

Viscosities of Some Biologically Important Compounds in Aqueous and Mixed Aqueous Solutions of an Electrolyte

P. Sahaya Amutha

*D-2, Police Quarters, Marsingpettai, Beema Nagar,
Trichu-I, Tamilnadu, India
E-mail: amndoss@gmail.com*

Abstract

Relative viscosities for the solutions of some biologically important compounds (Fructose, galactose and succinic acid) at different concentrations in water and in 0.5 mol kg⁻¹ aqueous sodium chloride and potassium chloride solutions at 308 and 318 K have been determined. The data have been analyzed using the Jones-Dole equation and the obtained parameters have been interpreted in terms of solute-solute and solute-solvent interactions. The activation parameters of viscous flow have been obtained which depicts the mechanism of viscous flow. All these three compounds studied behave as structure breakers in water and in sodium chloride and potassium chloride solutions.

Keywords: Viscosity, relative viscosity, Jones-Dole equation, structure, breakers, activation, parameters, solute-solute and solute-solvent interactions.

Introduction

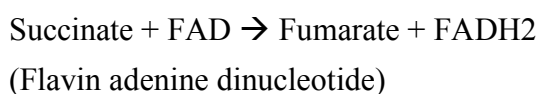
In continuation of earlier studies¹ on the determination of partial molar volumes of transfer of some biologically important compounds (Fructose, galactose and succinic acid) from water to aqueous sodium chloride and potassium chloride solutions at 308 and 318 K, we report herein studies on the determination of relative viscosities of the above compounds in water and in 0.5 mol kg⁻¹ aqueous sodium chloride and potassium chloride solutions.

Studies on viscosities for the solutions are of great help in characterizing the structure and properties of solutions²⁻⁵. Various types of interactions exist between the molecules in the solutions and of these solute-solute and solute-solvent interactions of

current interest. These interactions help in better understanding of the mixture of solute and solvent whether the added electrolyte modifies (or) distorts the structure of the solvent.

The importance of carbohydrates to living things can hardly be over emphasized. The energy stores of most animals and plants are both carbohydrates and lipids in nature. Carbohydrates are generally available as an immediate energy source⁸. Fructose, fruit sugar, is a simple monosaccharide found in many foods. Galactose, a nutritive sweetener is having a role in treatment of focal segmental glomerulosclerosis which is a kidney disease resulting in kidney failure and proteinuria.

Succinate, anion part of succinic acid is a compound of the citric acid cycle and is capable of donating electrons to the electron transport chain by the reaction⁹.



This is catalysed by the enzyme succinate dehydrogenase.

Experimental Methods

All the compounds (AR, qualigens) of highest purity grade were used without further purification. They were dried in an oven and kept over anhydrous calcium chloride for 48h before use. The solutions were prepared in doubly distilled deionised water having specific conductance less than $1 \times 10^{-6} \text{ Ohm}^{-1} \text{ cm}^{-1}$ and it was degassed before use. All the solutions were prepared by weight using Mettler balance having an accuracy of $\pm 0.01 \text{ mg}$.

Sprengel and Ostwald Pyknometer¹⁰ which was essentially a U-tube in shape with side arms being made up of small bore capillary used to measure the densities of solutions.

The viscosities were measured at desire temperature using Ostwald's suspended level type viscometer¹¹. Density and viscosity measurements were carried out in a well-stirred water bath having an accuracy of $\pm 0.01 \text{ K}$.

Results and Discussion

The relative viscosities and densities of the solutions of chosen compounds in water and in 0.5 mol kg^{-1} aqueous sodium chloride and potassium chloride solutions were measured at 308 and 318 K. the experimental results have been analysed by the Jones-Dole equation^{12,13}

$$\eta_{\text{rel}} = \eta/\eta_0 = 1 + AC^{1/2} + BC \quad (1)$$

where η and η_0 are the viscosities of the solution and solvent (water, water + NaCl, water + kcl) respectively and C is the molar concentration. A and B are the characteristics constants of solute-solute and solute-solvent interactions respectively.

The plots of $(\eta_r - 1) / \sqrt{c}$ versus \sqrt{c} for all the three compounds were found to be linear, with least scatter in water and in aqueous solutions of sodium chloride and

potassium chloride. The values of A and B parameters have been calculated using the least squares method by fitting the experimental results in Jones-Dole equation and these values along with standard errors are recorded in Table 1.

Table 1 show that the values of A coefficient are negative in water, less positive in sodium chloride and potassium chloride solutions, showing the presence of very weak solute and solute interactions¹⁶. It is also evident from Table 1 that the B coefficient are positive and fairly large for all the three compounds studied, suggesting the presence of strong solute-solvent interactions. The values of B coefficients is more in sodium chloride and potassium chloride solutions than in water, suggesting the increase in interactions of solute and cosolute with solvent¹⁷.

The value of B coefficient is more in sodium chloride solution than in potassium chloride solution, showing the increase in solute and cosolute – water interactions in sodium chloride solutions.¹⁸

The value of B coefficient increases with the raise in temperature for all the three compounds suggests that solute-solvent interactions¹⁹ are strengthened with the rise in temperature.

Table 1: Values of A and B parameters of Jones-Dole equation. Standard errors are given in parantheses.

	308 K		318 K	
	A dm ^{3/2} mol ^{-1/2}	B dm ³ mol ⁻¹	A dm ^{3/2} mol ^{-1/2}	B dm ³ mol ⁻¹
Fructose in water	- 0.012 (+ 0.003)	0.373 (+ 0.004)	- 0.014 (+ 0.001)	0.433 (+ 0.002)
0.5m Nacl	0.096 (+ 0.001)	0.407 (+ 0.002)	0.041 (+ 0.005)	0.451 (+ 0.004)
0.5m Kcl	0.057 (+ 0.006)	0.396 (+ 0.003)	0.014 (+ 0.006)	0.440 (+ 0.005)
Galactose in water	- 0.052 (+ 0.006)	0.396 (+ 0.001)	- 0.063 (+ 0.007)	0.539 (+ 0.004)
0.5m Nacl	0.030 (+ 0.007)	0.783 (+ 0.003)	0.003 (+ 0.001)	0.795 (+ 0.003)
0.5m Kcl	0.120 (+ 0.006)	0.491 (+ 0.005)	0.066 (+ 0.006)	0.643 (+ 0.001)
Succinic acid in water	- 0.063 (+ 0.005)	0.322(+ 0.003)	- 0.145 (+ 0.008)	0.377 (+ 0.001)
0.5m Nacl	0.100 (+ 0.004)	0.416 (+ 0.001)	0.096 (+ 0.001)	0.539 (+ 0.003)
0.5m Kcl	0.087 (+ 0.001)	0.395 (+ 0.006)	0.066 (+ 0.002)	0.422 (+ 0.003)

The viscosity data have also been analysed on the basis of transition state treatment of relative viscosity as suggested by Feakns et al.^{18 20}. The B parameter in terms of this theory is given by Eq (2).

$$B = \frac{\bar{V}_1^0 - \bar{V}_2^0}{1000} + \frac{\bar{V}_2^0}{1000} [\Delta\mu_2^{0*} - \Delta\mu_1^{0*}] \quad (2)$$

here V_1^0 is the mean volume of the solvent and V_2^0 is the partial molar volume of the solute. The free energy of activation per mole of the pure solvent ($\Delta\mu_1^0$), and the free energy of activation per mole of solute ($\Delta\mu_2^0$) were calculated²¹ with the help of Eqs (3) and (4) respectively.

$$\Delta\mu_1^{0*} = RT \ln (\eta_0 \bar{V}_1^0 / hN) \quad 3$$

and

$$\Delta\mu_2^{0*} = \Delta\mu_1^{0*} + RT / \bar{V}_1^0 [1000B - (\bar{V}_1^0 - \bar{V}_2^0)] \quad 4$$

Where h is the Planck's constant, N the Avogadro number, η_0 the viscosity of solvent, R the gas constant and T is the absolute temperature. The values of $\Delta\mu_1^0$ calculated from Eq (3) are given in Table 2. For the mixed solvents, each solvent mixture was treated as pure and the molar volume taken as a mean volume defined as

$$\bar{V}_1^0 = (x_1 M_1 + x_2 M_2) / d_1 \quad 5$$

where x_1 , M_1 and x_2 , M_2 are the mole fractions and molecular weights of water and sodium chloride (or) potassium chloride, respectively and d_1 is the density of solvent (water + sodium chloride (or) water + potassium chloride). The values of V_2^0 , the partial molar volumes at infinite dilution for all the compounds, determined from density data, are also recorded in Table 2. The values of $\Delta\mu_2^0$ and V_1^0 , calculated with the help of relations (4) and (5) respectively, are also listed in Table 2.

Table 2: Values of V_1^0 ($\text{dm}^3 \text{mol}^{-1}$), V_2^0 ($\text{dm}^3 \text{mol}^{-1}$), $\Delta\mu_1^{0*}$ (kJmol^{-1}) and $\Delta\mu_2^{0*}$ (kJmol^{-1})

	308 K			318 K		
	Water	0.5 m NaCl	0.5 m kcl	Water	0.5 m NaCl	0.5 m kcl
V_1^0	17.62	17.82	19.05	17.74	17.92	19.16
$\Delta\mu_1^0$	62.01	62.06	62.11	64.00	64.03	64.01
Fructose	75.50	68.40	71.30	77.50	67.70	70.10
V_2^0						
$\Delta\mu_2^{0*}$	123.13	127.82	122.01	135.77	137.89	131.75
Galactose V_2^0	118.50	89.90	108.80	122.00	85.80	107.40
$\Delta\mu_2^{0*}$	132.50	107.38	140.17	157.70	114.29	164.91
Succinic acid V_2^0	52.00	49.50	50.60	57.00	48.30	49.40
$\Delta\mu_2^{0*}$	112.56	126.40	119.45	124.63	148.01	126.41

It is clear from Table 2 that the values of $\Delta\mu_2^0$ are positive and larger than $\Delta\mu_1^0$ which suggest that the formation of the transition state is less favoured in the presence of these compounds, meaning thereby that the formation of transition state is accompanied by the breaking and distortion of the intermolecular bonds between sodium chloride, potassium chloride and water i.e. solvent.

The value of dB / dT is positive for all the three compounds in water as well as in water + sodium chloride, water + potassium chloride solutions, showing that the studied compounds act as structure breakers in all the three systems studied.

The activation entropy for the compounds studied has also been calculated from

the following relation Eq. (6)

$$d(\Delta\mu_2^{0*})/dT = -\Delta S_2^{0*} \quad 6$$

The activation enthalpy (ΔH_2^{0*}) has been calculated with the help of Eq. (7)

$$\Delta H_2^{0*} = \Delta\mu_2^0 + T\Delta S_2^{0*} \quad 7$$

Both the values are recorded in Table 3.

Table 3: Entropy, $T\Delta S_2^{0*}$ (kJmol^{-1}) and enthalpy, ΔH_2^{0*} (kJmol^{-1}) of activation for viscous flow.

	308 K		318 K	
	$T\Delta S_2^0$	ΔH_2^0	$T\Delta S_2^0$	ΔH_2^0
Fructose in water	-389.31	-266.18	-401.95	-266.18
0.5m Nacl	-310.16	-182.34	-320.23	-182.34
0.5m Kcl	-299.99	-177.98	-309.73	-177.98
Galactose in water	-776.16	-643.66	-801.36	-643.66
0.5m Nacl	-212.83	-105.45	-219.74	-105.45
0.5m Kcl	-761.99	-621.82	-786.73	-621.82
Succinic acid in water	-371.76	-259.20	-383.83	-259.20
0.5m Nacl	-665.59	-539.19	-687.20	-539.19
0.5m Kcl	-214.37	-94.92	-221.33	-94.92

It is evident from Table 3 that both enthalpy and entropy of activation are negative for the compounds studied, which suggests that the transition state is associated with bond breaking and increase in order.

References

- [1] Sahaya Amutha P & Rosario Rajkumar X, Oriental Journal of Chemistry, 26(4), (2010) 1537.
- [2] Clarke RG, Hnedkovsky L, Tremaine PR & Majer V, J Phys Chem, 104B (2000) 11781.
- [3] Kikuchi M, Sakurai M & Nitta K, J Chem Eng Data, 40 (1995) 935.
- [4] Pal A & Kumar S, J Indian Chem Soc, 79 (2002) 866.
- [5] Pal A & Kumar S, J Indian Chem Eng Data, 43 (1998) 143.
- [6] Pal A & Kumar S, J Indian Chem, 44A (2004) 469.
- [7] Mishra AP, Indian J Chem, 43A (2004) 730.
- [8] Ernst B, Hart GW & Sinay P, Carbohydrates in Chemistry and Biology (Wiley – vchverlagweinheim) 1 (2000).
- [9] Walter F. Boron, Medical Physiology: A Cellular and molecular approach Elsevier / Saunders ISBN 1-4160-2328-3: 837.

- [10] Shoemaker DP & Garland CW, Experiments in Physical Chemistry (Mcgraw Hill, New York) 131 (1967).
- [11] Timmerman J, Physiochemical Constants of Pure Organic Compounds (Elsevier, Amsterdam), 1950, pp. 335, 502.
- [12] Jones G & Dole M, J Am Chem Soc, 51 (1929) 2950.
- [13] Li S, Hu X, Lin R & Zong H, Thermochim Acta 342 (1999) 11.
- [14] Belibagli K & Agranci E, J Solution Chem 19 (1990) 867.
- [15] Bhat R, Kishore N & Ahluwalia J.C., J Chem Soc Faraday Trans 1, 88 (1988) 2651.
- [16] Banipal PK, Gumeet Kaur & Banipal TS, Indian J Chem, 43A (2004) 35.
- [17] Parmar ML & Thakur RC, Indian J Chem, 45A (2006) 1631.
- [18] Changwei Zhao, Peisheng Ma & Jiding Li, J Chem Thermodynamics, 37 (2005) 37.
- [19] Feakins D, Freemental JD & Lawrence KG, J Chem Soc Faraday Trans I, 70 (1974) 795.
- [20] Glasston S, Laidler K & Eyring H, The Theory of Rate Processes (Mc Graw-Hill, New York), 1941, pp.477.
- [21] Sarma TS & Ahluwalia JC, Rev Chem Soc, 2 (1973) 217.
- [22] Gurney, RW, Ionic process in Solution (Mc Graw-Hill, New York), 1953.