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Effect of glycine on aqueous solution behavior of saccharides at different temperatures: Volumetric and ultrasonic studies

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ABSTRACT

Densities (ρ) and speeds of sound (u) of some saccharides in aqueous glycine solutions (0.000, 0.025, 0.050, and 0.100 mol kg^{-1}) have been measured in the concentration range 0.050–0.100 mol kg^{-1} at 293.15, 298.15, 303.15, 308.15, and 313.15 K. Using the ρ and u data, the apparent molar volumes at infinite dilution (V_φ^o), transfer apparent molar volumes at infinite dilution ($\Delta_{tr}V_\varphi^o$), partial molar expansion coefficients $\left(\partial V_\varphi^o / \partial T\right)_p$, second derivatives $\left(\partial^2 V_\varphi^o / \partial T^2\right)_p$, isentropic compressibilities (κ_s), apparent molar isentropic compressions at infinite dilution ($\kappa_{s,\varphi}^o$), and transfer apparent molar isentropic compressions at infinite dilution ($\Delta_{tr}\kappa_{s,\varphi}^o$) have been calculated. The trends of variations of experimental and computed parameters have been deliberated in terms of different types of the interactions occurring in the present ternary system.

1. Introduction

Saccharides being the important chemicals of living organism are of considerable interest in various aspects of researches and applications. Saccharides help in stabilizing the native confirmation of ubiquitous globular proteins or reduce the extent of denaturation by other reagents [1–4]. Most of the saccharides located at the cell surface act as receptors to the viruses, hormones, enzymes, antibodies, etc. [5]. Therefore there interaction studies with proteins have been proved very useful for immunology, medicine and pharmacology. Besides, the interactions of amino acid with sugar help us in explicating the intramolecular interactions between amino acid residues of glycoproteins and the sugar part of the glycoprotein with proteolytic enzymes.

Even if several mechanisms for the stabilization of proteins by sugars have been proposed [6], the understanding of the mechanism is still incomplete, probably due to the complex nature of their interactions. The simplest approach that may help in this regard and requires less complex measurement techniques is to study sugar–amino acid interactions in solutions. Literature surveys point out that these interactions can be studied by different spectroscopic techniques [7–11], chromatography data [12,13] and computer calculations [14–16]. In addition, recently, researchers have studied the thermodynamic properties of saccharides in aqueous electrolytic solutions [17–21]. Anyhow, there is relatively little information available on such properties in aqueous amino acids solutions [22–24].

In view of the above, and in light of our previous work [25–31] on thermodynamic studies of ternary systems, in this paper we have explored the interactions between D (−) ribose, D (+) maltose monohydrate and D (+) raffinose pentahydrate (saccharides) and glycine (amino acid) in water.

2. Experimental

2.1. Materials

The deionized distilled water with a conductivity of 1–2 × 10^{-7} s cm^{-1} and pH of 6.8–7.0 (at 298.15 K) was collected from a Millipore-Elix system. The specifications of D (−) ribose (monosaccharide), D (+) maltose monohydrate (disaccharide), D (+) raffinose pentahydrate (trisaccharide) and glycine of high purity were provenance from LOBA Chemie and Calbiochem, respectively. The saccharides and glycine were recrystallized twice in distilled water and dried in vacuum oven. After this they were kept in a vacuum desiccator over anhydrous calcium chloride at room temperature for a minimum of 48 h. The details of the chemicals used in the present work are also given in Table 1.

2.2. Methods and procedures

Stock solutions of glycine (0.025, 0.050, and 0.100 mol kg^{-1}) were prepared in distilled water and were used as solvents for the

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Table 1
Specifications of chemicals used.

Chemical name	CAS No.	M. wt. (kg mol^{-1})	Supplier	Mole fraction purity[a]
Glycine	56-40-6	0.7510	Calbiochem	0.99
D (−) ribose	50-69-1	0.1501	LOBA Chemie Pvt. Ltd.	0.99
D (+) maltose monohydrate	6363-53-7	0.3603	LOBA Chemie Pvt. Ltd.	>0.95
D (+) raffinose pentahydrate	17629-30-0	0.5945	LOBA Chemie Pvt. Ltd.	0.99

[a] Purity as provided by suppliers.

preparation of different saccharide solutions. These solutions were prepared by using Shimadzu balance with a precision of ±0.0001 g. Densities and speeds of sound of aqueous saccharide solutions with and without glycine were measured simultaneously using Anton Paar DSA-5000 instrument. The two-in-one instrument is equipped with a density cell at a pulse–echo speed of sound cell. Both cells are temperature controlled by a built-in Peltier thermostat. The instrument has a built-in thermostat to maintain the temperature between 0 and 70 °C. The instrument was calibrated at all studied temperatures with distilled water, dimethylsulfoxide and 1,4-dioxane. The reproducibility in density and speed of sound measurements were ± 0.2 m s^{-1} and $\pm 2 \times 10^{-6}$ g cm^{-3}, respectively. The densities and speeds of sound of these solvents are found to be in good compliance with the literature values as indexed in Table 2.

3. Results and discussion

3.1. Apparent molar volume

Densities and speeds of sound for different saccharides at molalities ranging from 0.050 to 0.100 mol kg^{-1} in water and aqueous glycine solutions (0.025, 0.050, and 0.100 mol kg^{-1}) have been listed in Table 3. The apparent molar volumes, V_φ, have been estimated from the equation

$$V_\varphi = \frac{M}{\rho} - \left[\frac{(\rho - \rho_o)}{m\rho\rho_o}\right] \quad (1)$$

where m is the molality (mol kg^{-1}) of the solution, M is the molar mass of the saccharides (kg mol^{-1}) and ρ_o and ρ are the densities of the solvent and solution (kg m^{-3}), respectively. By examining Table 4, the V_φ values altered linearly with molalities of saccharides at all concentration of glycine and temperatures, thence, apparent molar volumes at infinite dilution, V_φ^o, have been obtained by least squares fitting of experimental data to the equation,

$$V_\varphi = V_\varphi{}^o + S_v m \quad (2)$$

where S_v is the experimental slope. V_φ^o represents the solute—solvent interactions and S_v means the solute–solute interactions. This type of linear alteration in V_φ values is in contrast to our earlier studies of SDS–saccharide and CTAB–glycine systems [32,33], where V_φ varies non-linearly before CMC and then becomes almost constant above the CMC. The evaluated V_φ^o and S_v values with standard errors are expressed in Table 5. The V_φ^o values of different saccharides in water are found to be in good compliance with corresponding literature values [17]. A survey of Table 5 suggests that V_φ^o values are positive for all saccharides in all the studied systems indicating strong solute–solvent interactions [34]. Further, V_φ^o values in aqueous glycine systems are higher than those without glycine and increase with the concentration of glycine. This behavior may be explained on the basis of the following types of interactions occurring in the ternary saccharide–amino acid–water system [35]:

(1) hydrophilic–ionic interactions between the OH groups of saccharide and the zwitterionic center of glycine,
(2) hydrophilic–hydrophilic interactions between OH groups of saccharide and the OH groups of glycine through the hydrogen bond,
(3) hydrophilic–hydrophobic interactions between OH groups of saccharide/glycine and the non-polar groups of glycine/ saccharide and

Table 2
Comparison of densities, ρ, and speeds of sound, u, values for pure liquids with literature values at different temperatures.

T (K)	ρ_{exp} (kg m^{-3})	ρ_{lit} (kg m^{-3})	u_{exp} (m s^{-1})	u_{lit} (m s^{-1})
Water				
293.15	998.218	998.220[1]	1482.96	1483.10[10] 1483.00[11]
298.15	997.055	997.100[2]	1497.06	1497.00[11]
303.15	995.651	995.640[1]	1509.39	1509.40[12]
308.15	994.030	994.058[3]	1520.08	1519.83[13]
313.15	992.204	992.210[4]	1529.19	1529.10[12]
1,4-Dioxane				
293.15	1033.651	1033.660[5]	1363.15	–
298.15	1028.050	1028.120[5] 1027.882[6]	1344.15	1345.50[14] 1344.74[15] 1344.85[16]
303.15	1022.225	1022.230[5] 1022.219[6]	1322.65	–
308.15	1016.880	1016.890[5] 1016.595[6]	1300.95	–
313.15	1011.029	1011.033[6]	1278.05	1277.70[14]
Dimethylsulfoxide (DMSO)				
293.15	1100.403	1100.410[7]	1501.95	1502.60[17]
298.15	1096.011	1096.020[8]	1488.25	1489.00[17] 1484.51[18]
303.15	1090.523	1090.380[9] 1090.540[8]	1474.55	1474.00[17] 1477.00[9]
308.15	1085.231	1085.240[8]	1455.81	1455.00[17]
313.15	1080.628	1080.640[8]	1436.57	–

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