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Acoustical Properties of Oxalic Acid-Tartaric Acid-Water Solutions

G. S. UPADHYAY*, (LATE) R. SINGH, J. PRASAD and H. SINGH

Department of Chemistry
Magadh University, Bodh-Gaya–824 234, India

The paper reports the acoustical properties of multi component solutions (oxalic acid-tartaric acid-citric acid-water) at 40°C. The ultrasonic velocities of solutions have been measured and the values of ultrasonic velocity have been utilized to calculate other acoustical parameters such as the adiabatic compressibility, acoustic impedance, apparent molar compressibility, molar sound velocity and molar sound compressibility. The ultrasonic velocities of solutions increase with the increase in the concentration of its any individual component.

INTRODUCTION

Knowledge of acoustical properties of any solution provides information about the interactions occurring in the solution. References on acoustical properties show that most of the works are concerned with the solutions having one or two components. However in chemical industries and physiological processes of body fluids, solutions with more than two components are seen. With this view we have selected: oxalic acid-tartaric acid-citric acid-water solutions for our study.

EXPERIMENTAL

Oxalic acid, citric acid, tartaric acid, KCl, KBr, KI and glucose (all BDH) were used without further purification and their solutions were prepared in conductivity water having sp. conductance 0.21×10^{-5} mhos cm^{-1} at 35°C. Densities were measured at constant temperature with the help of a double capillary pyknometer (25 ml capacity). Ultrasonic velocity of the solution was measured with the help of a single crystal ultrasonic interferometer working at a fixed frequency of 2 MHz. Water from a thermostat fixed at the desired temperature was passed through the ultrasonic cell.

RESULTS AND DISCUSSION

Part 1

(A) Following three systems:

System I O.A. (Ci)—Tt.A (0.1 M)—C.A. (0.1 M)—H_2O
System II O.A. (0.1 M)—Tt.A (Ci)—C.A. (0.1 M)—H_2O
System III O.A. (0.1 M)—Tt.A (0.1 M)—C.A. (Ci)—H_2O

were prepared. The concentration of the component whose concentration is changed has been represented by Ci. The value of Ci varies from 0.1 M to 0.2 M. Ultrasonic velocity of each solution was measured at 40°C and the values obtained have been recorded in Table 1.

TABLE 1

ULTRASONIC VELOCITIES OF SOLUTIONS OF SYSTEM I SYSTEM II AND SYSTEM III

Ci (mol. lit^{-1})	Ultrasonic velocities (V) at 40°C in cm sec^{-1}		
	System I	System II	System III
0.10	1.5078×10^5	1.5078×10^5	1.5078×10^5
0.12	1.5164×10^5	1.518×10^5	1.5200×10^5
0.14	1.5180×10^5	1.5229×10^5	1.5269×10^5
0.18	1.520×10^5	1.5380×10^5	1.5457×10^5
0.20	1.534×10^5	1.547×10^5	1.550×10^5

These values of ultrasonic velocity have been utilized to evaluate acoustical parameters such as specific acoustic impedance (Z), adiabatic compressibility (β), inter-molecular free length (L_f), apparent molal compressibility (ϕ_k), molar sound velocity (R) and molar compressibility (W) for each system at different concentrations using following equations:

$$Z = \rho v \tag{1}$$

$$\beta = \frac{1}{v^2 \rho} \tag{2}$$

$$\phi_k = \frac{1000(\beta\rho_0 - \beta_0\rho)}{\rho \cdot \rho_0} + \frac{\overline{M}}{\rho} \tag{3}$$

$$L_f = K\sqrt{\beta} \tag{4}$$

$$R = \left(\frac{M}{\rho}\right) v^{1/3} \tag{5}$$

$$W = \left(\frac{M}{\rho}\right) \beta^{-1/7} \tag{6}$$

where ρ_0 and β_0 are the density and the adiabatic compressibility of the solvent. ρ is the density of the solution and K is the temperature dependent Jacobson's constant. $\overline{M}$ and M are average molecular weight of the solutes and solution respectively $\overline{M}$ and M are calculated by the equation:

$$\overline{M} = \sum_{j=1}^{j=n} X_j M_j \tag{7}$$

$$M = \sum_{j=0}^{j=n} X_j M_j \tag{8}$$

where n is the no. of solutes present in the solution and X_j is the molal weighing factor $\left(= \frac{m_j}{m_T}\right)$ where m_j = molarity of the jth component and m_T is the total molarity given as $m_T = \Sigma\, m_j \cdot M_j$ is the molecular weight of the jth component and M_0 is the molecular weight of the solvent.

Acoustical parameters calculated from these equations have been recorded in Table 2.

TABLE 2

ACOUSTICAL PARAMETERS OF SOLUTIONS OF SYSTEM I, SYSTEM II AND SYSTEM III

Systems	Ci mol lit^{-1}	ρ	$\beta \times 10^{11}$ cm^2 dyne^{-1}	L_f	$Z \times 10^{-5}$ gm cm^{-2} sec^{-1}	$\phi_K \times 10^9$	R c.g.s. unit	W c.g.s. unit
System I	0.10	1.0134	4.3400	0.42290	1.5280	3.368	981.811	557.780
	0.12	1.0135	4.2900	0.42040	1.5369	2.662	985.255	559.535
	0.14	1.0136	4.2810	0.42000	1.5386	2.430	986.900	560.413
	0.18	1.0139	4.2689	0.41946	1.5412	2.069	989.985	562.137
	0.20	1.0140	4.1559	0.41559	1.5560	1.096	994.288	564.352
System II	0.1	1.0134	4.340	0.4229	1.5280	3.368	981.811	557.780
	0.12	1.0137	4.281	0.4200	1.5387	2.710	986.579	560.228
	0.14	1.0141	4.251	0.4185	1.5443	2.366	989.924	562.083
	0.18	1.0146	4.166	0.4143	1.5604	1.407	998.050	560.467
System III	0.1	1.0134	4.340	0.42290	1.5280	3.3680	981.811	557.780
	0.12	1.0139	4.2689	0.41940	1.5411	2.6700	987.617	560.792
	0.14	1.0143	4.2287	0.41740	1.5487	2.3116	992.305	563.367
	0.18	1.0154	4.1220	0.4121	1.5695	1.2326	1002.411	568.860
	0.20	1.0157	4.0716	0.4096	1.5794	0.7220	1007.747	571.748

Data of ultrasonic velocities clearly indicate that ultrasonic velocity increases with the increase in the total molarity of the solution. It has also been observed that the ultrasonic velocity depends on the component being added to the solution. Here it is obvious that for the solution of the same total molarity, ultrasonic velocities of various systems follow the order:

System I < System II < System III

Hence it may be said that the addition of citric acid causes greater increase in the ultrasonic velocity than the addition of tartaric acid and the addition of the later compound causes greater increase than the addition of oxalic acid. This fact may also be observed by comparing ultrasonic velocities of various solutions in each system to the common solution which is the solution having Ci = 0.1 M

The variation of ultrasonic velocity with concentration is

$$\frac{dV}{dc} = -\frac{V}{2}\left[\frac{1}{\rho}\left(\frac{d\rho}{dc}\right) + \frac{1}{\beta}\left(\frac{d\beta}{dc}\right)\right] \tag{9}$$

For each system the value of dv/dc is positive. Other workers have also reported positive values for electrolyte solutions.

The plot of ultrasonic velocity vs. the total molarity of the solution is linear and the variation of ultrasonic velocity with the total molarity of the solution follows the relationship

$$V = V_0 + Gm_T \tag{10}$$

The value of V_0 is obtained by extrapolation of the plots and G is the slope of the plot. The values of V_0 for system I, system II and system III are 1.505×10^5 cm/sec, 1.504×10^5 cm/sec and 1.5035×10^5 cm/sec respectively, whereas the values of G for these systems are 2.692×10^{-4} cm mol^{-1} sec^{-1}, 3.866×10^4 cm mol^{-1} sec^{-1} and 4.761×10^4 cm mol^{-1} sec^{-1} respectively.

Observation of Table 2 makes it clear that the values of β and L_f decrease with the increase in ultrasonic velocity which increases with the increase in the total molarity of the solution. The decrease in the values of β and L_f indicates that there is a significant interaction between the solute and solvent molecules. Data show that the values of β and L_f of solutions having same molarity follows the order

System I > System II > System III

Hence the addition of citric acid causes the highest interaction between the solute and solvent molecules whereas the addition of oxalic acid causes the lowest. The values were used to examine the Bachem's relationship which is

$$\beta = \beta_0 + AC + BC^{3/2} \tag{11}$$

where C is the concentration of the solution. A and B are constants obtained from the intercept and the slope of the plots of $\beta - \beta_0/C$ vs. $\sqrt{C}$. This relationship has not been found to be followed by these multicomponent solutions.

The calculated values of ϕ_k from the equation (3) have been plotted against the total molarity of the solutions. The values of ϕ_k decrease linearly with the increase in the values of m_T and are best fitted to the equation.

$$\phi_k = \phi_k^0 + S_{k \cdot m_T} \tag{12}$$

where ϕ_K^0 is the apparent molal compressibility at infinite dilution and S_k is the experimental slope. The values of ϕ_k^0 and S_k have been recorded in Table 3.

TABLE 3

VALUES OF ϕ_K^0 AND S_K FOR SYSTEM I, SYSTEM II AND SYSTEM III AT 40°C

Systems	$\phi_K^0 \times 10^9$	$S_K \times 10^9$
System I	3.552	−22.3642
System II	3.600	−24.1666
System III	3.630	−25.9740

The value of molar sound velocity, molar sound compressibility and specific acoustic impedance increases with the increasing total molarity of the solution.

REFERENCES

1. H. C. Pandey and J. D. Pandey, *Indian J. of Physics*, **51A**, 38 (1977).
2. S. K. Kar and Kailash, *Indian J. Pure Appl. Physics*, **24**, 179 (1986).
3. M. A. Sidkey and N. S. Abdel Aal, *Indian J. of Physics*, **71B**, 31 (1987).
4. H. Kundu, *Indian J. of Physics*, **61A**, 261 (1987).
5. S. Singh, *Indian J. Pure Appl. Physics*, **18**, 2541 (1980).
6. S. Prakash and O. Prakash, *Acoustica*, **32**, 279 (1975).
7. P. K. Gupta, *Indian J. Pure Appl. Physics*, **19**, 359 (1981).

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