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Thermo-acoustic behavior of synthesized 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one in ethanol and in different percentage composition of DMSO in ethanol

Neha Sawhney, Mukesh Kumar and Meena Sharma*

Department of Chemistry, University of Jammu, Jammu-180 006, Jammu & Kashmir, India

E-mail: mlakhanpal123@gmail.com

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In the present investigation 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one was synthesized by aldol condensation and the obtained product was characterized by ^{1}H NMR and ^{13}C NMR spectra. Binary and ternary solutions of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one were prepared in pure ethanol and in different compositions of DMSO in ethanol. The interactions of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one with solutions of ethanol and in different composition of DMSO in ethanol as a function of temperature and concentration have been studied by combination of volumetric, viscometric and acoustic studies. The obtained results were discussed in terms of molecular interactions occurring in these solutions.

Keywords: 3-(4-Chlorophenyl)-1-phenylprop-2-en-1-one, density, viscosity, speed of sound.

Introduction

Compounds belong to chalcone moiety represent a key role in the plethora of biologically active molecules including synthetic and natural products. These are α,β-unsaturated ketones and the presence of double bond in conjugation with carbonyl group is responsible for the biological activity of chalcones[1,2]. The compounds acquire chalcone structural motif possess various biological activities like: anti-oxidant, anti-inflammatory, anti-fungal, anti-tuberculosis, anti-tumor, anti-HIV etc.[3–8]. Ultrasonic energy is used for the synthesis of various chemical substances and to study chemical processes. Ultrasonic technique has been used to recognize the type of molecular interactions in pure liquids, liquid mixtures and in various other solutions[9,10].

The solvents ethanol and DMSO were preferred because of their applicability in biological processes, chemical, pharmacy and medicine (microbiology, dermatology, etc.)[11–13]. Alcohols are hydrogen-bonded solvents and the degree of association is very susceptible to temperature change and carbon chain length[14]. Thermodynamic studies of ethanol play a very significant role in chemical engineering calculation, modelling and evaluation of processes during ethanol production and its use for food and non-food applications[15]. DMSO consist of highly polar S=O group molecule, large dipole moment and high dielectric constant and is preferred because of its utilization in broad range of medical applications[16,17]. The main important pharmacological use of DMSO in drugs (e.g. idoxuridine) is to improve the dispersion of the drug into the skin[18]. DMSO consists of hydrogen acceptor oxygen atom so it can form H-bonds with hydroxyl group of alcohols.

A literature survey shows that work on acoustical properties of solutions of organic compounds were carried out by using ultrasonic technique[19]. The acoustical and physico-chemical studies of some organic compounds like triazoles, Schiff bases etc. have been studied in different solvents. Kulshrestha *et al.* has studied physico-chemical properties of some synthesized chalcones of furaldehyde[20–22].

In continuation to our earlier studies on chalcones in different solvents[23], we synthesised 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one and report here the density, ρ, speed of sound, u and viscosity, η of its different solutions in ethanol and in 10%, 30% and 50% DMSO in ethanol as a function of temperature. These experimentally measured values were used to calculate various acoustic and thermodynamic parameters viz. adiabatic compressibility, k_s, acoustic impedance, Z, intermolecular free length, L_f and free volume, V_f. These parameters have been used to discuss various types of molecular interactions occurring in these solutions.

Experimental

Materials and methods:

Acetophenone, *p*-Cl benzaldehyde and NaOH used for the synthesis of chalcones were purchased from Sigma-Aldrich. Solvents ethanol and DMSO were obtained from Merck chemicals and used as such. Solutions of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one as a function of molality (0.00313 to 0.1) mol kg^{-1} were prepared in pure ethanol and in mixed percentage composition of DMSO in ethanol (i.e. 10%, 30% and 50%). The weighing of samples was done on an electronic single pan five digit analytic balance (Mettler Toledo, Model: ML204) with standard uncertainty of ±0.01 mg. The standard uncertainties in molality (*m*) of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one were found to be within ±0.00001 mol kg^{-1}.

The speed of sound was measured using single-crystal variable path multi-frequency ultrasonic interferometer (Model: M-82S, Mittal Enterprises, India) having stainless steel sample cell with digital micrometer functioning at fixed frequency of 6 MHz with an uncertainty of ±0.45 m s^{-1}. The temperature was maintained to a precision of ±0.01 K using an electronic controlled thermostatic water bath (Model: TIC-4000N, Thermotech, India).

U-tube denstimeter (Anton Paar DMA 5000M, Austria) was used for the measurement of density with standard uncertainty of ±0.055 kg m^{-3} and the temperature was automatically kept constant with its built in thermostat with in ±0.003 K. Ubbelohde type suspended level viscometer was used for the measurement of viscosity. The viscometer containing test liquid was vertically immersed in thermostatic water bath for 45 min so that thermal variation in viscometer was minimized. The viscometer was calibrated with deionised distilled water at different temperatures (298.15–308.15 K). The efflux time of solutions were recorded three times with digital stop watch with an accuracy of ±0.01 s. The average of three sets of flow time for each solution was measured as the final efflux time for each sample and can be used for calculation of viscosity. The uncertainty in viscosity measurements was found to be ±0.02 m Pa s.

Synthesis:

Chalcone: 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one was prepared by using desired amount of acetophenone and *p*-Cl benzaldehyde in basic medium[24]. The general method for the preparation for the chalcones was already explained in our earlier studies[23]. The crude products so obtained were recrystallized in ethanol and were characterized by using ^{1}H and ^{13}C NMR spectra.

Characterization of synthesized chalcone:

The synthesized chalcone: 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one was characterized by ^{1}H NMR (400 MHz) and ^{13}C NMR (100 MHz) in $CDCl_3$, on Brukeravance III spectrometer using TMS as an internal standard.

Results and discussion

By using experimentally measured values of density, viscosity and speed of sound various acoustic parameters were determined and the results obtained from these parameters were discussed in terms of solute-solvent interactions in these solutions.

Density and viscosity:

Table 1 shows the experimentally measured values of density, ρ and viscosity, η in pure ethanol and in varied composition of DMSO in ethanol as a function of molality of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one.

The variation of density and viscosity of solutions of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one in pure ethanol and in different percentage composition of DMSO in ethanol at different temperatures are reported in Table 1. Fig. 1 demonstrate the linear increase in values of density and viscosity with increase in concentration of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one for pure ethanol. This shows the presence of strong intermolecular hydrogen bonding between hydroxyl (-OH) group of ethanol and carbonyl (-C=O) group of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one.

As demonstrated from Table 1 the values of density and viscosity increases with increase in percentage composition of DMSO in ethanol is due to the existence of intermolecular hydrogen bonding between -S=O group of DMSO and -OH group of ethanol[25]. Similar results were obtained by M. M. Palaiologou *et al.* for alcohol and DMSO by determining excess molar volumes of these solutions[26]. In this binary solvent mixture with the increase in molality of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one a non-linear behavior is observed up to some concentrations of solute.

For 10% DMSO in ethanol solution slight decrease in these values up to 0.00625 *m* concentration of 3-(4-

Table 1. Density, ρ and viscosity, η, of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one in ethanol and in different percentage composition of DMSO in ethanol at different temperatures and pressure, p = 101 kPa

	T (K)					
	298.15		303.15		308.15	
m (mol kg^{-1})	ρ×10^{-3} (kg m^{-3})	η×10^{3} (kg m^{-1} s^{-1})	ρ×10^{-3} (kg m^{-3})	η×10^{3} (kg m^{-1} s^{-1})	ρ×10^{-3} (kg m^{-3})	η×10^{3} (kg m^{-1} s^{-1})
3-(4-Chlorophenyl)-1-phenylprop-2-en-1-one + ethanol:						
0.00000	0.78591	1.07300	0.78160	0.97150	0.77726	0.88900
0.00313	0.78656	1.12060	0.78216	1.01952	0.77793	0.92561
0.00625	0.78773	1.17906	0.78340	1.08175	0.77905	0.97344
0.01250	0.78891	1.26835	0.78455	1.18657	0.78025	1.06862
0.02500	0.79000	1.34671	0.78567	1.25521	0.78133	1.14972
0.05000	0.79223	1.39174	0.78778	1.28934	0.78345	1.18113
0.10000	0.79672	1.46379	0.79257	1.36183	0.78824	1.25823
3-(4-Chlorophenyl)-1-phenylprop-2-en-1-one + 10% DMSO in ethanol:						
0.00000	0.82009	1.18192	0.81569	1.09192	0.81125	1.00192
0.00313	0.81878	1.17674	0.81437	1.08702	0.80995	0.99784
0.00625	0.81726	1.16064	0.81287	1.06962	0.80839	0.97844
0.01250	0.82098	1.21576	0.81694	1.12239	0.81235	1.03393
0.02500	0.82197	1.31123	0.81773	1.22517	0.81329	1.12452
0.05000	0.82560	1.35529	0.82113	1.26742	0.81707	1.17554
0.10000	0.83011	1.45752	0.82567	1.36803	0.82134	1.28031
3-(4-Chlorophenyl)-1-phenylprop-2-en-1-one + 30% DMSO in ethanol:						
0.00000	0.88720	1.29079	0.88265	1.19081	0.87807	1.09083
0.00313	0.88956	1.33459	0.88515	1.23381	0.88057	1.13847
0.00625	0.88652	1.28798	0.88198	1.18817	0.87741	1.08843
0.01250	0.89083	1.40017	0.88637	1.30042	0.88178	1.21926
0.02500	0.89187	1.46592	0.88779	1.36930	0.88268	1.26735
0.05000	0.89278	1.51371	0.88807	1.41772	0.88269	1.31743
0.10000	0.89457	1.58490	0.88963	1.48595	0.88476	1.39061
3-(4-Chlorophenyl)-1-phenylprop-2-en-1-one + 50% DMSO in ethanol:						
0.00000	0.94930	1.46590	0.94463	1.36610	0.93995	1.26632
0.00313	0.95335	1.54513	0.94858	1.44615	0.94432	1.34635
0.00625	0.95217	1.50896	0.94705	1.40918	0.94315	1.31029
0.01250	0.95519	1.56349	0.95028	1.46476	0.94568	1.36483
0.02500	0.95587	1.57542	0.95103	1.4 7649	0.94647	1.37682
0.05000	0.95628	1.63371	0.95185	1.53468	0.94710	1.43463
0.10000	0.96342	1.70553	0.95893	1.60673	0.95415	1.50708

chlorophenyl)-1-phenylprop-2-en-1-one is shown in Fig. 1(b). The partial weakening of existing bond between ethanol and DMSO i.e. Et-OH···O=S(Me)$_2$ results slight decrease in these values. This regular decrease in these values up to 0.00625 *m* concentration of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one for 10% DMSO solution in ethanol as compared to 3-(4-methoxyphenyl)-1-phenylprop-2-en-1-one[23], is due to the dominating nature of –I effect of -Cl group of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one at this concentration. But above this concentration (0.00626 *m*) of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one in this solvent mixture the values of density and viscosity increases.

For 30% DMSO in ethanol and 50% DMSO in ethanol, slight increase in values of density and viscosity for 0.00313

m concentration of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one is due to the dominating nature of +M effect of -Cl group of 3-(4-chlorophenyl)-1-phenylprop- 2-en-1-one at this concentration. Due to dominance of +M effect of -Cl group at this concentration polarity of carbonyl group increases which results an increase in solute-solvent interactions as shown in Fig. 1(c) and Fig. 1(d). But slight decrease in values of density and viscosity for 0.00625 *m* concentration of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one in this solvent mixture is due to the weakening of existing bond between -OH group of ethanol and -S=O group of DMSO and strengthening of bond between carbonyl group of 3-(4- chlorophenyl)-1-phenylprop-2-en-1-one and -OH group of ethanol. For higher concentrations of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one the values of density and viscosity shows regular increasing trend because of increasing strength of bond between (-OH) group of ethanol and (-C=O) group of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one.

Speed of sound and adiabatic compressibility:

Speed of sound of various solutions were experimentally measured and adiabatic compressibility, k_s, was calculated by using measured values of density and speed of sound[27,28]:

$$k_s = \frac{1}{\rho} \times u^2 \text{ (m kg}^{-1} \text{ s}^2\text{)} \quad (1)$$

The values of speed of sound and adiabatic compressibility are reported in Table 2.

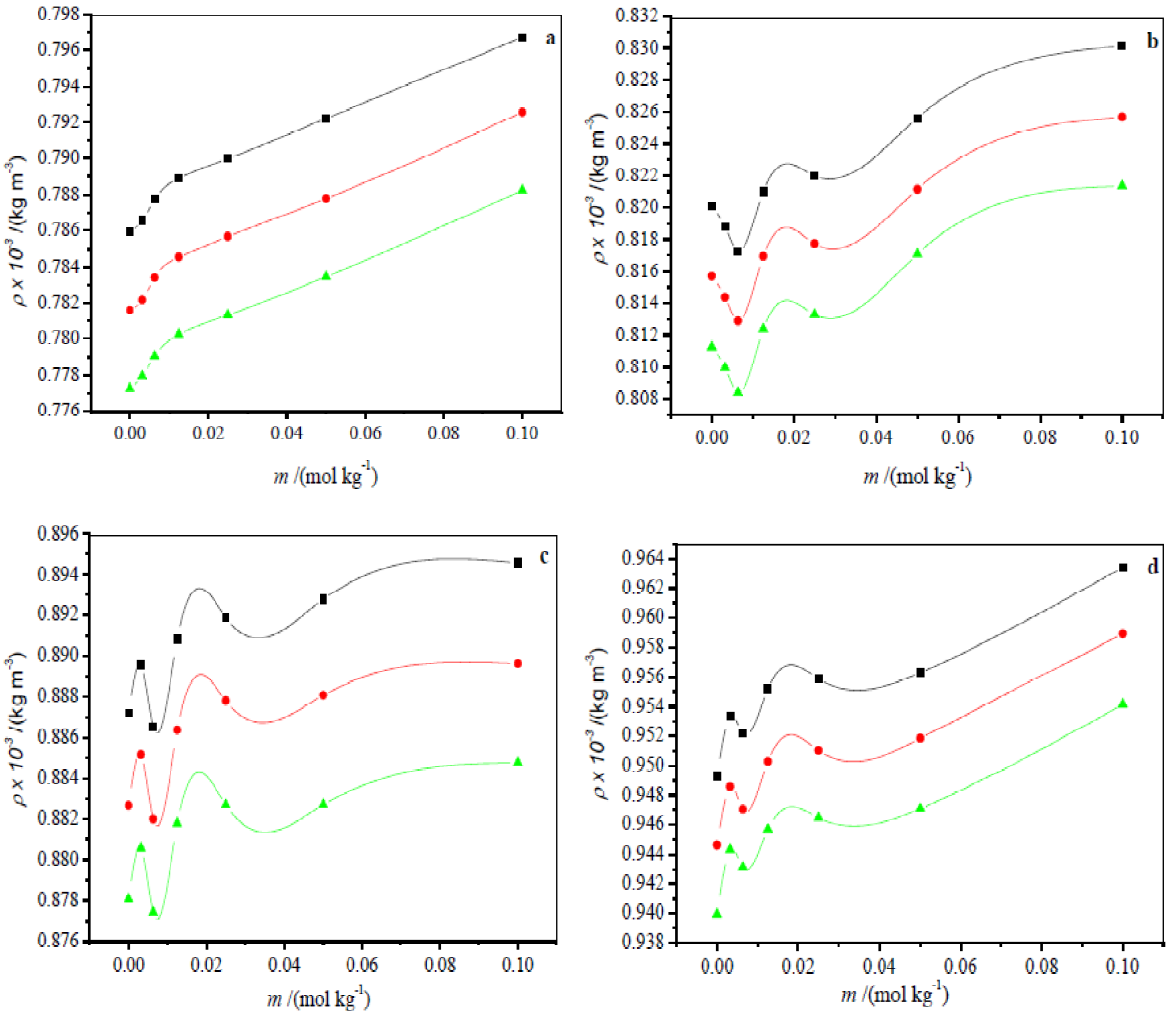

Fig. 1. Plots of density, ρ, versus molality, *m*, of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one in (a) pure ethanol; (b) 10% DMSO in ethanol; (c) 30% DMSO in ethanol and (d) 50% DMSO in ethanol at temperatures: 298.15 K, 303.15 K, 308.15 K.

Table 2. Speed of sound, u and adiabatic compressibility, k_S, of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one in ethanol and in different percentage composition of DMSO in ethanol at different temperatures

	T (K)					
	298.15		303.15		308.15	
m (mol kg^{-1})	$u \times 10^{-3}$ (m s^{-1})	$k_S \times 10^9$ (m kg^{-1} s)	$u \times 10^{-3}$ (m s^{-1})	$k_S \times 10^9$ (m kg^{-1} s)	$u \times 10^{-3}$ (m s^{-1})	$k_S \times 10^9$ (m kg^{-1} s)
3-(4-Chlorophenyl)-1-phenylprop-2-en-1-one + ethanol:						
0.00000	1.15240	0.95812	1.13165	0.99906	1.11760	1.03006
0.00313	1.15671	0.95021	1.13806	0.98713	1.12355	1.01830
0.00625	1.16213	0.93997	1.14604	0.97189	1.12903	1.00699
0.01250	1.16779	0.92949	1.15196	0.96052	1.13525	0.99445
0.02500	1.17177	0.92191	1.15522	0.95374	1.13858	0.98728
0.05000	1.17575	0.91310	1.15946	0.94424	1.14292	0.97714
0.10000	1.18955	0.88701	1.17335	0.91645	1.15652	0.94850
3-(4-Chlorophenyl)-1-phenylprop-2-en-1-one + 10% DMSO in ethanol:						
0.00000	1.19891	0.84833	1.16791	0.89879	1.13691	0.95366
0.00313	1.19594	0.85391	1.16492	0.90487	1.13389	0.96028
0.00625	1.19109	0.86248	1.15873	0.91625	1.12862	0.97114
0.01250	1.20813	0.83453	1.17718	0.88333	1.14731	0.93518
0.02500	1.21482	0.82437	1.18315	0.87360	1.15206	0.92641
0.05000	1.21753	0.81709	1.18633	0.86532	1.15592	0.91598
0.10000	1.23178	0.79396	1.20000	0.84107	1.17018	0.88914
3-(4-Chlorophenyl)-1-phenylprop-2-en-1-one + 30% DMSO in ethanol:						
0.00000	1.24328	0.72919	1.21327	0.76965	1.18329	0.81337
0.00313	1.25092	0.71840	1.22135	0.75736	1.19106	0.80051
0.00625	1.24132	0.73206	1.21141	0.77261	1.18073	0.81752
0.01250	1.25846	0.70880	1.22921	0.74668	1.19874	0.78920
0.02500	1.26937	0.69586	1.23894	0.73382	1.20678	0.77793
0.05000	1.27389	0.69023	1.24438	0.72719	1.21462	0.76791
0.10000	1.28373	0.67833	1.25413	0.71467	1.22378	0.75469
3-(4-Chlorophenyl)-1-phenylprop-2-en-1-one + 50% DMSO in ethanol:						
0.00000	1.30354	0.61994	1.27052	0.65580	1.23755	0.69466
0.00313	1.32608	0.59650	1.29293	0.63063	1.26007	0.66695
0.00625	1.31313	0.60907	1.27999	0.64449	1.24731	0.68151
0.01250	1.32845	0.59323	1.29551	0.62700	1.26255	0.66337
0.02500	1.33013	0.5913 I	1.297 I I	0.62496	1.26408	0.66122
0.05000	1.33783	0.58427	1.30485	0.6 1704	1.27129	0.65330
0.10000	1.35821	0.56267	1.32512	0.59389	1.29295	0.62693

Adiabatic compressibility and speed of sound are inversely related to each other as clearly observed from Table 2. Speed of sound increases with increase in concentration of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one in pure ethanol. This increase in values is due to the strong molecular interactions between hydroxyl (-OH) group of ethanol and carbonyl (-C=O) group of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one.

Decrease in values of speed of sound in binary solvent (i.e. 10% DMSO in ethanol) mixture with increase in molality of solute is due to the dominating nature of –I effect of -Cl group of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one. But above this concentration (0.00625 *m*) of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one in this solvent mixture the values of speed of sound increases. Slight increase in values of speed of sound for binary solvent mixture i.e. 30% DMSO in

ethanol and 50% DMSO in ethanol is due to the dominance of +M effect of -Cl group of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-ones at 0.00313 *m* concentration of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-ones. Decrease in value of speed of sound for 0.00625 *m* concentrations of solute in binary solvent mixture is due to the weakening of existing bond between -OH group of ethanol and -S=O group of DMSO as already explained. Above 0.00625 *m* concentration of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one the increase in values of speed of sound favors strengthening of bond between carbonyl (-C=O) group of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one and hydroxyl (-OH) group of ethanol.

The adiabatic compressibility decreases with increase in concentration of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one for pure ethanol. The adiabatic compressibility shows a non-linear behavior up to 0.00625 *m* concentration of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one for 10%, 30% and 50% DMSO in ethanol and above this concentration the compressibility of the solution decreases due to increase in solute-solvent interactions and the values of density and speed of sound increases. Further with the increase in temperature adiabatic compressibility of solutions increases, this increase in values of compressibility of solution is due to the weak interactions between solute and solvent molecules which results an expansion in volume.

Acoustic impedance and free volume:

Acoustic impedance is the barricade of sound waves and is defined as a measure of the resistance offered by the medium for the propagation of sound waves through it. Acoustic impedance, *Z* was calculated using experimentally measured value of speed of sound and density using following relation[29,23]:

$$Z = u \times \rho \ (\text{kg m}^{-2}\ \text{s}) \qquad (2)$$

Table 3 illustrates the variation of acoustic impedance with increase in concentration of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one in ethanol and in different composition of DMSO in ethanol at different temperatures. The obtained values of acoustic impedance of solutions give an idea about intermolecular interactions. The obtained values of acoustic impedance in pure ethanol increases with increase in concentration of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one. This increase in values is due to the strong molecular interactions between hydroxyl (-OH) group of ethanol and carbonyl (-C=O) group of 3-(4-chlorophenyl)-1-phenylprop-

Table 3. Acoustic impedance, *Z* and free volume, V_f, of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one in ethanol and in different percentage composition of DMSO in ethanol at different temperatures

	T (K)					
	298.15		303.15		308.15	
m (mol kg^{-1})	$Z \times 10^{-4}$ (kg m^{-2} s^{-1})	$V_f \times 10^9$ (m^3 mol^{-1})	$Z \times 10^{-4}$ (kg m^{-2} s^{-1})	$V_f \times 10^9$ (m^3 mol^{-1})	$Z \times 10^{-4}$ (kg m^{-2} s^{-1})	$V_f \times 10^9$ (m^3 mol^{-1})
3-(4-Chlorophenyl)-1-phenylprop-2-en-1-one + ethanol:						
0.00000	0.90568	–	0.88450	–	0.86867	–
0.00313	0.90982	3.69876	0.89015	4.15958	0.87404	4.71674
0.00625	0.91544	3.45461	0.89781	3.84972	0.87957	4.40976
0.01250	0.92128	3.12403	0.90377	3.38254	0.88578	3.87195
0.02500	0.92570	2.88119	0.90762	3.13432	0.88961	3.49846
0.05000	0.93146	2.77618	0.91340	3.04892	0.89542	3.40322
0.10000	0.94774	2.65905	0.92996	2.90288	0.91162	3.19861
3-(4-Chlorophenyl)-1-phenylprop-2-en-1-one + 10% DMSO in ethanol:						
0.00000	0.98322	3.83342	0.95265	4.15066	0.92231	4.53553
0.00313	0.97921	3.84804	0.94868	4.16662	0.91839	4.54947
0.00625	0.97343	3.90817	0.94190	4.23870	0.91237	4.65719
0.01250	0.99185	3.73091	0.96169	4.04543	0.93202	4.40252
0.02500	0.99855	3.37229	0.9675	3.58873	0.93696	3.92136
0.05000	1.00519	3.24500	0.97413	3.45121	0.94447	3.71603
0.10000	1.02251	3.00682	0.99080	3.17949	0.96112	3.38171

Table-3 (contd.)

3-(4-Chlorophenyl)-1-phenylprop-2-en-1-one + 30% DMSO in ethanol:						
0.00000	1.10304	4.05646	1.07090	4.41316	1.03901	4.84817
0.00313	1.11277	3.89737	1.08108	4.22997	1.04881	4.59587
0.00625	1.10046	4.06825	1.06844	4.42654	1.03598	4.85815
0.01250	1.12107	3.67219	1.08953	3.96050	1.05702	4.20126
0.02500	1.13211	3.42518	1.09992	3.65842	1.06520	3.94969
0.05000	1.13730	3.36896	1.10510	3.58844	1.07213	3.86306
0.10000	1.14839	3.23607	1.11571	3.44206	1.08275	3.66486
3-(4-Chlorophenyl)-1-phenylprop-2-en-1-one + 50% DMSO in ethanol:						
0.00000	1.23745	4.16912	1.20018	4.45926	1.16324	4.80334
0.00313	1.26422	3.95808	1.22645	4.20843	1.18991	4.50746
0.00625	1.25032	4.04550	1.21221	4.31407	1.17640	4.62847
0.01250	1.26892	3.91213	1.23110	4.15479	1.19397	4.44419
0.02500	1.27143	3.89315	1.23359	4.13213	1.19641	4.41469
0.05000	1.27934	3.75422	1.24202	3.97187	1.20404	4.22608
0.10000	1.30853	3.66874	1.27070	3.86655	1.23367	4.10227

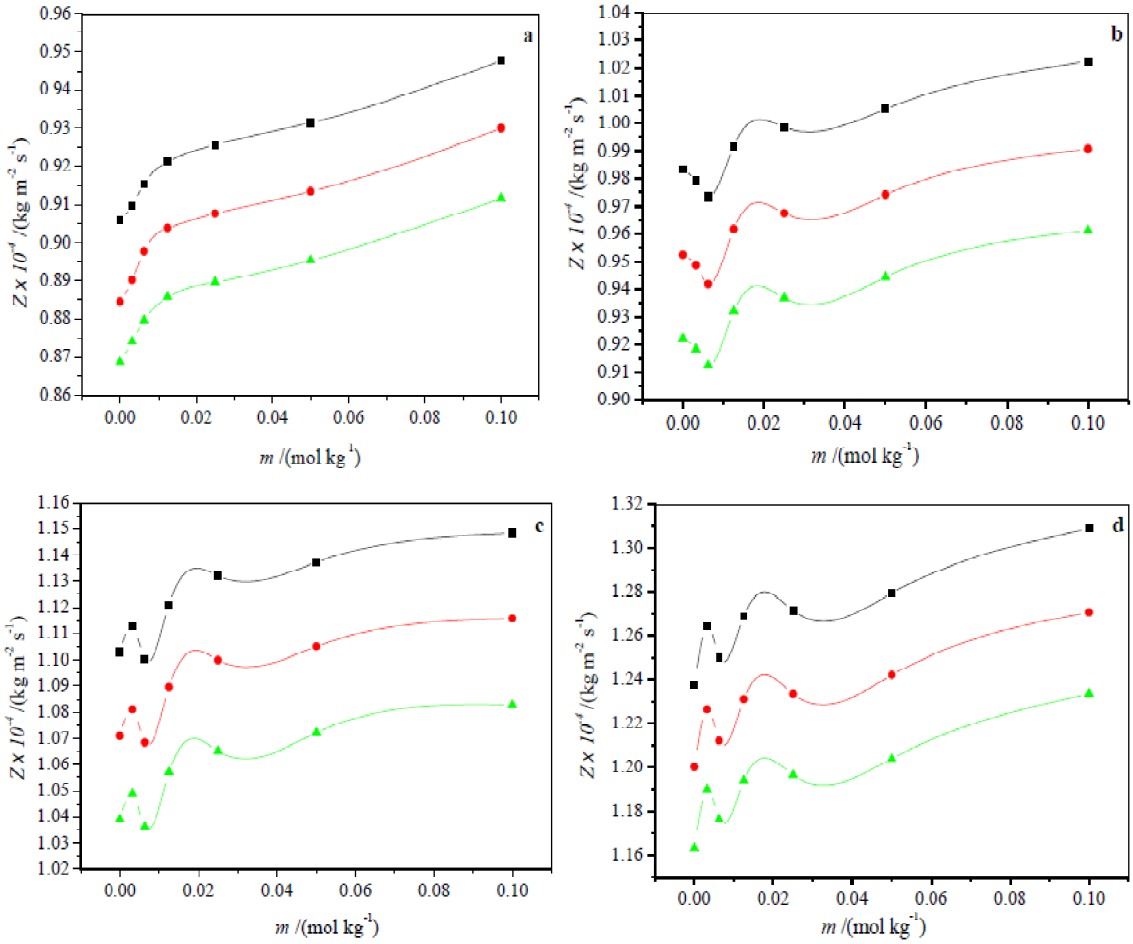

Fig. 2. Plots of acoustic impedance, *Z*, versus molality, *m*, of 3-(4-chlorophenyl)-1-phenylprop-2-en-1- one in (a) pure ethanol; (b) 10% DMSO in ethanol; (c) 30% DMSO in ethanol and (d) 50% DMSO in ethanol at temperatures: 298.15 K, 303.15 K, 308.15 K.

2-en-1-one as shown in Fig. 2(a).

Decrease in values of acoustic impedance up to some concentration (0.00625 *m*) of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one for binary solvent mixtures is due to the weakening of existing bond between -OH group of ethanol and -S=O group of DMSO. Above 0.00625 *m* concentration of solute, acoustic impedance increases for 10%, 30% and 50% DMSO in ethanol, this increase in values of acoustic impedance above some concentration of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one signifies the existence of molecular interactions between different components of the mixture. The non-linear behavior of acoustic impedance for 10% DMSO in ethanol, 30% DMSO in ethanol and 50% DMSO in ethanol is shown in Fig. 2(b), Fig. 2(c) and Fig. 2(d), respectively.

Free volume is defined as the empty space between the molecules and is defined as the standard volume in which the central molecule can move inside the theoretical cell due to repulsion of surrounding molecules. Free volume, V_f was calculated using the following relation[30]:

$$V_f = \left(U \times M_{eff} / k \times \eta \right) (m^3\ mol^{-1}) \quad (5)$$

where, M_{eff} is the effective molecular weight and expressed as $M_{eff} = \Sigma m_i x_i$, m is the molecular weight and x is the mole fraction of individual component in the mixture. The constant $k = 4.28 \times 10^9$ is temperature independent constant. Table 3

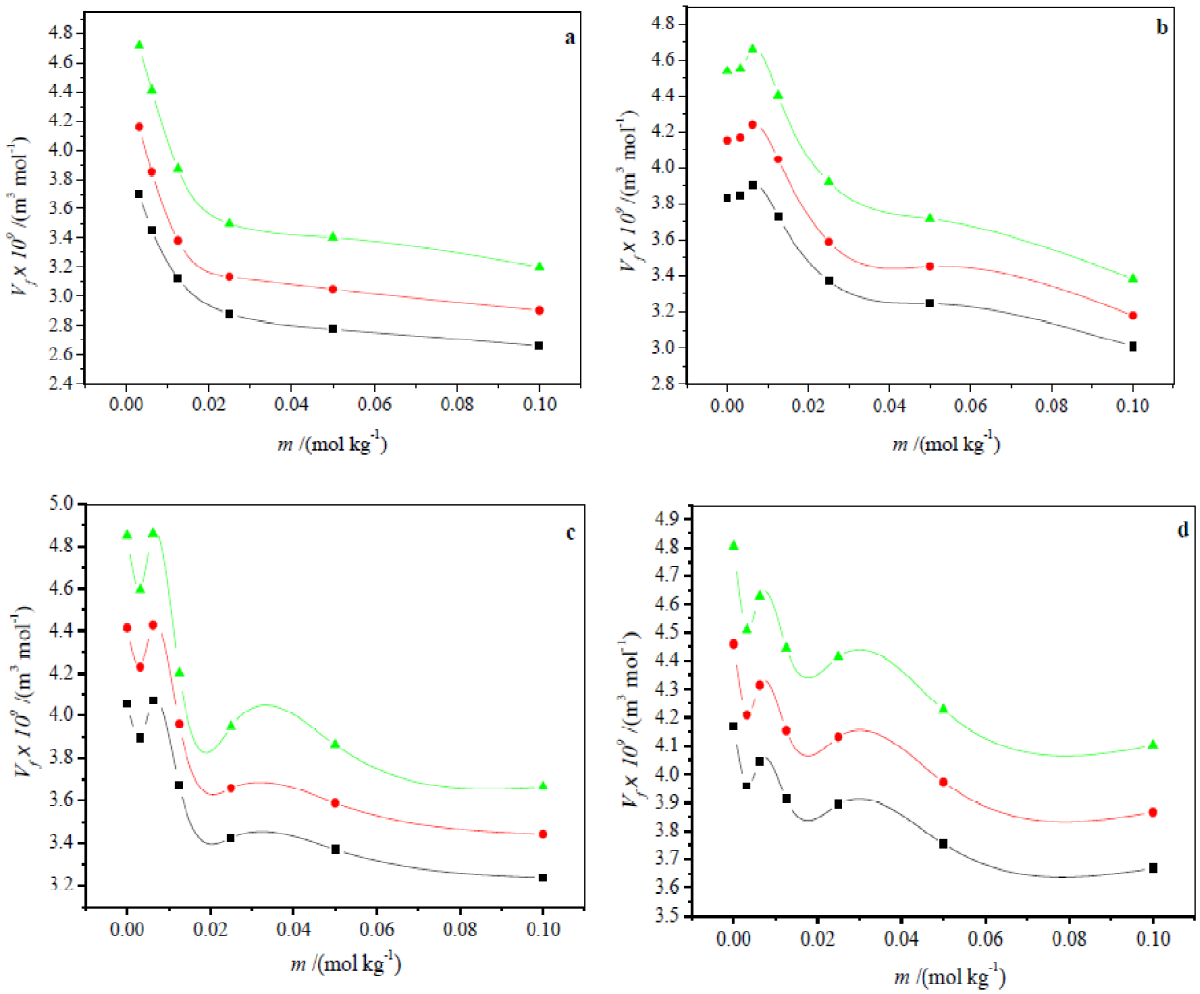

Fig. 3. Plots of free volume, V_f, versus molality, m, of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one in (a) pure ethanol; (b) 10% DMSO in ethanol; (c) 30% DMSO in ethanol and (d) 50% DMSO in ethanol at temperatures: 298.15 K, 303.15 K, 308.15 K.

illustrates the calculated values of intermolecular free length and free volume of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one in ethanol and in different percentage composition of DMSO in ethanol at different temperatures.

The perusal of Table 3 shows that the decrease in free volume with increase in concentration of solute above 0.00625 *m* concentration of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one for pure ethanol and for all percentage composition (10%, 30% and 50%) of DMSO in ethanol, results a decrease in entropy of the system and an increase in free volume with increase in temperature is due to the weakening of solute-solvent interactions. The observed trends of free volume for different concentrations of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one in different solvent composition shows the existence of strong solute-solvent interactions in the studied systems and are shown in Fig. 3.

Conclusions

The current work leads to systematic experimental measurements of density, ρ, speed of sound, *u*, and viscosity, η of different solutions of 3-(4-chlorophenyl)-1-phenylprop-2-en-1- one in ethanol and in different percentage composition of DMSO in ethanol as a function of temperature. Using these experimental measured values various acoustic parameters were obtained and the obtained results were discussed in terms of various solute-solvent interactions in studied system. The solutions observed non-linear behavior for lower concentrations but above 0.00625 *m* concentration of 3-(4-chlorophenyl)-1-phenylprop-2-en-1-one for solvent mixtures normal trend is observed. The general outcome obtained from various derived parameters is that there exists strong structure making property of added solute (3-(4-chlorophenyl)-1-phenylprop-2-en-1-one) over structure breaking property.

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