.4612	1.2558
0.1134	1518	1520	1345	1048	1058	1022	1.6472	1.5972	1.3371
0.1532	1543	1563	1439	1034	1046	1017	1.6568	1.6968	1.4065
0.1742	1585	1520	1396	1019	1042	1005	1.8317	1.7817	1.5107

Table 2. The values of Adiabatic compressibility (β), Free Length (L_f) and Free Volume (V_f), at 303K, 313K and 323K

Mole fraction of X_2	Adiabatic compressibility (β) ($10^{-10} \text{N}^{-1} \text{m}^2$)			Free length (L_f) (10^{-10}m)			Free Volume (V_f) ($10^{-7} \text{m}^3 \text{mol}^{-1}$)		
	303K	313K	323K	303K	313K	323K	303K	313K	323K
Sodium acetate with N, Methyl formamide in ethanol									
0.0132	6.1840	7.0580	7.5930	5.5174	5.9683	6.2712	3.3072	3.2302	3.3531
0.0342	7.3310	7.7950	8.2430	5.9920	6.2621	6.5251	2.4911	2.6972	3.0841
0.0512	7.6760	8.2320	8.6260	6.1265	6.4285	6.6691	2.2691	2.4031	2.6811
0.0732	8.0060	8.6780	9.0830	6.2515	6.5931	6.8371	2.1301	2.2291	2.4541
0.0943	8.4360	9.0400	9.5430	6.4105	6.7245	7.0001	2.0131	2.0941	2.2671

0.1134	8.4150	9.0250	9.5270	6.4031	6.7182	6.9950	1.9761	2.0461	2.1981
0.1332	8.4420	9.0270	9.5020	6.4125	6.7066	6.9860	1.9080	1.9831	2.1124
0.1543	8.1100	8.5930	9.2670	6.2905	6.5620	6.9030	1.8730	1.9451	2.0371
Sodium acetate with N, Methyl acetamide in ethanol									
0.0143	5.1435	6.1185	6.5044	5.0384	5.5660	5.8162	3.2982	3.1672	3.3011
0.0311	7.1836	7.7537	8.1844	5.9335	6.2465	6.5031	2.6811	2.7582	3.3121
0.0521	7.4757	8.1521	8.5425	6.0485	6.3985	6.6382	2.4271	2.6281	2.9861
0.0714	7.7947	8.5387	8.8855	6.1715	6.5427	6.7651	2.1891	2.4441	2.7551
0.0923	8.1577	8.9048	9.3285	6.3085	6.6595	6.9595	2.149	2.3841	2.6971
0.1122	8.1277	8.8598	9.2845	6.2965	6.6525	6.9082	1.9511	2.1771	2.5041
0.1341	8.1187	8.8428	9.2655	6.2935	6.5115	6.9021	1.9191	2.1401	2.5691
0.1542	7.8637	8.4558	9.0445	6.1975	5.5660	6.8232	1.9031	2.0331	2.2901
Sodium acetate with N, N-Methyl formamide in ethanol									
0.0132	5.4475	6.0821	7.1274	5.1844	5.8255	6.0823	3.1982	3.2042	3.2752
0.0322	5.0124	5.6612	6.1542	4.9744	5.2654	5.6613	3.1022	3.3432	3.4702
0.0521	6.2355	6.1985	7.4112	5.5394	5.7984	6.1982	2.4501	2.7652	3.0009
0.0731	6.7896	6.5002	8.1784	5.7745	6.0616	6.5002	2.2701	2.5491	2.7012
0.0923	7.9758	6.8152	9.0245	6.0165	6.3317	6.8532	2.1011	2.3391	2.5111
0.1132	6.4467	6.5761	8.3772	5.8315	6.1255	6.5766	2.0961	2.3521	2.5523
0.1342	6.0476	6.1691	7.3384	5.7484	5.9632	6.1695	2.1181	2.3891	2.7345
0.1543	6.5086	6.3611	7.8204	5.9815	6.1493	6.3614	2.0611	2.2591	2.5823
Sodium acetate with N, N-Dimethyl acetamide in ethanol									
0.0144	6.0821	6.5475	8.1174	6.1744	6.4255	6.5823	4.2982	4.2042	3.8752
0.0324	5.6612	6.1124	7.1442	5.9644	6.0654	6.1613	4.2022	4.3432	4.0702
0.0521	6.1985	7.3355	6.4012	6.5294	6.5984	6.6982	3.5501	3.7652	3.6009
0.0752	6.5002	7.8896	7.1084	6.7245	6.8616	7.1200	3.3701	3.5491	3.3012
0.0932	6.8152	8.1758	8.0045	7.0365	7.1317	7.3532	3.2011	3.3391	3.1211
0.1134	6.5761	7.5467	7.3672	6.8015	5.8255	7.0766	3.1961	3.3521	3.1523
0.1532	6.1691	7.1476	8.3084	6.7084	6.7632	6.6695	3.2181	3.3891	3.3345
0.1742	6.3611	7.5086	8.8304	6.9015	6.9493	6.8614	3.1611	2.2591	3.1823

Table 3. The values of Internal Pressure (π_i), Viscous Relaxation Time (τ) and Acoustic impedance (Z) at 303K, 313K and 323K

Mole fraction of X ₂	Internal pressure (π_i) (10 ⁻⁶ Pa)			Viscous Relaxation Time (τ)(10 ⁻¹² s)			Acoustic impedance(Z) (Kg/m ² .sec ⁻¹)		
	303K	313K	323K	303K	313K	323K	303K	313K	323K
Sodium acetate with N, Methyl formamide in ethanol									
0.0132	142.9	141.6	137.7	12.4961	11.1239	10.4961	94.9002	92.7102	90.5142
0.0342	147.3	145.6	139.8	12.3203	11.0032	10.3203	97.6689	95.4281	93.1384
0.0512	152.5	151.8	147.3	12.9302	11.7312	10.9302	97.2433	95.1233	93.0022
0.0732	155.6	155.5	151.6	13.3227	12.0221	11.3227	95.7459	93.6159	91.3154
0.0943	158.3	158.1	155.3	14.3472	13.0412	12.3472	93.9992	91.7592	89.4522
0.1134	157.3	156.8	145.6	14.6240	13.3223	12.6240	92.6069	90.5239	88.2391
0.1332	157.9	157.3	156.3	14.5390	13.3355	12.5390	92.8195	90.7195	88.4155
0.1543	156.7	156.6	156.7	12.4961	11.1239	10.4961	91.6075	89.5275	87.2225
Sodium acetate with N, Methyl acetamide in ethanol									
0.0143	140.5	136.6	132.6	11.6122	10.3912	9.3261	94.9002	89.1022	87.4412
0.0311	143.3	145.1	136.7	11.2031	10.1032	9.2213	94.8966	92.2810	90.1244
0.0521	149.6	147.5	142.4	11.9111	10.8222	9.8230	94.2433	92.1233	90.1009
0.0714	157.2	151.8	146.8	12.2271	9.1321	10.2287	92.7152	90.6221	88.3051
0.0923	157.9	153.2	147.4	13.3212	12.1412	11.2272	90.8292	98.5925	86.2295
0.1122	166.7	159.9	151.9	13.6120	12.3023	11.5210	89.6562	87.2392	85.9102

0.1341	167.1	160.5	149.3	13.5520	11.3255	11.4350	89.8085	87.7125	85.4155
0.1542	161.2	159.9	157.7	11.4856	10.1009	9.3592	88.6175	86.5562	84.2511
Sodium acetate with N, N-Methyl foramide in ethanol									
0.0132	138.1	132.9	128.7	10.6122	9.3912	8.3261	92.9852	88.1232	86.4412
0.0322	130.9	130.9	131.1	10.2031	9.1032	8.2213	92.7256	91.2923	89.1244
0.0521	142.3	137.6	135.5	11.9111	9.8222	8.8230	92.4333	91.1233	89.1009
0.0731	143.5	138.5	137.9	11.2271	8.1321	9.2287	90.6152	89.6331	87.3051
0.0923	144.8	139.8	138.2	11.3212	11.1412	10.2272	88.7529	87.5855	85.2295
0.1132	139.8	134.5	132.2	11.6120	11.3023	10.5210	87.5162	86.2459	84.9102
0.1342	133.5	138.2	122.2	12.5520	10.3255	10.4350	87.9285	86.7525	84.4155
0.1543	130.1	126.6	121.1	10.4856	9.1009	8.3359	87.5175	85.5662	83.2511
Sodium acetate with N, N-Dimethyl acetamide in ethanol									
0.0144	158.1	152.9	148.7	9.6122	9.2912	8.5261	90.9852	87.1232	83.4412
0.0324	150.9	150.9	151.1	9.2031	8.9032	8.4213	90.7256	90.2923	87.1244
0.0521	162.3	157.6	155.5	10.9111	9.7222	9.0230	90.4333	90.1233	87.1009
0.0752	163.5	158.5	157.9	10.2271	7.9321	9.4287	88.6152	88.6331	85.3051
0.0932	164.8	159.8	158.2	10.3212	9.1412	10.4272	86.7529	96.5855	83.2295
0.1134	169.8	154.5	152.2	10.6120	9.3023	10.7210	85.5162	85.2459	82.9102
0.1532	153.5	158.2	132.2	10.5520	8.3255	10.6350	83.9285	85.7525	82.4155
0.1742	150.1	146.6	131.1	9.4856	7.1009	8.5359	81.5175	84.5662	81.2511

Conclusion

The ultrasonic velocity, density, viscosity and other related parameters were calculated. The existence of type of molecular interaction in solute-solute is favored in the system, confirmed from the U , ρ , η , β , L_f , Z , η and π_i data. Weak dispersive type intermolecular interactions are confirmed in the systems investigated. Components maintain their individuality in the system investigated. All the experimental determinations of acoustic parameters are strongly correlated with each other.

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