

Molecular interionic interaction studies of copper sulphate in water and in aqueous glycine solutions using viscometric method at temp. 305K.

Monika Singh

Department of Chemistry, K.B. Sahay Senior Secondary School, Patna-23
E-mail:monikasingh.horizon@gmail.com

Manuscript received online 07 February 2020, accepted on 19 March 2020

Abstract: Densities and viscosities for the solutions of copper sulphate, at different concentration (0.05 to 0.3 mol kg⁻¹) have been determined in aqueous and in binary aqueous mixture of glycine at temp 305K. The viscosities data were analysed using the Jones-Dole equation and values of the falkenhagen co efficient A and Jones-Doles B- coefficient were calculated. The outcomes were expressed in terms of the molecular interactions and the variations in parameters under varying solute concentrations.

(Key Words : Viscosity, Falkenhagen coefficient A, B- coefficient)

Introduction

Viscosity is one of the key transport properties of solution. Studies on viscosity of ionic solutions are of great help to ascertain the structure properties of solutions. Several studies¹⁻⁸ also reveal that many biochemical processes occur in aqueous media involves various types of electrolyte. Mixed electrolytes are very important in that they are found in numerous processes in chemical industry. They occur in enormous quantities in water of the oceans and have an important role in the physiological process of body fluids and cell equilibria.¹¹⁻¹³

Various types of interactions exist between the ions in solutions and of these ion-ion and ion-solvent interactions are of current interest in all branch of chemistry. Viscometric studies of solutions have proven to be a very useful tool in estimating the feasibility of reaction in solution

and understanding the theoretical aspect of solutions structure.

Through viscometric studies the aim of present study is to bring about new information about molecular interaction of CuSO₄ in purely aqueous solution and in aqueous binary solution of glycine at 305 K temp.

Experimental

The chemicals selected for the present study CuSO₄ (Merck) and Glycine (Sisco research Lab Pvt. Ltd.) were used without further treatment. The experimental solutions were prepared using doubly distilled water specific conductivity (~10⁻⁶ Scm⁻¹) as a solvent. Different molar concentrations of copper sulphate ranging from 0.05 to 0.3mol kg⁻¹ were prepared in pure water and in aqueous glycine solution. The solutions were prepared with care and stored in special airtight bottles to avoid contamination and evaporation. The density was determined using a specific gravity bottle made up of Borosil glass by relative measurement method. The water of the sample was measured using electronic digital balance (Metler) with an accuracy of (±0.1 mg).

The viscosities of the solutions were measured by using Ostwald viscometer (Glass 80-12- Aston standards) made up of Borosil. The viscometer containing the experimental liquid was allowed to stand for about 20 minutes in a thermostatic water bath so that the thermal

fluctuations in viscometer were minimised. The time of flow was recorded in triplicate with a digital stopwatch with an accuracy of ± 0.015 . The measurement of time of flow of solution between the two points on the viscometer was performed at least 10 times and the results were averaged. The temperature of the test solutions during the measurements was maintained to an accuracy of ± 0.01 K in an electronically digital operated constant thermostat from viscometer Baths Webcon Ltd.

Result and Discussion

The densities of experimental binary and ternary solutions ($C = 0.05$ mol kg⁻¹ to 0.3 M) were determined same as discussed in earlier paper²⁻⁴. The time of flow of these solutions were recorded at 305 K. The η and η_r values were calculated from following relations, and given in tables 1 and 2 (a, b, c, d, e).

$$\eta = (\rho \cdot t) / (\rho_0 \cdot t_0) \eta_0 \quad \dots\dots(1)$$

$$\frac{\eta}{\eta_0} = \eta_r = (\rho \cdot t) / (\rho_0 \cdot t_0) \quad \dots\dots(2)$$

Where η and η_0 are viscosities of solution (water + Amino acid + salt) and solvent (water + Amino acid), t and t_0 are the flow time of solution and solvent and ρ and ρ_0 are the densities of solution and solvent, respectively. $\eta_r = \eta/\eta_0$ is the relative viscosity of the system.

Precise viscosity data are necessary to accurately calculate the physical parameters of Jones-Dole equation which was used to analyze the experimental data.^{13, 14}

$$\frac{\eta}{\eta_0} = \eta_{rel} = 1 + A \sqrt{C} + BC \quad \dots\dots(3)$$

$$(\eta_r - 1) = A \sqrt{C} + BC \quad \dots\dots(4)$$

$$\frac{\eta_r - 1}{\sqrt{C}} = A + B \sqrt{C} \quad \dots\dots(5)$$

Where, C is the molal concentration of the solute-solvent system. A is the Falkenhagen coefficient and represents the solute-solute interactions

coupled with the size and the shape effects of the solute and to some extent, solute-solvent interaction.¹⁶⁻²¹ Due to the lack of appropriate theoretical knowledge its significance is not fully understood. B , the Jones-Dole coefficient, reflects the effect of solute-solvent interactions on the mixture viscosity.²²

The values of A and B have been obtained from the linear plots of $(\eta_r - 1)/\sqrt{C}$ versus $\sqrt{C}$ by computed least squares fit of the above equation. On the basis of Falkenhagen theory, the negative values of A have no significance and may be neglected [10]. The B parameter which measures the structure making/breaking capacity of an electrolyte in solution also contains a contribution from structural effects and is responsible for solute solvent interaction in a solvent.

The experimental observations of aqueous $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ solution for different molalities (0.05 to 0.03 mol kg⁻¹) at 305 K are shown in given table 1. A plot of $(\eta_r - 1)/\sqrt{C}$ versus $\sqrt{C}$ was used to calculate the values of A and B . Observations for $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ in aqueous glycine solutions (0.05 to 0.03 mol kg⁻¹) are given in table-2 (a, b, c, d, e). It is observed that the values of viscosity increases with increase in solute concentration in all the system and decreases with rise in temperature. The increasing trends indicate the existence of molecular interaction occurring in these systems. In order to shed more light on this, the role of viscosity B -coefficient has also been obtained.

It is seen from the table 3 that the values of coefficient A are negative in purely aqueous solution as well as in aqueous solutions of glycine at different ionic strengths. The negative values indicate the presence of weak ion-ion interactions in all the mixed electrolyte systems. The values of constant B of Jones-Dole equation for $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ in purely aqueous solution and in aqueous glycine solution are shown in table 4 which have been calculate from linear plot of $(\eta_r - 1)/\sqrt{C}$ versus $\sqrt{C}$ as mentioned earlier.

From the table [4]] it is observed that B-coefficient of Jones-Dole equations are positive in aqueous as well as in aqueous glycine solution. The behaviour of B- coefficient in all the systems suggests the existence of strong ion-solvent interaction. Further it is seen that the values of B-coefficient become larger with the increase of ionic strength which indicate that ion-solvent interactions become stronger at higher ionic strength.

The sign of B-coefficient depends on the degree of solvent structuring effect introduced by the ions. A positive value of the B-coefficient is associated with structure-making (ordering) ions, while a negative value of the B- coefficient is associated with structure-breaking (disordering)

ions. The structure-making ions are called Kosmotropes, while the structure breaking ions chaotropes, according to their relative abilities to induce the structuring of water. The degree of water structuring is determined mainly by the increase or decrease of solution viscosity due to added salt.¹⁵

The positive value of coefficient B indicate that $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ behave as structure maker in water as well as in aqueous glycine solution. The Kosmotropic behaviour (structure maker) of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ in mixtures, indicating an alignment of metal ions with zwitterions/water dipoles.

Table - 1
Viscosities (η) and Relative Viscosities (η_r) of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ in Water at Temperature 305K

S. No.	Molality (m) (mol kg^{-1})	Concentration (c) $\text{g mol cm}^{-1} \times 10^{-3}$	Density (ρ) g cm^{-3}	Viscosity (η) ($10^{-3} \text{ kg m}^{-1} \text{ s}^{-1}$)	Relative Viscosity (η_r)	$\frac{\eta_r - 1}{\sqrt{C}}$
1	0.051271	0.049529	1.002863	0.006906	0.891084	-0.048940
2	0.112570	0.098581	1.010500	0.007901	1.019340	0.061597
3	0.152054	0.147144	1.022018	0.008179	1.055355	0.144306
4	0.204870	0.195323	1.030274	0.008496	1.096258	0.217801
5	0.302167	0.290411	1.044104	0.009139	1.179226	0.332578

Table-2 (a):
Viscosities (η) and Relative Viscosities (η_r) of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ in aqueous solution of 0.05m Glycine at Temperature 305 K

Sl. No.	Molality (m) (mol kg^{-1})	Concentration (c) $\text{g mol cm}^{-1} \times 10^{-3}$	Density (ρ) g cm^{-3}	Viscosity (η) ($10^{-3} \text{ kg m}^{-1} \text{ s}^{-1}$)	Relative Viscosity (η_r)	$\frac{\eta_r - 1}{\sqrt{C}}$
1	0.050165	0.049578	1.001660	0.006945	0.913295	-0.38945
2	0.102556	0.099576	1.008105	0.007005	0.912680	-0.24945
3	0.150464	0.146815	1.015321	0.007208	0.947920	-0.14987
4	0.214476	0.194922	1.023278	0.007397	0.972764	-0.06192
5	0.302216	0.290413	1.040554	0.007901	1.039066	0.07371

Table -2 (b): Viscosities (η) and Relative Viscosities (η_r) of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ in aqueous solution of 0.1m Glycine at Temperature 305 K

Sl. No.	Molality (m) (mol kg^{-1})	Concentration (c) $\text{g mol cm}^{-1} \times 10^{-3}$	Density (ρ) g cm^{-3}	Viscosity (η) ($10^{-3} \text{kg m}^{-1} \text{s}^{-1}$)	Relative Viscosity (η_r)	$\frac{\eta_r - 1}{\sqrt{C}}$
1	0.051064	0.049459	1.003142	0.007096	0.901353	-0.44357
2	0.115437	0.098620	1.008332	0.007236	0.919260	-0.25753
3	0.150452	0.146901	1.016020	0.007437	0.944620	-0.14449
4	0.201456	0.194977	1.023564	0.007617	0.967501	-0.07360
5	0.305210	0.289416	1.036981	0.008567	0.108819	0.16394

Table- 2(c): Viscosities (η) and Relative Viscosities (η_r) of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ in aqueous solution of 0.15m Glycine at Temperature 305 K

Sl. No.	Molality (m) (mol kg^{-1})	Concentration (c) $\text{g mol cm}^{-1} \times 10^{-3}$	Density (ρ) g cm^{-3}	Viscosity (η) ($10^{-3} \text{kg m}^{-1} \text{s}^{-1}$)	Relative Viscosity (η_r)	$\frac{\eta_r - 1}{\sqrt{C}}$
1	0.051223	0.049578	1.003055	0.007021	0.893065	-0.48007
2	0.100128	0.099577	1.008513	0.007121	0.905806	-0.30010
3	0.150124	0.146815	1.014722	0.007373	0.938112	-0.16100
4	0.200145	0.194592	1.021546	0.007686	0.977560	-0.05100
5	0.311010	0.289292	1.036538	0.008390	1.067178	0.12675

Table-2(d): Viscosities (η) and Relative Viscosities (η_r) of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ in aqueous solution of 0.2m Glycine water at Temperature 305 K

Sl. No.	Molality (m) (mol kg^{-1})	Concentration (c) $\text{g mol cm}^{-1} \times 10^{-3}$	Density (ρ) g cm^{-3}	Viscosity (η) ($10^{-3} \text{kg m}^{-1} \text{s}^{-1}$)	Relative Viscosity (η_r)	$\frac{\eta_r - 1}{\sqrt{C}}$
1	0.050112	0.049469	1.003566	0.007069	0.886839	-0.50878
2	0.103321	0.098758	1.008765	0.007370	0.924801	-0.23929
3	0.150312	0.147495	1.016188	0.007387	0.926969	-0.19016
4	0.210332	0.195190	1.024688	0.007830	0.982522	-0.03956
5	0.300211	0.290749	1.048156	0.008645	1.084768	0.15720

Table-2 (e): Viscosities (η) and Relative Viscosities (η_r) of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ in aqueous solution of 0.3M Glycine at Temperature 305 K

Sl. No.	Molality (m) (mol kg^{-1})	Concentration (c) $\text{g mol cm}^{-3} \times 10^{-3}$	Density (ρ) g cm^{-3}	Viscosity (η) ($10^{-3} \text{kg m}^{-1} \text{s}^{-1}$)	Relative Viscosity (η_r)	$\frac{\eta_r - 1}{\sqrt{C}}$
1	0.051012	0.049818	1.008821	0.007396	0.915853	-0.37700
2	0.110421	0.099074	1.014272	0.007408	0.917344	-0.26255
3	0.150352	0.147426	1.019653	0.007530	0.932385	-0.17605
4	0.200341	0.195207	1.026794	0.007706	0.954183	-0.10372
5	0.310854	0.291085	1.042968	0.008156	1.009927	0.01840

Table-3: Values of constant A of Jones Dole Equation for $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ in water and in aqueous solution of Glycine

Sl. No.	Molality of glycine (mol kg^{-1})	Values of Constant A ($\text{cm}^{3/2} \text{mol}^{-1/2} \times 10^{3/2}$)			
		305 K	315 K	325 K	335 K
1	0.00	- 0.317	- 0.136	- 0.087	- 0.072
2	0.05	- 0.725	- 0.326	- 0.232	- 0.217
3	0.10	- 0.856	- 0.374	- 0.269	- 0.236
4	0.15	- 0.920	- 0.800	- 0.635	- 0.431
5	0.20	-0.933	- 0.866	- 0.691	- 0.160
6	0.30	-0.656	-0.444	- 0.466	- 0.326

Table - 4 Values of constant B of Jones Dole Equation for $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ in water and in aqueous solution of Glycine.

S. No.	Molality of glycine (mol kg^{-1})	Values of Constant B ($\text{cm}^3 \text{mol}^{-1} \times 10^3$)			
		305 K	315 K	325 K	335 K
1	0.00	1.207	0.820	0.715	0.675
2	0.05	1.507	0.885	0.737	0.689
3	0.01	1.858	0.969	0.848	0.745
4	0.15	1.975	1.544	1.107	0.775
5	0.20	2.022	1.747	1.445	0.865
6	0.30	1.250	1.031	0.998	0.739

Conclusion

The experimental data of density viscosity and related parameter of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ in aqueous and in binary aqueous solution of glycine have been reported at 305 K. This work reveals the various kinds of interactions present in binary and ternary solutions of copper sulphate in the presence of amino acids.

The viscosity data accurately calculated with the Jones_Dole equation indicate positive values for B-coefficient for all the studies systems. On the basis of the viscometric studies and results we conclude that copper sulphate gave Kosmotrope behaviour (structure making for pure water and for aqueous amino acid solutions).

References

1. Shema khan, Rashmi Sharma, Journal of physical science, **Vol. 30** (2), 51 (2019).
2. Kalpana Shahi and Monika Singh., *J. Chemtracks*, **15** (1), 91 (2013).
3. Kalpana Shahi, Preety Pandey, Monika Singh And Sudhir Kumar, *J. Chemtracks*, **15**(2) 541(2013).
4. Kalpana Shahi, Preety Pandey, Monika Singh And Sudhir Kumar, *J. Chemtracks*, **14**(2) 521 (2012).
5. Sundaramurthi, N., Rajamannan, B., and Rajalakshmi S. *International Journal of Current research*. **Vol. 3** pp.89, April, (2010).
6. K.D Umaley, G.B. Pethe, and A.S aswar *Russian Journal of Physical chemistry B*, **Vol.7**, pp-11-12, (2013).
7. M. L. Parmar and D.S. Banyal, *J. Indain Chem. Soc.* **Vol. 84**, pp577 June 2007
8. Reena Gupta and Mukhtar Singh, *J. Chem, Soc.*, **Vol 81**, July 2004, pp.561-569.
9. Man singh and Manisha Pandey, *J. Indain chem. Soc.* **82**,1091 (2005).
10. B. Nagedra Prasad, N. surendra Babu, M. C. S. subha and K Chowdaji Rao, *J. Indain Chem. Soc.*, **77**, 8 (2000).
11. Shipra Baluja, Ashif Solanki, nirmal Pandya and Nikunj S. Kachhadia, *J. Indian Chem. Soc.* **Vol 84**,1130 (2007).
12. Rita mehra and Brij Bihari Malav, *J. Chem. Bio. Phy. Sci.* **Vol. 12 A**, 153 (2011).
13. G.Jones and M. Dole, *J. Am Chem. Soc.* **51**, 2950 (1929)
14. H.falkenhagen and E. L Vernan. *Z. Phys*, 33,140 (1932)
15. B.Hribar, N.T southhall, V. vlachy and K.A.Dill, *J. Am. Chem. Soc.* **124**, 12302 (2009).
16. Bhoj Bhadur Gurung, Ankan choudhary, Mahendra nath ray, *J. Indian Chem. Soc.*, **Vol. 81**, pp.330 (2004).
17. Thirumaran S. Sathish K, *Research Journal of Chemical Science*, **Vol-1(18)**, 63 Nov. (2011)
18. Amlendu pal and Rekha Gaba, *J.Indian Chem.soc.*, **Vol, 84**, pp-661, (2007)
19. Amalia, stefaniu, Olga iulian and oana ciocirlan, *Rev. Roum, chim*, **56(9)** 869 (2011).
20. M. L Parnar, R. C Thakur, *Journal of Molecular liquids*, **128**, 85 (2006).
21. M. L Parnar, praveen Sharma and M. K Gularia *Indan Journal of Chemistry*, **Vol. 48 A**, 57().
22. Mithlesh and Mukhtar singh. *J. Indian Chem. Soc.* **Vol. 83**, pp-803-812, Aug (2006).