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ARTICLE

Acoustical Properties of multicomponent Solutions (Sucrose-Citric Acid-Water)

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ABSTRACT

This paper studies the acoustical properties of multicomponent solutions (sucrose-citric acid-water). The ultrasonic velocities of the ternary solution have been measured at different concentrations at 40 ºC. The experimental values of ultrasonic velocity have been utilized to calculate other acoustical parameters such as the adiabatic compressibility, acoustic impedance, molar sound velocity, intermolecular free length, apparent molar and molar sound compressibilities. The ultrasonic velocities of the multicomponent solutions increase with the increase in the concentration of its any individual component. The value of acoustical parameters also increases with the increase in total molarity of the ternary solutions.

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INTRODUCTION

Ultrasonic wave propagation in liquids and liquid mixtures is crucial for establishing the nature of intermolecular and intramolecular interactions [1-3]. Ultrasonic velocity measurements can be combined with other experimental data like density and viscosity to calculate various acoustical parameters like adiabatic compressibility, free length, acoustic impedance, relaxation time, free volume, and internal pressure, which are useful in understanding the acoustical properties of a fluid. Ultrasonic velocity is an important physical property that is affected by structural variables [4-7].

However, very little attention has been paid to the solutions having three components or more. In chemical industries and physiological process of body fluids, multicomponents solutions are generally seen. Studies of these solutions with reference to the measurement of ultrasonic velocity will certainly provide a base to know different types of interactions occurring in these solutions [8]. This will be helpful in shortenings a large number of problems associated with industries and human body. Citric acid and sucrose are generally consumed by human beings. Different types of interactions and change of in these interactions due to addition of some materials will be useful in knowing some facts for upgrading the qualities of these solutions. With this view, we have selected sucrose-citric acid-water solutions in the present study.

EXPERIMENTAL

Sucrose and citric acid (Sigma-Aldrich, USA) were used without further purification and their solutions were prepared in conductivity water having conductivity 0.21×10^{-15} mho cm^{-1} at 35 ºC. Densities were measured at constant temperature with the help of a double capillary pyknometer (25 mL capacity). Ultrasonic velocities were measured with the help of a single crystal ultrasonic interferometer working at a fixed frequency of 2 MHz. Distilled water from a thermostat fixed at the desired temperature was passed through the ultrasonic cell.

RESULTS AND DISCUSSION

Different concentration citric acid solutions (0.1 M, 0.125 M and 0.25 M) were prepared in conductivity water as well as in sucrose solutions of different molarities. The ultrasonic velocity of each solution was recorded at 40 ºC. These values of ultrasonic velocity were used to evaluate other acoustical parameters such as adiabatic compressibility (β), acoustic impedance (Z), molar sound velocity (R), molar sound compressibility (W), apparent molar compressibility (Φ_K) and intermolecular free length (L_f). Following equations have been used to evaluate the above said parameters:

$$Z = \rho V \quad (1)$$

$$B = \frac{1}{V^2 \rho} \quad (2)$$

$$\Phi_K = \frac{1000(\beta\rho_o - \beta_o\rho)}{(\rho - \rho_o)} + \frac{\bar{M}}{\rho} \quad (3)$$

$$L_f = K.\sqrt{\beta} \quad (4)$$

$$R = \left(\frac{M}{\rho}\right) V^{\frac{1}{3}} \quad (5)$$

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

where ρ_o and β_o are the density and the adiabatic compressibility of solvent, respectively; ρ is the density of the solution and K is temperature dependent Jacobson's constant. $\bar{M}$ and M are the average molecular weight of the solutes and solutions, respectively $\bar{M}$ and M are calculated by the following equations:

$$\bar{M} = \sum_{j=1}^{j=n} X_j M_j$$

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

where n is the number of solutes present in the solution and X_j is the molal weighing factor (m_j/M_T). m_j stands for molarity of the j^{th} component and M_T is the total molarity given as $M_T = \Sigma m_j.M_j$. M_j is the molecular mass of the j^{th} component and M_0 is the molecular mass of the solvent.

All the values of different parameters have been recorded in Tables 1-3.

TABLE-1
ULTRASONIC VELOCITIES OF SOLUTIONS IN WATER AT 40 °C

Solutions	Ultrasonic velocities (V) × 10^{-5} (cm s^{-1})
0.100 M citric acid	1.503
0.125 M citric acid	1.510
0.250 M citric acid	1.532

TABLE-2
ULTRASONIC VELOCITIES OF CITRIC ACID-SUCROSE SOLUTIONS AT 40 °C

$M_{Citric\ acid}$	$M_{sucrose}$	Ultrasonic velocities (V) × 10^{-5} (cm s^{-1})
0.100 M	0.333	1.522
	0.222	1.519
	0.178	1.518
0.125 M	0.222	1.521
	0.178	1.519
	0.111	1.517
0.250 M	0.222	1.553
	0.178	1.545
	0.133	1.533

Experimental findings clearly indicate that the ultrasonic velocity increases with increase in the total molarity of the solution. The addition of sucrose increases the ultrasonic velocity of the solution. The variation of ultrasonic velocity with concentration is given as:

$$\frac{dV}{dC} = -\frac{V}{2}\left[\frac{1}{\rho}\left(\frac{d\rho}{dC}\right) + \frac{1}{\beta}\left(\frac{d\beta}{dC}\right)\right] \quad (7)$$

For each of the solution, the value of dV/dC is positive. Other workers [8-12] have also reported positive values for electrolytic solutions.

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

TABLE-3
ULTRASONIC VELOCITIES AND RELATED ACOUSTICAL PARAMETERS OF THE TERNARY SOLTIONS (SUCROSE-CITRIC ACID-WATER) AT 40 °C

$M_{Citric\ acid}$	$M_{sucrose}$	ρ	(V) × 10^{-5} (cm s^{-1})	β × 10^{-11}	Φ_K × 10^{9}	Z × 10^{-5}	L_f (Å)	R	W
0.100 M	0.333	1.019	1.522	4.240	2.152	1.550	0.418	1001.713	569.529
	0.222	1.013	1.519	4.277	2.816	1.537	0.419	988.537	561.696
	0.178	1.010	1.518	4.295	2.976	1.533	0.421	984.472	559.141
0.125 M	0.222	1.013	1.521	4.269	2.511	1.540	0.419	990.661	52.851
	0.178	1.011	1.519	4.283	2.518	1.536	0.420	984.759	559.386
	0.111	1.009	1.517	4.299	2.478	1.532	0.421	974.876	553.703
0.250 M	0.222	1.0199	1.553	4.073	0.726	1.581	0.410	997.609	566.635
	0.178	1.0195	1.545	4.113	0.459	1.573	0.411	989.958	562.420
	0.133	1.0142	1.533	4.197	0.391	1.554	0.415	984.569	559.309

$$V = V_o + G.m_T \quad (8)$$

The value of V_o is obtained by extrapolation of the plots and G is the slope of the plot. The value of V_o comes to be 1.504×10^5 cm s^{-1} whereas the value of G appears 3.840×10^4 cm s^{-1} mol^{-1}.

The value of β and L_f decreases with increase in the total molarity of the solution. The decrease in the values of β and L_f indicates significant interaction between the solute and solvent molecules. It is also formed that the value of β and L_f decrease when the amount of sucrose is increased in the solution. This suggests that interaction is suppressed when the amount of sucrose is increased. The values of β were used to examine the Bachem's relationship which is

$$\beta = \beta_o + AC + BC^{1/2} \quad (9)$$

where C stands for concentration of the solution. A and B are constants obtained from the intercepts and the slope of the plots of $\beta - \beta_o/C$ *vs*. $\sqrt{C}$. Thus relationship has not be found to be followed by this solution.

The calculated values of Φ_K have been plotted against the total molarity of the solution. The value of Φ_K decreases with increase in the value of total molarity of the solution. These values are best fitted to the equation:

$$\Phi_K = \Phi_K^o + S_K \cdot m_T \quad (10)$$

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

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