

Measurement of acoustical parameters of organic fertilizer urea at various temperatures

S.Rathika, K.Renuka Devi*, S.Geetha, A.Gomathiyalini

Department of Physics, Government Arts College for Women (A), Pudukkottai, TamilNadu.

Abstract: Synthetic fertilizers are commonly used for growing all crops, with application rates depending on the soil fertility. Urea is an example of a synthetic organic fertilizer, an organic substance manufactured from inorganic materials. Organic fertilizers have been known to improve biodiversity, and long term productivity of soil, and may prove a large depository for excess carbon dioxide. Urea fertilizer provides nitrogen, which promotes green leafy growth. Urea has the highest nitrogen content, equal to 46% and it can be used for all types of crops and soils¹. The investigation based on the behavior of propagation of ultrasonic waves in fertilizer system are now rather well established as an effective means for examine certain physical properties of the materials. Ultrasonic velocity, density and viscosity values for the fertilizer urea are found in the concentration range of 0.3m to 2.1m at various temperatures from 308°K to 323°K. The values of acoustical and thermodynamical parameters such as adiabatic compressibility, acoustic impedance, relaxation time, molal hydration number, free length, apparent molal volume, and apparent molal compressibility are determined. Their variation with concentration is useful in understanding the nature of molecular interaction in terms of physical parameters. These results were confirmed by soil test. A soil test gives the information about the availability and lack of nutrients in the soil. The quantity of available nutrients in the sample determines the amount of fertilizers that is recommended for a particular crop. This is also confirmed by the values of absorption coefficient of aqueous urea solution at higher concentration.

Key Words: Ultrasonic velocity, absorption coefficient, relaxation time, hydration number, soil test.

I. Introduction:

In the recent years, ultrasonic studies are extensively used for characterizing the thermodynamic properties and to predict the solute-solvent and ion solvent interactions in aqueous solutions. The velocity of sound in solution is used to give information about bonding between the molecules and formation of complexes at different temperatures through various interactions². Literature survey shows that many researchers have studied the molecular interactions of nitrogenous fertilizers in aqueous or mixed solvent systems by ultrasonic velocity and viscosity studies³⁻⁴. The ultrasonic velocity and density of urea fertilizer at different temperatures have been reported in the present paper. From these experimental data, the number of acoustical and thermodynamic parameters like specific acoustic impedance (z), intermolecular free length (L_f), relaxation time (τ) hydration number (n_h), apparent molal compressibility (ϕ_k), apparent molal volume (ϕ_v), have been calculated. The values of the parameters have been used to interpret various molecular interactions occurring in the solutions at different temperatures and concentrations of urea.

II. Experimental Details:

In the present investigation, urea of molecular weight of 60.06 gm/mole was taken. The solutions were prepared by dissolving known amount of substance in double distilled water so as to make 0.3m to 2.1m concentration. Ultrasonic velocity was measured using ultrasonic interferometer of fixed frequency 2 MHz (Model F-81, Mittal enterprises, New Delhi). The density was measured using specific gravity bottle and viscosity by Ostwald's viscometer. The temperature was kept constant using constant temperature water bath with an accuracy of $\pm 0.1^\circ\text{C}$. The measurements are taken from 308°K to 323° K.

The various physical parameters were calculated using the following standard formulae,

- | | |
|---------------------------------------|--|
| (i) Adiabatic compressibility | $\beta = 1/(U^2 * \rho) \text{ Kg}^{-1}\text{ms}^2$ |
| (ii) Inter molecular free length | $L_f = K*(\beta)^{1/2} \text{ m}$ |
| (iii) Acoustic impedance | $Z = (U * \rho) \text{ Kg m}^{-2}\text{s}^{-1}$ |
| (iv) Relaxation time | $\tau = (4/3)* \beta * \eta \text{ sec}$ |
| (v) Hydration number | $n_h = (n_s/n_i) * (1 - \beta / \beta_0)$ |
| (vii) Apparent molal volume | $\phi_v = (1000 * (\rho_0 - \rho) / m \rho_0) + (M / \rho_0) \text{ ml mol}^{-1}$ |
| (viii) Apparent molal compressibility | $\phi_k = (1000 * (\rho_0 \beta - \rho \beta_0) / m \rho_0) + (M \beta_0 / \rho_0) \text{ ml mol}^{-1} \text{ cm}^2 \text{ dyne}^{-1}$ |
| (ix) Absorption coefficient | $\alpha / f^2 = (8\pi^2 \eta) / (3 \rho U^3) \text{ s}^2 \text{ m}^{-1}$ |

Where, T- absolute temperature, η – viscosity, U – ultrasonic velocity,
M - molecular weight of the solute, ρ and ρ_0 - density of solution and solvent,

n_s and n_i – number of moles of a solvent and solute in the solution.
 β and β_0 – are the adiabatic compressibility of solution and solvent.

III. Results and discussions

Acoustical parameters such as adiabatic compressibility, intermolecular free length, relaxation time, acoustic impedance and hydration number were calculated for various concentrations of aqueous urea solution and tabulated in table 1. The ultrasonic velocity of aqueous solution of urea increases with increase in concentration as well as with temperature is shown in figure (1). The increasing value of density and viscosity shows that there is strong attraction between solute and solvent molecules. The decrease in values of density and viscosity with increase in temperature shows decrease in intermolecular forces due to increasing thermal energy of the system⁵.

Adiabatic compressibility decreases generally with increase in concentration and temperature, because this depends on electron donor and acceptor capacity. Water is polar solvent when urea is added, the association of solute and solvent molecules occurs resulting in close packing of molecules. The decreased values of adiabatic compressibility indicate strong intermolecular association between urea and water molecules. The compressibility of a solvent is higher than that of a solution and decreases with increase in concentration of the solution is observed from figure (2).

Free length is the average distance between the surfaces of two neighbouring molecules, which is called intermolecular free length⁶. Free length decreases with increase in concentration but increase in the rise of temperature indicating dissociation of intermolecular forces due to increase in the thermal energy of the system which causes increase in volume expansion. The decrease in free length with increase in concentration is shown in figure (3). It indicates that there is significant interaction between solute and solvent molecules.

From the figure (4) it is evident that acoustic impedance values increase with increase in concentration of urea at all temperatures. This is found to be agreement with the theoretical requirements as the values of velocity and density both increase with increase of concentration of solute. The increase in impedance values also supports to the effective solute-solvent interactions.

The interaction between the solute and the solvent molecules is referred to as hydration. The positive values of hydration number increase as appreciable solvation of solutes. This also suggests that compressibility of the solutions will be less than that of the solvent. As a result, the solutes will gain mobility and have more probability of contacting the solvent molecules. The decreasing values of hydration number which indicate the increase in solute-solvent molecules and vice versa is noted at 308° K and is shown in fig (5). But at other temperatures the hydration number raises to a maximum at 0.6 mole and there after decreases with concentration. Such a decrease in hydration number values with increase of molality of the solute concentration leading to the reduction in the electrostriction⁷. The decreasing values of hydration number with the temperature indicates structure breaking tendency due to higher thermal energy over interaction energy. The same behaviour is also found in this case of apparent molal volume.

The apparent molal volume is positive at all concentrations and temperature is shown in fig (7). This behaviour supports that there is strong ion-ion interaction occurring in urea solution⁸. Apparent molal compressibility values are negative at all concentrations is shown in fig (8). It indicates the ionic interaction occurring in the solution. The same supported by decreasing in adiabatic compressibility with concentrations and temperatures.

The variation of relaxation time with concentration is shown in fig. (6). The absorption coefficient shows a similar trend to the relaxation time is shown in fig (9). This is due to a modification in the nature of the molecular interaction.

In soil test report, the value of nitrogen presented in the native soil is 84.0 Kilo/Acre. The value shows low phosphorous content in the soil at 0.6 mole of urea solution, the nitrogen and potassium content is increased as 140 and 460 k/Acre. It has been seen from table 2, that at higher concentrations of urea the macro nutrient (Phosphorous) and micronutrient (Magnesium) are found to be decreased. Phosphorous plays a prominent role in photosynthesis, early bud and seed formation. Magnesium aids chlorophyll formation, phosphorus metabolism and helps to regulate uptake of other nutrients, so higher concentration of urea supplement to the soil must be avoided..

IV. Conclusion

From the present study it is observed that urea behaves as a structure breaker for the clusters in water. The molecular structure of urea is such that it cannot fit into a group of intermolecularly hydrogen bonded water molecule. Being debarred from this state, it enters the dense water and dilutes this latter state. From the soil test report, it is found that the level of macronutrients decreases at higher concentration of urea. So the higher concentrations of urea supplement to the soil must be avoided. This also confirmed by the absorption coefficient values of aqueous urea solution at higher concentration.

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Table 1: Values of velocity, adiabatic compressibility, free length, acoustic impedance, absorption coefficient, hydration number, apparent molal volume, apparent molal compressibility, relaxation time of urea solution at different temperatures

Con (m)	U (m/s)	β (10^{-10} Kg ⁻¹ ms ⁻²)	L _f (10^{-10} m)	z (Kg m ⁻² s ⁻¹)	α/f^2 (s ² m ⁻¹)	η_h	ϕ_v (ml mol ⁻¹)	$\phi_c(10^{-8}$ mlmol ⁻¹ cm ² dyne ⁻¹)	τ (10^{-12} s)
308°K									
0.3	1524	4.3017	0.4148	1.5253	5.4599	4.1458	37.4950	-4.2927	4.2198
0.6	1533	4.2105	0.4103	1.5492	5.4341	3.9887	32.7092	-4.3788	4.2235
0.9	1548	4.1166	0.4057	1.5692	5.2273	3.9757	38.4453	-4.1161	4.1036
1.2	1549	4.1074	0.4053	1.5717	4.9975	3.0783	43.1431	-3.1979	3.9247
1.5	1553	4.0673	0.4033	1.5831	4.9302	2.7998	43.4266	-2.9646	3.8819
1.8	1566	3.9752	0.3987	1.6063	4.9797	2.9770	42.6449	-3.1392	3.9527
2.1	1568	3.9583	0.3979	1.6111	5.0019	2.6544	44.3922	-2.8069	3.9774
313°K									
0.3	1525	4.3149	0.4216	1.5197	4.6540	1.7293	46.1313	-2.0076	3.5983
0.6	1544	4.1731	0.4146	1.5519	4.5978	3.8209	38.8056	-3.9978	3.6000
0.9	1549	4.1286	0.4124	1.5636	4.5915	3.1666	41.2353	-3.3689	3.6058
1.2	1552	4.0970	0.4108	1.5726	4.2206	2.7044	42.8212	-2.9303	3.3218
1.5	1554	4.0743	0.4097	1.5794	4.7502	2.3529	44.3294	-2.5837	3.7434
1.8	1568	3.9810	0.4050	1.6019	4.7268	2.6092	44.0489	-2.8007	3.7586
2.1	1570	3.9682	0.4043	1.6051	4.1647	2.3129	46.0717	-2.4757	3.3141
318°K									
0.3	1532	4.2893	0.4235	1.5217	4.2236	1.0327	50.3273	-1.2600	3.2813
0.6	1548	4.1589	0.4170	1.5532	4.1571	3.2633	38.5138	-3.5347	3.2634
0.9	1552	4.1266	0.4154	1.5614	4.1435	2.6297	42.9109	-2.8438	3.2611
1.2	1556	4.0891	0.4135	1.5716	4.2454	2.3664	43.9830	-2.5892	3.3499
1.5	1560	4.0629	0.4122	1.5777	4.1812	2.1144	46.4251	-2.2844	3.3077
1.8	1569	3.9879	0.4083	1.5981	4.2239	2.2884	44.7403	-2.4947	3.3599
2.1	1572	3.9708	0.4075	1.6019	4.2204	2.0640	46.7877	-2.2288	3.3645
323°K									
0.3	1534	4.2803	0.4261	1.5230	4.1612	1.1067	43.0839	-1.5467	3.2354
0.6	1552	4.1588	0.4201	1.5492	3.9978	3.1148	34.9244	-3.1651	3.1465
0.9	1553	4.1458	0.4194	1.5531	3.7780	2.2605	40.5541	-2.3422	2.9746
1.2	1560	4.0862	0.4164	1.5687	4.0650	2.3235	49.8320	-2.4448	3.2158
1.5	1564	4.0507	0.4146	1.5784	3.8231	2.1587	45.0566	-2.2946	3.0322
1.8	1572	3.9922	0.4116	1.5934	4.0053	2.2102	43.5975	-2.3386	3.1929
2.1	1577	3.9555	0.4097	1.6031	4.1563	2.1158	45.8403	-2.2375	3.3230

Table 2: Soil test report for native and fertilized soil

S. No	Nature of the soil	Macronutrients			Micronutrients			
		N	P	K	Fe	Mn	Zn	Cu
1.	Native soil	84	2.0	400	9.248	8.318	0.590	0.866
2.	Urea (0.6)m	133	2.25	435	10.38	7.538	0.708	0.970
3.	Urea (2.1)m	140	1.25	460	10.64	6.922	0.624	1.038

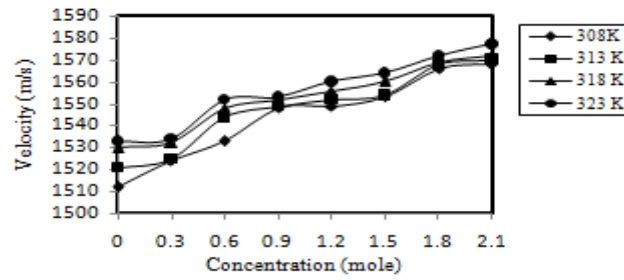


Fig 1. Velocity Vs Concentration

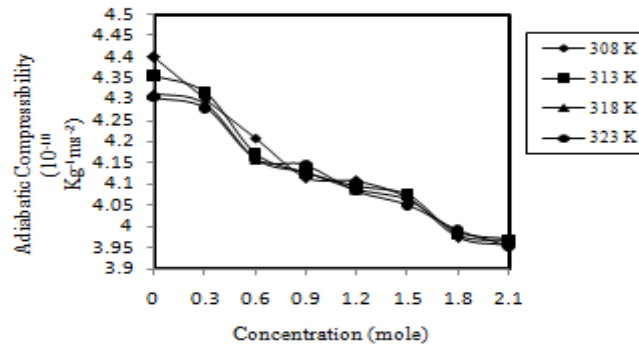


Fig 2. Adiabatic compressibility Vs Concentration

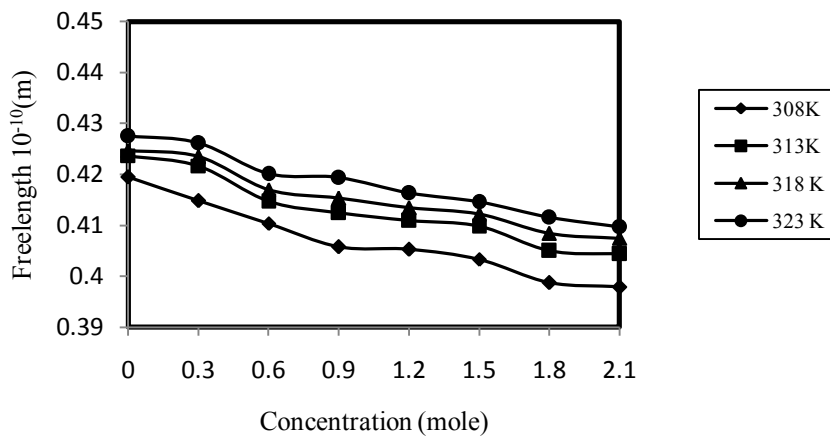


Fig 3. Free length Vs Concentration

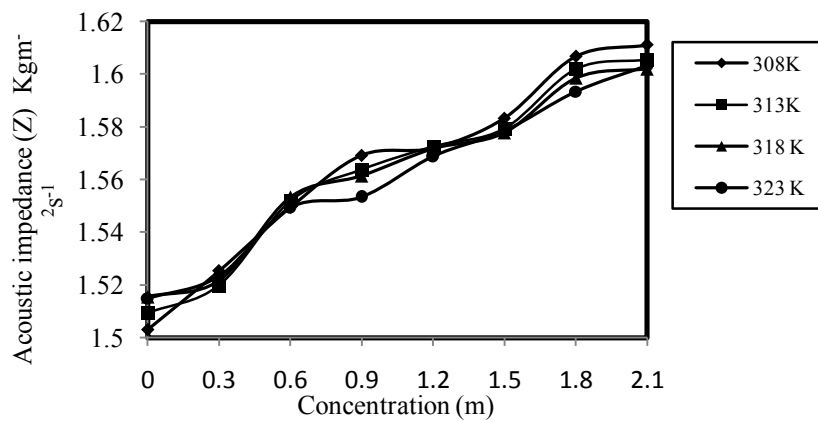


Fig 4. Acoustic impedance Vs Concentration

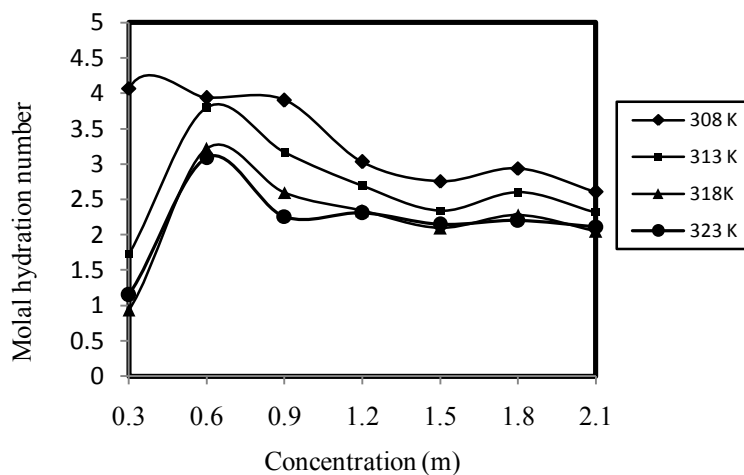


Fig 5. Molal Hydration number Vs Concentration

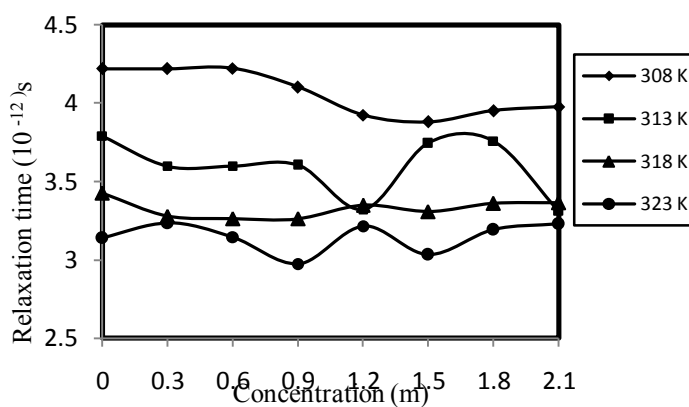


Fig 6. Relaxation time Vs Concentration

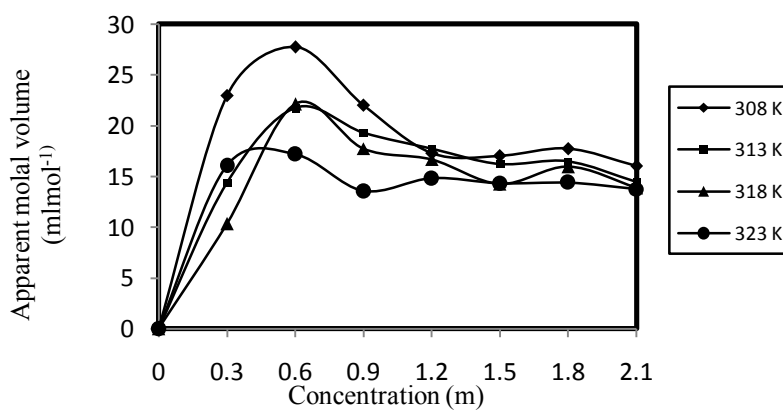


Fig .7 Apparent molal volume Vs Concentration

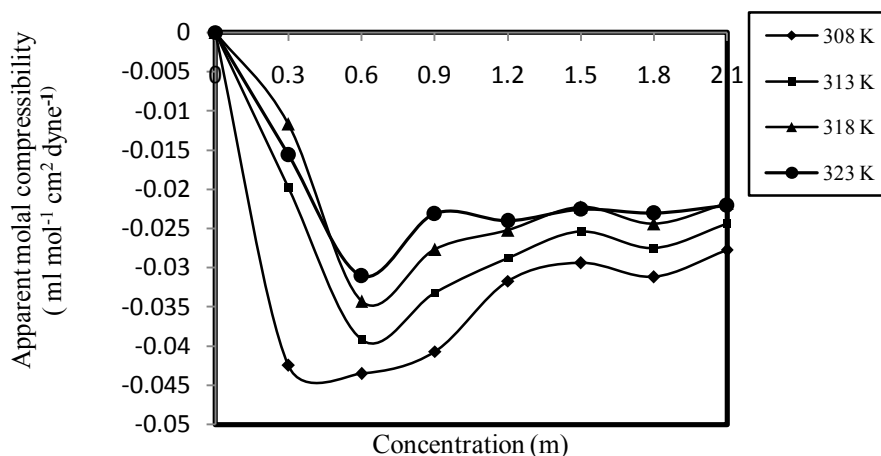


Fig. 8 Apparent molal compressibility Vs Concentration

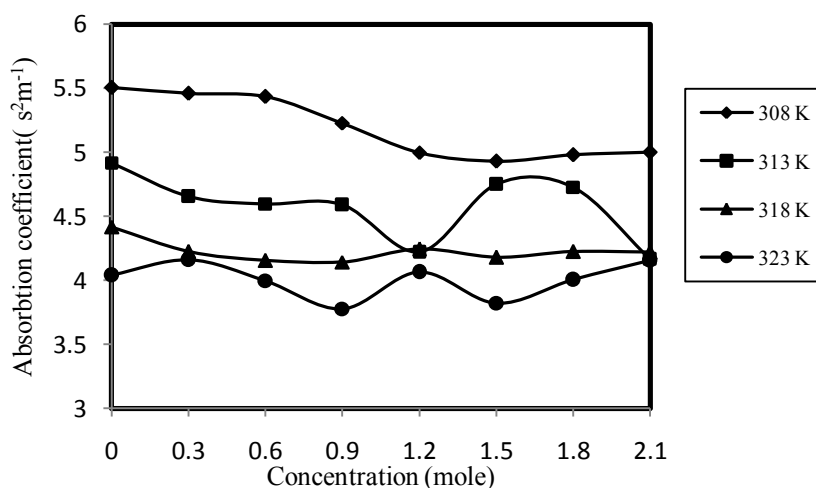


Fig. 9 Absorption coefficient Vs Concentration

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