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Study of Acoustical Parameters of Diammonium Phosphate Fertilizer Solution at Different Temperatures

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Abstract: ***DAP fertilizer is an excellent source of phosphorus (P) and nitrogen (N) for plant nutrition. It is highly soluble and thus dissolves quickly in soil to release plant-available phosphate and ammonia. In the present study, an attempt is made to investigate the amount of molecular interaction in aqueous DAP solution. Ultrasonic velocity (U), density (ρ), and viscosity (η) of Diammonium phosphate at different temperatures (308° K to 323° K) have been measured. Using these experimental values, the acoustical parameters such as acoustic impedance (Z), free length (L_f), surface tension (γ), relaxation time (τ), Rao's constant (R), Wada's constant (W), and vander Waal's constant (b) are calculated. The concentration range selected for DAP is from 0.1m to 0.6m. The results are interpreted on the basis of solute-solvent interactions.***

Keywords: Acoustic impedance, free length, surface tension, relaxation time, Rao's constant, Wada's constant, and vander Waal's constant.

1. Introduction

The study of behaviour of propagation of ultrasonic waves in liquid system is now well established as an effective means for examining certain physical properties of the materials[1]. The ultrasonic studies provide information about the state of solute in solvent media. Ultrasonic parameters are used extensively to study molecular interactions in aqueous and non-aqueous media. It has been found that the acoustical properties of solution should be an important parameter in the study of several chemical reactions and in the investigation of molecular interactions.

The measurement of ultrasonic velocity in pure liquids and mixtures is an important tool to study the physico-chemical properties and to explain the strength and nature of molecular interactions. Fertilizer is any material of natural or synthetic origin that is applied to soils or to plant tissues (usually leaves) to supply one or more plant nutrients essential for the growth of plants. Conservative estimates report 30 to 50 % of crop yields are attributed to natural or synthetic commercial fertilizer. DAP is rich in phosphorus content which plays an important role in storage and transfer of energy within the plants [2]. These considerations led us to undertake the study of DAP fertilizer in water media.

2. Experimental Study

Aqueous solutions of Diammonium phosphate of different concentrations were prepared with Analar grade salt and double distilled water. The ultrasonic velocities of the solutions were measured using an ultrasonic interferometer (Mittal F-81D) with a single crystal at a frequency of 2 MHz. The accuracy in the velocity measurement is $\pm$0.5%. The densities of the solutions were measured using specific gravity bottles and a digital balance with an accuracy of 0.0001 kg/m^3. Viscometric studies were carried out by Ostwald's viscometer. Throughout the experiment, the temperature was maintained using a constant temperature bath within $\pm$ 0.1°C accuracy.

3. Computational Method

Various acoustical parameters such as acoustic impedance (Z), free length (L_f), surface tension (γ), relaxation time (τ), Rao's constant (R), Wada's constant (W), and vander Waal's constant (b) have been calculated using the experimental data of velocity (U), density (ρ) and viscosity (η) by the following relations:

Acoustic impedance $Z = (U)^* \rho$ Kgm^{-2}s^{-1}
Intermolecular free Length $L_f = K^*(\beta)^{(1/2)}$ (m)
Surface tension $\gamma = (U)^{3/2} * (6.3\text{x}10^{-4}) * \rho$ (Nm^{-1})
Relaxation time $\tau = (4/3) * \beta * \eta$ (s)
Rao's constant, $R = (M_{eff}/\rho) * (U)^{(1/3)}$
Wada's constant, $B = (M_{eff}/\rho) * (\beta)^{(-1/7)}$
vander Waal's constant, $b = (M_{eff}/\rho) * [1-(RT/ M_{eff}U^2) * \{[1+(M_{eff}U^2/3RT)]^{(1/2)}-1\}]$

Where, U = Ultrasonic velocity (m/s), ρ = density (Kg/m^3), η= viscosity (Nsm^{-2}), M_{eff} = effective molecular weight, R = gas constant (8.314*10^7), T = temperature (Kelvin), K = temperature dependant constant, β = adiabatic compressibility of solution (Kg $^{-1}$ ms ^{2}).

4. Results and Discussion

The decrease in free length with increase in concentration (fig 1) indicates that there is significant interaction between solute and solvent molecules, suggesting a structure promoting behaviour on addition of DAP. The increase in temperature makes the free length to increase (Table1) as expected due to the thermal expansion of solutions [3].

The acoustic impedance is the parameter which depends on the concentration and temperature of the solution [4]. The increase of acoustic impedance (fig 2) is an indication of strong interaction between NH_4^+ of DAP and hydroxyl group of water molecules. The inference is confirmed by the decrease of intermolecular free length.

The surface tension of a liquid is defined as the energy required for breaking through the surface. The stronger the bonds between the molecules in the liquid, the greater will be the surface tension. Surface tension affects a number of handling and performance characteristics of a liquid like capillary action, wetting of surfaces which are desirable in agriculture. Surface tension also allows plants to move water and dissolved nutrients from their roots to their leaves [5]. Linear increase in surface tension with concentration (fig 3) at all temperature indicates that there are strong attractive forces between DAP and water.

Relaxation time is the time taken for the excitation energy to appear as translational energy and it depends on temperature and impurities [6]. The relaxation time decreases with increase in temperature (fig 4) shows the instantaneous conversion of excitation energy to translational energy, when temperature is increased [7]. It is observed that relaxation time decreases almost with increasing concentration (Table 1) and these behaviours are obvious as per kinetic theory of fluids. The variation of relaxation time is a cumulative effect of the density, viscosity and ultrasonic velocity.

Rao's constant (R) also known as molar sound velocity and Wada's constant (W) also known as molar adiabatic compressibility are the measures of interactions existing in the solution. R and W are in increasing trend with concentration (fig 5, 6). This indicates the availability of more number of components in a given region and hence leads to a close packing of the medium, thereby increases the interaction between the components [8]. R and W show a general increase with temperature and this variation confirms the change in molecular interaction. Vander Waal's constant also shows a similar trend (fig 7) as that of R and W which indicates strong solute-solvent interaction. Variations of R and W with concentration show that they are not constants, so that interaction in the solution is expected to be associative.

5. Conclusion

A systematic study of DAP in water has been carried out at different concentrations and at different temperatures. The acoustical parameters confirm the presence of strong solute–solvent interactions between the components molecule in the mixture studied at different temperatures. But, these interactions decrease with increase in temperature as indicated by the values of L_f. Hence it is evident that the ultrasonic velocity measurement in the given medium serves as a powerful probe in characterising the physico-chemical properties of that medium. Due to strong interaction, it is evident that DAP is completely dissolved in water and it can be easily penetrate into soil which can be inferred from the surface tension values. Hence the plants can absorb the nutrients, and the growth and yield will be enhanced by the applied DAP fertilizer.

Table 1: Acoustical parameters of DAP at various concentrations (0.1m – 0.6m) and various temperatures (308° K to 323° K)

Temp K	Conc M	L_f (10^{-11} m)	Z (10^6 $Kgm^{-2}s^{-1}$)	γ (10^4N/m)	τ (10^{-13} s)	Rao's constant	Wada's constant	vander Waal's constant
308° K	0	4.2269	1.5030	3.681	4.22	965.523	393.451	16.416
	0.1	4.1886	1.5245	3.742	4.24	968.016	394.970	16.447
	0.2	4.1157	1.5544	3.845	4.17	980.527	399.990	16.595
	0.3	4.0398	1.5907	3.963	3.81	987.410	403.04	16.654
	0.4	4.0215	1.6032	3.996	4.26	992.284	405.382	16.736
	0.5	3.9876	1.6232	4.055	4.02	996.613	407.528	16.794
	0.6	3.9562	1.6419	4.111	3.99	1001.78	409.965	16.867
313° K	0	4.2364	1.5093	3.708	3.79	969.252	394.753	16.453
	0.1	4.1877	1.5326	3.780	3.74	975.758	397.676	16.534
	0.2	4.0857	1.5800	3.934	3.62	981.704	400.401	16.556
	0.3	4.0688	1.5903	3.963	3.89	988.660	403.477	16.671
	0.4	4.0482	1.6037	4.000	3.49	993.656	405.862	16.753
	0.5	4.0184	1.6209	4.052	3.60	938.808	383.748	15.816
	0.6	3.9787	1.6434	4.120	3.64	1004.20	410.814	16.896
318° K	0	4.2464	1.5154	3.735	4.53	973.154	396.115	16.492
	0.1	4.1928	1.5407	3.814	3.23	979.753	399.071	16.570
	0.2	4.1145	1.5770	3.932	3.28	986.887	402.213	16.632
	0.3	4.097	1.5889	3.963	3.36	991.909	404.613	16.718
	0.4	4.073	1.6034	4.005	3.36	997.179	407.095	16.801
	0.5	4.0464	1.6207	4.053	3.45	1000.736	408.973	16.855
	0.6	3.998	1.6455	4.133	3.59	1008.017	412.15	16.942
323° K	0	4.2744	1.5149	3.737	3.14	975.896	397.071	16.530
	0.1	4.2296	1.5350	3.801	2.95	984.519	400.735	16.647
	0.2	4.1375	1.5742	3.935	2.91	995.547	405.236	16.754
	0.3	4.1076	1.5945	3.989	2.91	996.212	406.117	16.763
	0.4	4.0853	1.6079	4.028	2.95	1002.265	408.874	16.860
	0.5	4.0589	1.6234	4.074	3.02	1007.987	411.511	16.946
	0.6	4.0284	1.6425	4.128	3.07	1011.524	413.378	16.996

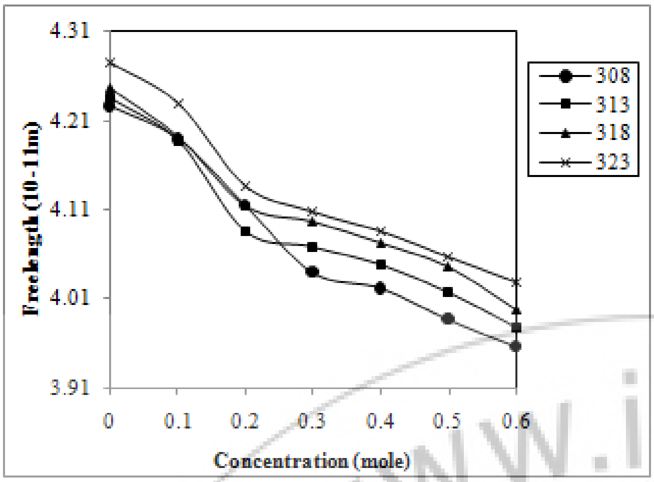

Figure 1: Variation of free length with Concentration

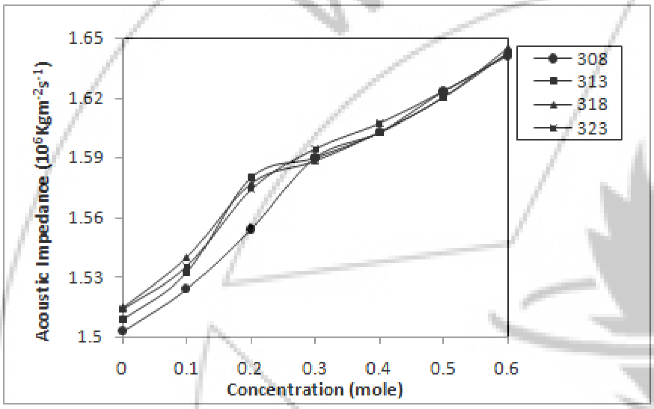

Figure 2: Variation of acoustic impedance with Concentration

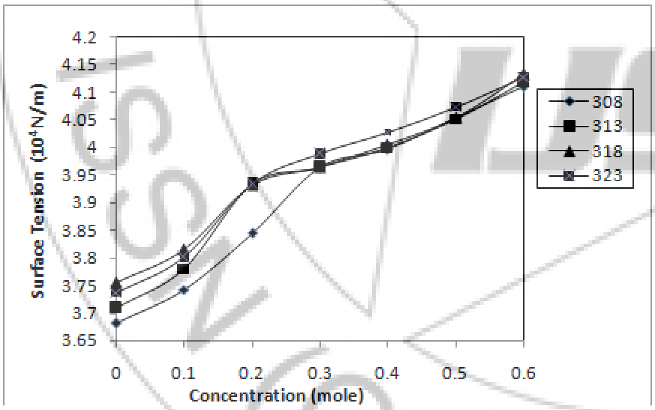

Figure 3: Variation of surface tension with Concentration

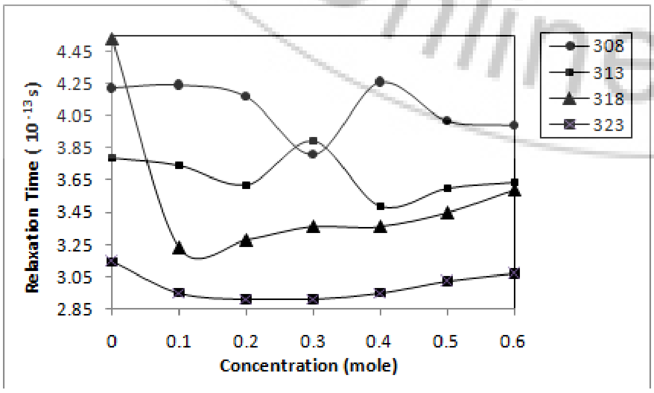

Figure 4: Variation of relaxation time with Concentration

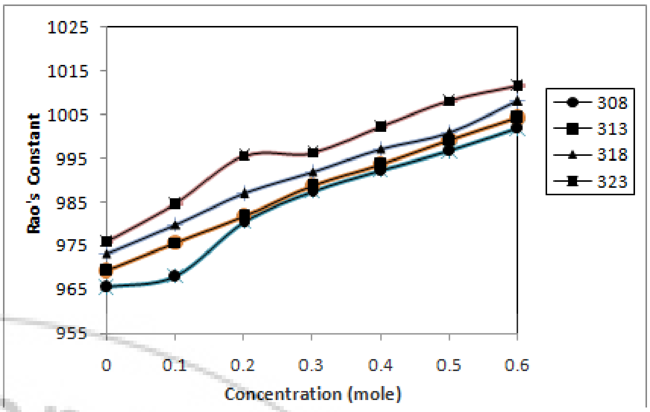

Figure 5: Variation of Rao's constant with Concentration

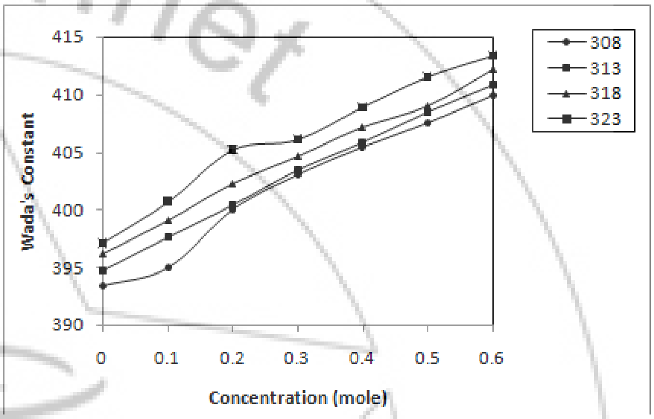

Figure 6: Variation of Wada's constant with Concentration

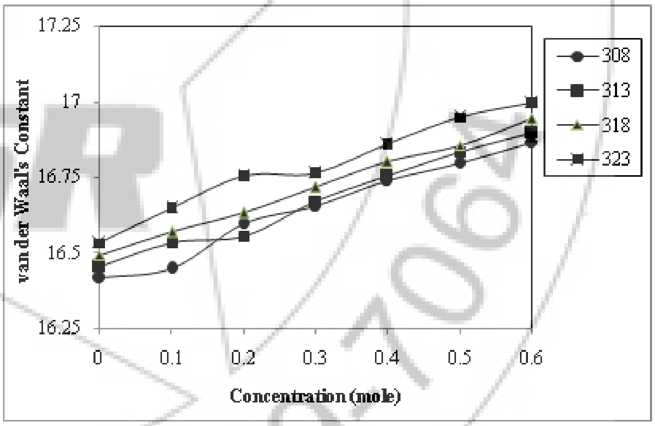

Figure 7: Variation of vander Waal's constant with Concentration

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