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A study on thermo-Acoustic and sound parameters of aqueous urea at different concentration and temperature.

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ABSTRACT

Present study outlines the estimation of different physical and thermodynamic parameters of aqueous urea solution over the entire range of concentrations viz. 0.02-0.2 mol-kg-1 at couple of temperature (298.15K and 303.15K) at 2 MHz frequency. The variation of the aligned parameters has been interpreted in terms of different kind of molecular interactions, physic-chemical behavior and their strength. The all parameters shows nonlinear increase or decrease with various concentration and temperature provide important information regarding molecular properties of solute and solvent interaction. In viewpoint of above facts, the ultrasonic velocity and density measurements carried out on aqueous urea. Hence the study investigates the structural sense of the liquid mixture.

Keywords: fertilizer, urea, non-linearity parameter, bulk modulus, available volume.

INTRODUCTION

Due to wide applications in the field of engineering, industry, pharmaceutical and agriculture, ultrasonic occupy the important place in the research.[1-3] The study of molecular interaction in binary and ternary liquid mixtures plays an important role in molecular science. During few previous years, ultrasonic has become a powerful tool in gathering information's about the physic-chemical properties of liquid mixture.[4-6]

The studies of various molecular interactions in the aqueous fertilizers throw light on the nature of intermolecular interactions existing in the solution. Thus in this paper we are reporting the various thermodynamic, acoustical and sound parameters of aqueous urea. As urea contain up to 46% of nitrogen. This type of fertilizer usually available to the public in white, crystalline, organic form and it can be used for all kinds of crops and soils which promotes green leafy growth.[7]

METHODOLOGY

AR grade Urea (99.8%), was obtained from Himedia Lab. Pvt. Ltd., Mumbai. Chemicals were used without further purification. The concentration of Urea in water was changed by weight.Ultrasonic velocity was measured by single crystal interferometer operating at frequency 2 MHz supplied from Vi Microsystems Pvt. Ltd., Chennai. The source of ultrasonic waves was a quartz crystal excited by a radio frequency oscillator placed at the bottom of a double jacketed metallic cylinder container. The cell was filled with the desired solution and water at constant temperature was circulated in the outer jacket. The cell was allowed to equilibrate for 30min. prior to making the measurements.

The densities of the solutions were determined accurately using 10ml specific gravity bottle and electronic balance. An average of triple measurements was taken into account. The experimental temperature was maintained constant by circulating water with the help of thermostatic water bath.

DEFINING RELATIONS

For the derivation of several acoustical and thermo-dynamical parameters the following defining relations reported in the literature are used:

1. Wada's Constant: (W)={Vm*$\beta^{-(1/7)}$} where, β= adiabatic compressibility.
2. Rao's Constant: (R) ={Vm*$U^{(1/3)}$}
3. Available Volume: (Va) ={Vm*[1-$\frac{U}{U_{\infty}}$]} where, U_{∞}=1600 m/s
4. Bulk Modulus (K) ={U2ρ}
5. Specific Heat Ratio (γ) ={$\frac{17.1}{T^{4/9} * \rho^{1/3}}$}
6. Non-Linearity Parameter (B/A)1 ={2+[$\frac{0.98*10^4}{U}$]}
7. Non-Linearity Parameter (B/A)2 ={-0.5+[$\frac{1.2*10^4}{U}$]}
8. Lenard-Jones Potential (n) ={6($\frac{V_m}{V_a}$) $- 13$}
9. Vander Waal Constant (a) ={$\frac{\rho U^2 {V_m}^2}{(\frac{B}{A}+1)}$}
10. Molar Volume (Vm) ={$\frac{M_{eff.}}{\rho}$}

Non-linearity parameter (B/A) values have been computed using the Hartmann-Balizer[8] and Ballou[9] expression.

RESULTS AND DISCUSSION

The values of ultrasonic velocity (u) and density (ρ) are taken from our previous paper[10] and with the help of these data various acoustic and thermodynamic parameters are calculated as a function of concentration and temperature for aqueous urea solution and tabulated in table1.

Rao's constant is also known as molar sound velocity while Wada's constant is known as molar compressibility. Rao's constant is known an adaptive property. Whereas Wada's constant is dependent on adiabatic compressibility and density.[11] The values of Rao's constant and Wada's constant shown in fig.1(a) and fig.1(b). From the experimental values it has been found that as concentration increases the values of both 'R' and 'W' are almost constant. But from the viewpoint of temperature it is observed that as temperature increases the values of 'R' and 'W' also increases which supports the molecular association.[12]

The available volume is used to study the intermolecular interaction present in the liquid solution.[13] It is observed that as the concentration of the solute increases, the value of 'Va' exhibit decreasing trend shown in fig.1(c). The decrease in available volume is the due to the net packing of molecules inside the shell, which may be formed by complexion between unlike molecules.[14] Further the increase in available volume (Va) with decrease in temperature means decrease in intermolecular free length.

Table 1: The values of various physical parameters as a function of concentration and temperature of System (Urea + Water).

Concentration (mol kg-1)		0.00	0.02	0.04	0.06	0.08	0.10	0.12	0.14	0.16	0.18	0.20
W*10-4	298.15K	3.915	3.912	3.912	3.913	3.913	3.914	3.915	3.916	3.915	3.917	3.918
	303.15K	3.926	3.922	3.923	3.921	3.920	3.923	3.925	3.924	3.924	3.925	3.925
R*10-4	298.15K	2.068	2.066	2.066	2.067	2.067	2.067	2.068	2.068	2.068	2.069	2.069
	303.15K	2.075	2.073	2.073	2.072	2.071	2.073	2.074	2.074	2.074	2.074	2.074
Va*10-6(m3)	298.15K	1.1511	1.140	1.136	1.13	1.125	1.119	1.109	1.099	1.093	1.087	1.08
	303.15K	1.049	1.045	1.041	1.034	1.02	1.009	1.001	0.995	0.988	0.975	0.968
K*109 (Nm-2)	298.15K	2.238	2.241	2.243	2.244	2.246	2.248	2.252	2.255	2.257	2.259	2.262
	303.15K	2.269	2.264	2.266	2.268	2.272	2.277	2.279	2.282	2.285	2.289	2.292
Γ	298.15K	0.13605	0.13604	0.13602	0.13601	0.13560	0.13599	0.13598	0.13596	0.13595	0.13594	0.13593
	303.15K	0.13511	0.13509	0.13508	0.13506	0.13504	0.13502	0.13501	0.13499	0.13497	0.13495	0.13492
(B/A)1(m-1s)	298.15K	8.542	8.538	8.536	8.534	8.532	8.530	8.526	8.522	8.520	8.517	8.515
	303.15K	8.5012	8.501	8.499	8.497	8.492	8.487	8.484	8.482	8.479	8.474	8.472
(B/A)2(m-1s)	298.15K	7.510	7.506	7.504	7.501	7.498	7.495	7.491	7.486	7.484	7.480	7.477
	303.15K	7.461	7.460	7.458	7.455	7.449	7.444	7.440	7.437	7.434	7.428	7.425
n (J mol-1)	298.15K	81.209	82.032	82.356	82.878	83.299	83.820	84.699	85.582	86.102	86.676	87.333
	303.15K	90.521	90.797	91.208	91.843	93.218	94.423	95.318	95.996	96.723	98.202	98.958
a(Nm4 mol-2)	298.15K	0.07662	0.07660	0.07668	0.07674	0.07682	0.07691	0.07709	0.07722	0.07727	0.07740	0.07754
	303.15K	0.07798	0.07788	0.07798	0.07796	0.07804	0.07833	0.07847	0.07855	0.07866	0.07883	0.07890
Vm*10-5(m3)	298.15K	1.8074	1.8056	1.8054	1.8057	1.8056	1.8057	1.8058	1.8057	1.8053	1.8058	1.806
	303.15K	1.8099	1.8078	1.808	1.8068	1.8057	1.8065	1.8071	1.8066	1.8064	1.8063	1.8057

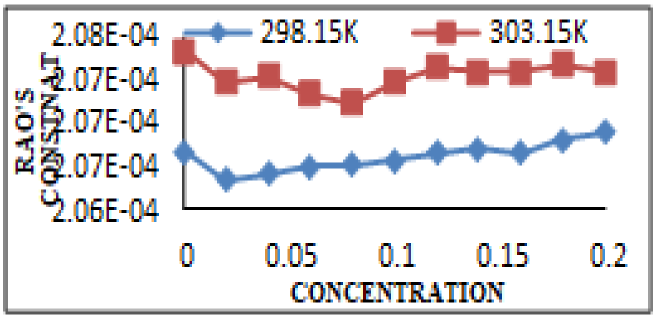

Fig. 1(a)

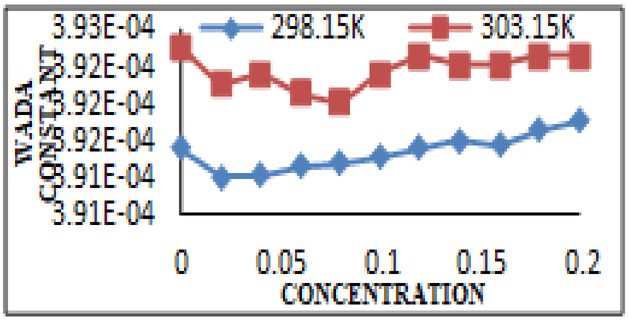

Fig. 1(b)

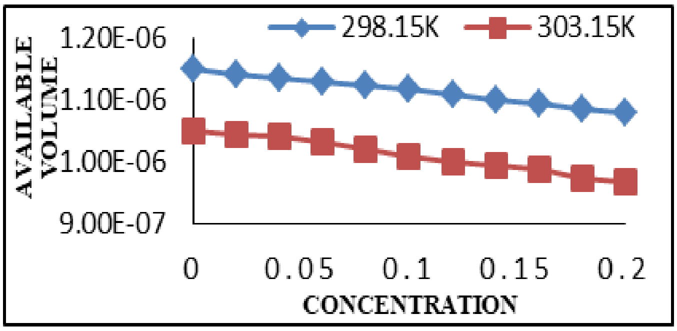

Fig. 1(c)

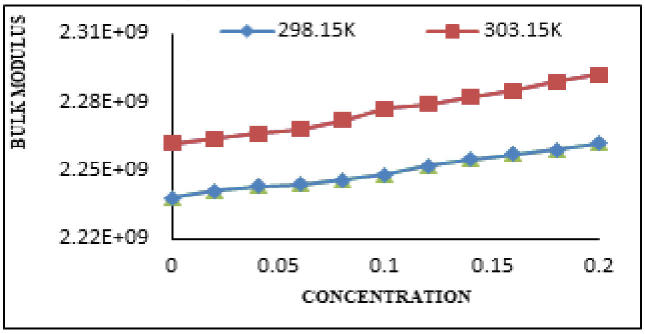

Fig. 1(d)

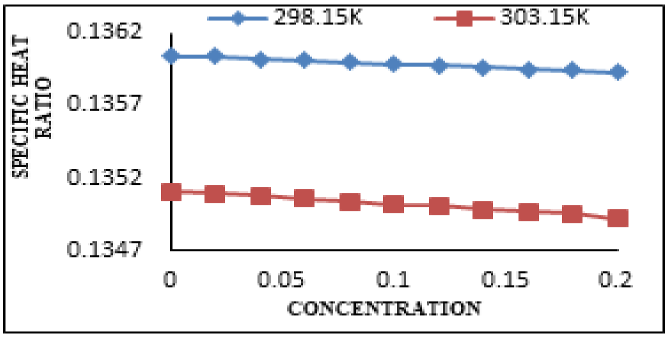

Fig. 1(e)

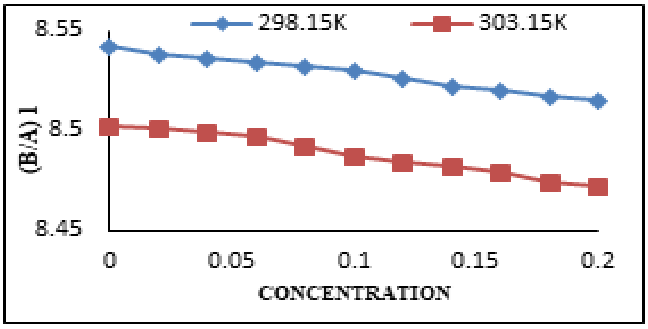

Fig. 1(f)

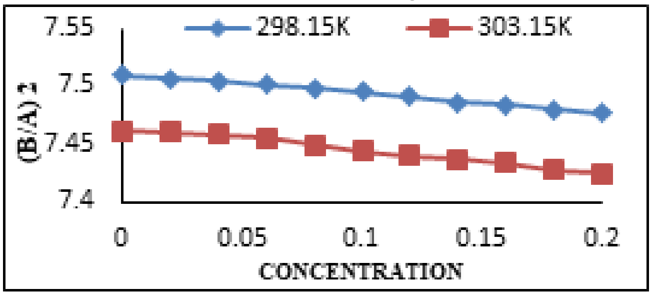

Fig. 1(g)

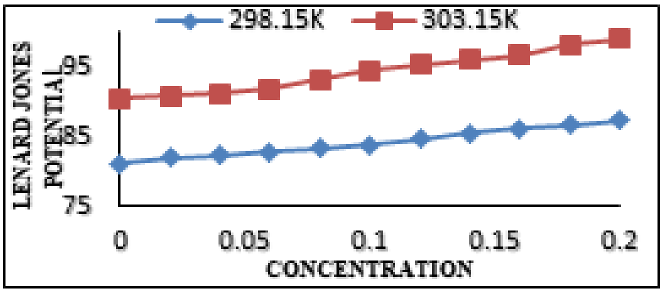

Fig. 1(h)

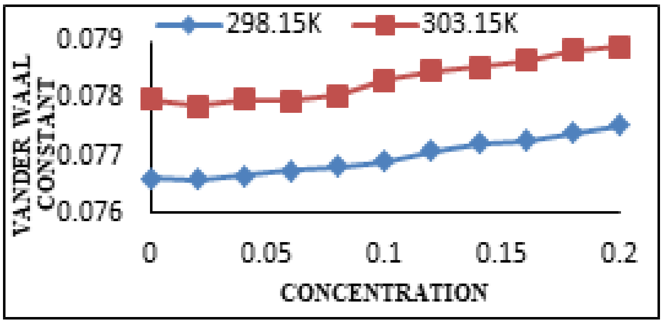

Fig. 1(i)

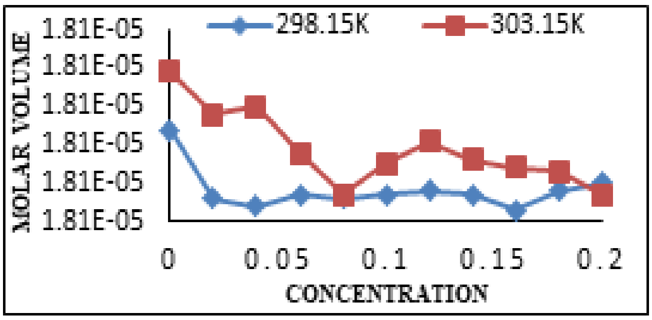

Fig. 1(j)

Bulk modulus is the reciprocal of adiabatic compressibility. The dependence of bulk modulus of aqueous urea solution with different concentrations is shown in fig. 1(d). The increase in bulk modulus values with concentration indicates that the hydrogen bonding between the unlike components in the solution increases.[15] Further bulk modulus mainly depends on the speed of sound. Hence, bulk modulus increased with raise in temperature.

Fig.1 (e) shows the variation of specific heat ratio at different concentration and temperature. The heat capacity ratio (γ) is constantly decreasing, which throw light on the fact that specific heat at constant volume is decreasing constantly with increasing both concentration as well as temperature.

Non-linear parameter (B/A) obtain by Hartmann-Balizer and Ballou is related to the internal pressure, hardness, intermolecular potential, molecular structure and molecular interaction of liquid. Fig.1 (f) and fig.1 (g) shows the non-linearity parameter for aqueous urea as a function of concentration and temperature. It is observed that the values of B/A shows decreasing trend with increasing temperature. This trend indicating that less array of molecules at low temperature hence high value of B/A and confirms the less interaction at low temperature.[16,17]

From Lenard-Jones potential (n) we can easily determine the kind of force (attractive or repulsive) acting between the components (solute-solvent) of the liquid mixture. Large value of 'n' confirms the attractive force while small value of 'n' confirms the repulsive force. From fig. 1(h) it is observed that as the concentration increases at all temperature, the value of 'n' also increases which results in molecular interaction in the urea solution. Also the value of 'n' increases with increase in temperature indicates the increase in attractive forces due to increase in molecular interaction in the aqueous urea solution. This explains the cause for increase in ultrasonic velocity with increase in temperature.

The vander-waal constant 'a' shown in fig. 1(i) represents the effective volume of a molecule. In this study the constant 'a' increases with increase in concentration of urea. This indicates the attractive force in the binary liquid mixture increases and hence we say that the distance of closest approach of molecules also increases. Also from the viewpoint of temperature the values of vander-waal constant 'a' increases with increase in temperature which supports the increase in velocity due to the change in intermolecular geometry.[18]

It is clear from the fig.1 (j) that the molar volume (Vm) fluctuate. The increase in the value of 'Vm' with increase in temperature is an indication of weak interaction between the components of molecules.[19] But it is noted that as concentration increases the value of 'Vm' decreases it means the free length between the constituent molecules of solute and solvent decreases. This supports the bonding between molecules of solute and solvent and favors of strong interaction.

CONCLUSION

Ultrasonic and volumetric measurements were carried out on aqueous urea for various concentrations (0.02-0.2 mol-kg-1) at 298.15K and 303.15K temperatures. In the light of above experimental values of ultrasonic velocity, density and their allied thermo-acoustical parameters, it may be concluded that there exist of solute-solvent interaction in the present system. The increase in the value of 'R', 'W', 'K', 'n', 'a' and 'Vm' and decrease in the value of rest parameters with rise in temperature confirms the presence of solute-solvent interaction in the system.

Conflicts of interest: The authors stated that no conflicts of interest.

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