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"Comparative Study Of Temperature Effect On Viscosity And Apparent Molar Volumes Of Potassium Aluminium Sulphate In Binary Mixture Of Aqueous DMSO And Aqueous DMF."

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Abstract: ***Viscosity B coefficients and apparent molar volumes (ϕ_v) for potassium aluminium sulphate in pure Dimethylformamide (DMF) and pure Dimethyl sulphoxide (DMSO) and also aqueous Dimethylformamide (DMF) and aqueous Dimethyl sulphoxide (DMSO) were studied from density (ρ) and viscosity (η) at various temperatures as 308.15, 313.15, 318.15 and 323.15 K with help of bicapillary pycnometer and Ubbelohde viscometer instruments respectively.***

Keywords: Viscosity; potassium aluminium sulphate; Jone-Dole equation; DMF; DMSO.

1. INTRODUCTION

The maximum numbers of reactions that are of chemical or biological interest occur in aqueous as well as in non aqueous solutions. It has become increasingly clear during the past decades that the properties of the majority of the solute are significantly modified by all solvents. Conversely, the nature of the strongly structured solvents such as water is substantially modified by the presence of certain solutes. In the recent years, considerable work was done to explore the reason for such modifications have appeared in the literature. In understanding the behaviour of such solutions, the knowledge of solute-solvent, ion - ion and ion - solvent interactions in a solvent is essential. In order to investigate ion – solvent and solute – solvent interaction, it is essential to carry out characterizations[1,2] of electrolytic solutions by carrying out all measurements either at infinite dilution or to extrapolate results to infinite dilution so as to exclude the effect of ion - ion interaction.

The Ram Gopal and researchers[3,4] were reported the study of some common salts and tetra-alkyl ammonium iodides in N- methyl acetamide (NMA), N- methyl propionamide (NMP), dimethyl sulphoxides (DMSO)and propylenecarbonate (PC). Dependence of the apparent molal volume on concentration has been successfully represented by Masson's equations[5].

$$\Phi_v = \Phi_v^0 + S_v \sqrt{C} \quad \ldots (1)$$

Where ϕ_v is the apparent molal volume of an electrolyte, ϕ_v^0 is the limiting apparent molal volume and S_v is the experimental slope. It is believed that the salts, having small ions, have positive slop (S_v) of the Masson's equations (1) in solvents of high dielectric constant and it is further divided that the sign of the slop, S_v, can be interpreted in terms of solute – solvent interactions.

Variation of limiting apparent molal volumes, Φ_v^0, of electrolytes with temperature has also been employed to study solute – solvent interactions by many researchers working on the

same[6,7] both in aqueous and non aqueous solutions, probably it is the simplest thermodynamic property to measure.

At concentrations C, less than 0.1 mol.dm^{-3}, the relative viscosity η_r of a binary electrolyte solution can be represented by the Jones and Dole[8] equation.

$\eta_r = \eta/\eta_0 = AC^{1/2} + BC$ ……(2)

Where η and η_0 are the solution and the solvent viscosities. A and B are constant characteristics of the electrolytes. The A coefficient represents the contribution from the interionic electrostatic forces[9]. The B coefficient represents the solute – solvent and ion – solvent interactions and measures the order or disorder introduced by the ions into the solvent structre.

Generally all the liquids are somewhat viscous in nature due to its shearing effect in the liquid which is the movement of liquid layers over each other. The important information regarding solute-solvent, solute-solute and solvent-solvent interactions in an aqueous solution studied viscometrically. The molecular interactions of an electrolyte in binary mixtures of liquids studied by Kapadi and Das[10] has done by viscometrically study of N,N-dimethyl acetamide and ethanol binary mixtures at various temperatures. Viscosity concentration dependence of dilute electrolyte solution was studied by the Jones-Dole equation. Interactions of electrolytes in binary mixtures of two liquids have been studied in terms of B coefficient of viscosity[11].

The aim of the present work is to understand molecular interactions as well as solvation behaviour of potassium aluminium sulphate in various compositions of binary mixture solutions of pure DMF, DMSO and aqueous DMF and aqueous DMSO at various temperatures.

2. MATERIALS AND METHODS

All chemicals such as DMSO and DMF used were of analytical grade and purchased from Merck, Germany, used without further purification. Demineralised water were double distilled and used. The component potassium aluminium sulphate was purified by crystallization and dried in oven at 50 ^{O}C and then used to prepare solutions of different proportion.

Viscosity measurements

The dynamic viscosities of the solution were evaluated by measuring flow time of solution using an Ubbelohde suspended-level viscometer, calibrated with double distilled demineralised water. The flow time measurements were measure on Electronic digital stopwatch with readability of 0.01 s. At least three repetitions of every data measurement carried out. Viscosity values of solution were determined using the relation[12].

$\eta_1/\eta_2 = \rho_1 t_1/\rho_2 t_2$ … (3)

Preparation of Solution of Electrolytes

In present work potassium aluminium sulphate is used as electrolyte. Molecular weight of potassium aluminium sulphate is 474.39 gm/mole. The electrolyte potassium aluminium sulphate used was AR grade quality (99.5% pure E-Merck chem.) was used as such without further purification. Accurately weight amounts of electrolytes were dissolved in a particular solvent to give a concentration of 1 M. This served as stock solution. After formation of stock solution of potassium aluminium sulphate, this stock solution were used for preparation of different concentration like 0.008M, 0.01M, 0.02M, 0.04M, 0.06M, 0.08M and 0.1M concentration in distilled water. These concentrations were obtained by using dilution technique.

The concentrations of solutions varied from 0.008 M to 0.1 M. 0 % DMF, 10 % DMF,20 % DMF, 30 % DMF, 40 % DMF, 50 % DMF, 60 % DMF, 70 % DMF, 80 % DMF, 90 % DMF

and 100 % DMF similar was prepared for the DMSO were used as solvents for to prepare the molal concentration of potassium aluminium sulphate. Stock solutions of ionic liquids were prepared by mass and then diluted by N,N- Dimethylformamide- water and dimethylsulphoxide - water to get the test sample. The aqueous solution of potassium aluminium sulphate was made by weight and molarities were converted in to molarities.

Solutions of the salt were prepared by weighing dilution of stock solution using analytical balance. All the preparations and manipulations involving anhydrous material were performed in dry box. The solutions were stored in dark colour amber bottles which were kept in a dry box. Two sets of potassium aluminium sulphate in two solvent system N,N-Dimethylformamide–water and dimethylsulphoxide – water are designated as two systems.

3. RESULTS AND DISCUSSION

The apparent molar volume of solution was calculated from density data using the given equation[13,14].

$\Phi_v = [1000(\rho_0 - \rho)/C\rho_0] + [M/\rho_0]$ … (4)

Where M, C, ρ_0 and ρ are the molar mass of the potassium aluminium sulphate, concentration of salts in aqueous DMF or DMSO (mol L^{-1}) and the densities of the solvent and solution respectively.

Apparent molar volume of solution may be considered to be the sum of the geometric volume of the solute molecules and changes that occur in to the solution due to its solute - solvent interaction. The limiting partial molar volumes were evaluated by Masson equation[15] and experimental slope by least square method[16].

$\Phi_v = \Phi_v^0 + S_v\sqrt{C}$ … (5)

Where ϕ_v^0 is limiting apparent molar volume and S_v a semi empirical parameter which depends on the temperature, nature of solvent and solute.

The relative viscosities have been analyzed by Jones-Dole equation[32] given as.

$(\eta_r - 1)/\sqrt{C} = A + B\sqrt{C}$ … (6)

Where $\eta_r = (\eta/\eta_o)$ and η, η_o are viscosities of the solution and solvent respectively, C is molar concentration, A is the Falkenhagen coefficient which is the measure of solute-solute interactions[17] and B is the Jones- Dole coefficient which is the measure of solute - solvent interaction.

Finally the Moulik and Roots parameters were evaluated by the given equations[18,19].

$\eta_r^2 = M + KC^2$ … (7)

$(\rho - \rho_0)/C = R - SC^{1/2}$ … (8)

Values of standard densities and viscosities of pure components i.e. pure aqueous DMF and aqueous DMSO were given in table 1 to 6 also it is compared with values reported by various researchers working in the same fields.

A plot of apparent molar volumes (ϕ_v) vs. $\sqrt{C}$ was found with positive slopes in different compositions of binary liquid mixture of aqueous DMF and aqueous DMSO and is shown in figure 1 at 308.15 K.

The limiting apparent molar volumes (ϕ_v^o) of the solutions were calculated using equation (5) from the intercept of linear plots, it is listed in Table 13. The (ϕ_v^o) values provide us the information regarding the solute-solvent interactions in the solution, it is close values to Table 13, shows the positive values of limiting apparent molar volume (ϕ_v^o). These positive values of (ϕ_v^o) show strong solute-solvent interactions[20,21]. The positive values of S_v show strong solute - solute interactions. With rise in temperature S_v values increase it indicates an increased solute-solute interaction in solution.

Viscosities (η) of the binary mixture solution increases with increasing concentration of solution while decreases with rise in temperature or vice versa. This indicated the existence

of molecular interactions occurring in the system. The viscosity data of the solution were analyzed by using Jones –Dole equation (6). The values of 'A' and 'B' coefficients are recorded in Table 14. All the values of 'A' coefficient are positive showing solute-solute interaction[22]. The value of 'A' coefficient increases with increase in concentration of potassium aluminium sulphate in binary liquid mixture of aqueous DMF + aqueous DMSO solutions. Further the value of 'A' coefficient increases with rise in temperature form 308.15 K to 323.15 K.

The viscosity 'B' coefficients are positive for all the composition of potassium aluminium sulphate in binary liquid mixture of aqueous DMF + aqueous DMSO solutions. The value of 'B' coefficient increases with increase in concentration of salts in aqueous DMF + aqueous DMSO solutions. Further the value of 'B' coefficient increases with rise in temperature which due to solute-solvent interaction[23].

Finally the values of 'R' and 'S' coefficients of Root's equation are recorded in table 14. The 'R' coefficients of Root's equation for all compositions are positive. The positive values show strong solute-solute interactions. The 'S' coefficients of Root's equation for all compositions are negative. The values of 'M' and 'k' coefficients of Moulik equation were tabulated in table 14. 'M' and 'K' coefficients are positive in all solvent systems and temperatures. 'M' values are of low magnitudes and 'K' values are of higher magnitudes. These models also support the presence of strong solute-solute interactions.

Table 1 Experimental density □□ and viscosity η data for DMF – water mixtures at 308.15, 313.15, 318.15 and 323.15 K.

Wt. % of DMF	308.15K	313.15K	318.15K	323.15K
□□ / g cm^{-3}				
0	0.99715	0.99459	0.99102	0.99232
20	099601	0.99449	0.99291	0.99099
40	0.99565	0.99391	0.99208	0.98982
60	0.99544	0.99308	0.99092	0.99841
80	0.99954	0.99926	0.99201	0.99923
η/ mpa s				
0	0.9010	0.7890	0.7230	0.6662
20	1.0015	0.8928	0.7972	0.7198
40	1.1256	0.9962	0.8901	0.8006
60	1.2598	1.1126	0.9861	0.8808
80	1.3256	1.2632	0.9956	0.8932

Table 2 Experimental density □ and viscosity η data for DMSO – water mixtures at 308.15, 313.15, 318.15 and 323.15 K.

Wt. % of DMSO	308.15K	313.15K	318.15K	323.15K
□ / g cm^{-3}				
0	0.99705	0.99565	0.99403	0.99222
20	1.01028	1.00935	1.00774	1.00591
40	1.01286	1.01011	1.00904	1.00827
60	1.01422	1.01225	1.011024	1.00925
80	1.02655	1.01925	1.020526	1.00992
η/ mpa s				
0	0.8905	07980	0.71901	065301
20	1.10230	1.09605	1.08906	1.08186
40	1.11038	1.10212	1.10095	1.08963

60	1.11717	1.11497	1.10751	1.10118
80	1.11895	1.11695	1.10956	1.10191

Table 3 Physical properties of pure liquid - Water.

Temp. K	□ / g cm^{-3}		ɳ/ mpa s	
	Expt.	Lit.	Expt.	Lit.
308.15	0.99715	0.99705[24] 0.997045[25] 0.997047[26]	0.9010	0.891[71] 0.890[72] 0.8905[27]
313.15	0.99459	0.99565[71] 0.99565[73]	0.7890	0.798[71] 0.796[74]
318.15	0.99102	0.99403[71] 0.994031[72] 0.994032[73]	0.7230	0.719[71] 0.7190[73]
323.15	0.99232	0.99222[71]	0.6662	0.653[71] 0.6523[74] 0.6560[28]

Table 4 Physical properties of pure liquid – N,N-dimethyl formamide (DMF).

Temp. K	□ / g cm^{-3}		ɳ/ mpa s	
	Expt.	Lit.	Expt.	Lit.
308.15	0.9444	0.9445[71] 0.9444[29]	0.794	0.794[71] 0.790[30]
313.15	0.9430	0.943[77] 0.9398[31] 0.9406[32]	0.750	0.750[77]
318.15	0.9400	0.940[77] 0.9358[33]	0.711	0.710[77]
323.15	0.9370	0.937[77] 0.9310[79]	0.681	0.681[77]

Table 6 Physical properties of pure liquid – Dimethyl sulphoxide (DMSO).

Temp. K	□ / g cm^{-3}		ɳ/ mpa s	
	Expt.	Lit.	Expt.	Lit.
308.15	1.09541	1.09541[34] 1.0950[35] 1.0952[36]	1.993	1.991[71] 1.990[82] 1.993[83]
313.15	1.09049	1.0904[71] 1.0905[83] 1.09049[83]	1.807	1.808[71]
318.15	1.0853	1.0854[71]	1.691	1.690[71]
323.15	1.0804	1.0804[83]	1.512	1.511[71]

Table 7 Concentration (C), Density (ρ), Viscosity (η), apparent molar volume (ϕ_v) of potassium aluminium sulphate in aqueous DMF and 10% DMSO.

C/ mol/ dm^3	**ρ/ g.cm^3**	**η/ Nm^{-3} s.**	**ϕ_v/ cm^3 mol^{-1}**	**ρ/ g.cm^3**	**η/ Nm^{-3}s.**	**ϕ_v/ cm^3 mol^{-1}**	**ρ/ g.cm^3**	**η/ Nm^{-3}s.**	**ϕ_v/ cm^3 mol^{-1}**	**ρ/ g.cm^3**	**η/ Nm^{-3} s.**	**ϕ_v/ cm^3 mol^{-1}**

DMF												
	308.15K			313.15K			318.15K			323.15K		
0.0150	0.94868	0.8173	47.53	0.94181	0.7239	55.06	0.93949	0.7295	57.03	0.93235	0.6998	65.56
0.0329	0.95324	0.8102	54.75	0.94834	0.7436	58.39	0.94358	0.7400	63.99	0.93554	0.7136	71.73
0.0577	0.95589	0.8405	59.48	0.95402	0.7907	66.34	0.94773	0.7557	77.23	0.94983	0.7205	76.21
0.0894	0.96463	0.8889	62.83	0.95673	0.8110	69.38	0.95892	0.7746	79.61	0.94753	0.7454	81.72
0.1281	0.96769	0.8938	68.53	0.96436	0.8234	74.41	0.95941	0.7960	85.78	0.95777	0.7756	90.50
10 % DMSO												
	308.15K			313.15K			318.15K			323.15K		
0.0150	0.96259	0.8144	47.13	0.96245	0.8342	58.55	0.95251	0.7714	65.21	0.95549	0.77572	71.19
0.0329	0.96813	0.8535	51.29	0.96452	0.8458	62.24	0.95349	0.8844	71.49	0.95735	0.79552	73.22
0.0577	0.97974	0.9867	64.59	0.96972	0.8674	76.37	0.96417	0.8905	76.34	0.95653	0.84275	86.14
0.0894	0.97852	0.9603	68.57	0.97467	0.8998	79.94	0.96553	0.8908	83.14	0.96797	0.83358	91.76
0.1281	0.98198	0.9491	71.87	0.98744	0.9043	83.37	0.97671	0.8651	91.37	0.96941	0.86789	99.45

Table 8 Concentration (C), Density (ρ), Viscosity (η), apparent molar volume (ϕ_v) of potassium aluminium sulphate in aqueous DMF and 20% and 30% DMSO.

C/ mol/ dm^3	ρ/ g.cm^3	η/ Nm^{-3} s.	ϕ_v/ cm^3 mol^{-1}	ρ/ g.cm^3	η/ Nm^{-3} s.	ϕ_v/ cm^3 mol^{-1}	ρ/ g.cm^3	η/ Nm^{-3} s.	ϕ_v/ cm^3 mol^{-1}	ρ/ g.cm^3	η/ Nm^{-3} s.	ϕ_v/ cm^3 mol^{-1}
20 % DMSO												
	308.15K			313.15K			318.15K			323.15K		
0.0150	0.94860	0.8175	48.55	0.94185	0.7234	56.08	0.93969	0.7195	56.02	0.93255	0.6918	66.57
0.0329	0.95326	0.8104	55.77	0.94834	0.7437	59.34	0.94378	0.7300	62.98	0.93574	0.7156	72.77
0.0577	0.95581	0.8407	58.49	0.95408	0.7905	68.34	0.94793	0.7457	75.28	0.94903	0.7225	77.29
0.0894	0.96465	0.8888	63.82	0.95678	0.8112	70.34	0.95812	0.7646	78.64	0.94773	0.7474	82.73
0.1281	0.96761	0.8934	69.52	0.96434	0.8236	75.47	0.95961	0.7860	84.75	0.95797	0.7776	91.59
30 % DMSO												
	308.15K			313.15K			318.15K			323.15K		
0.0150	1.02967	1.2215	62.38	1.02677	1.1355	68.50	1.01842	1.0577	74.19	1.01461	1.0119	79.08
0.0329	1.03288	1.2443	69.325	1.02987	1.1498	76.54	1.02183	1.0749	81.15	1.01752	1.0325	86.54

0.0577	1.03609	1.2517	75.98	1.03397	1.1605	82.55	1.02554	1.0975	89.15	1.02131	1.0659	90.44
0.0894	1.04112	1.2833	83.92	1.03886	1.1935	89.20	1.03042	1.1249	93.05	1.02543	1.0984	98.34
0.1281	1.04741	1.3073	89.31	1.04433	1.2116	95.65	1.03556	1.1584	102.34	1.03079	1.1348	108.64

Table 9 Concentration (C), Density (ρ), Viscosity (η), apparent molar volume (ϕ_v) of potassium aluminium sulphate in aqueous DMF and 40% DMSO and 50% DMSO.

C/ mol/ dm^3	ρ/ g.cm^3	η/ Nm^{-3} s.	ϕ_v/ cm^3 mol^{-1}	ρ/ g.cm^3	η/ Nm^{-3} s.	ϕ_v/ cm^3 mol^{-1}	ρ/ g.cm^3	η/ Nm^{-3} s.	ϕ_v/ cm^3 mol^{-1}	ρ/ g.cm^3	η/ Nm^{-3} s.	ϕ_v/ cm^3 mol^{-1}
40 % DMSO												
	308.15K			313.15K			318.15K			323.15K		
0.0150	1.07489	1.8256	61.55	1.08542	1.6542	72.85	1.07445	1.5261	77.32	1.07155	1.4492	81.45
0.0329	1.08748	1.8642	76.21	1.08555	1.7630	75.64	1.07705	1.5418	81.70	1.07325	1.4792	87.29
0.0577	1.09129	1.9532	85.54	1.08572	1.7348	88.24	1.08018	1.5848	92.76	1.07771	1.5192	97.14
0.0894	1.09842	1.9413	92.94	1.09951	1.7935	93.24	1.08562	1.6265	99.10	1.08196	1.5642	107.81
0.1281	1.10478	1.9699	98.64	1.09164	1.8754	109.14	1.08983	1.6773	106.81	1.08552	1.6116	113.94
50% DMSO												
	308.15K			313.15K			318.15K			323.15K		
0.0150	1.09799	2.0159	73.12	1.09353	1.8273	76.05	1.08754	1.6452	85.44	1.08553	1.5444	91.84
0.0329	1.10074	2.0315	81.42	1.09649	1.8452	85.18	1.09079	1.6774	91.35	1.08747	1.5821	96.44
0.0577	1.10434	2.0623	88.25	1.10059	1.8747	92.17	1.09893	1.7156	101.54	1.09054	1.6243	105.94
0.0894	1.10842	2.1071	97.74	1.10483	1.9197	101.15	1.09976	1.7665	107.04	1.09422	1.6720	114.84
0.1281	1.11344	2.1642	104.34	1.10874	1.9673	108.92	1.10196	1.8175	116.14	1.09791	1.7342	124.24

Table 10 Concentration (C), Density (ρ), Viscosity (η), apparent molar volume (ϕ_v) of potassium aluminium sulphate in aqueous DMF and 60% and 70% DMSO.

C/ mol/ dm^3	ρ/ g.cm^3	η/ Nm^{-3} s.	ϕ_v/ cm^3 mol^{-1}	ρ/ g.cm^3	η/ Nm^{-3} s.	ϕ_v/ cm^3 mol^{-1}	ρ/ g.cm^3	η/ Nm^{-3} s.	ϕ_v/ cm^3 mol^{-1}	ρ/ g.cm^3	η/ Nm^{-3} s.	ϕ_v/ cm^3 mol^{-1}
60 % DMSO												
	308.15K			313.15K			318.15K			323.15K		
0.0150	0.98976	0.8145	46.68	0.94605	0.7724	55.80	0.93915	0.7377	62.80	0.93557	0.7095	69.88
0.0329	0.95898	0.8205	52.07	0.95009	0.7844	58.57	0.94394	0.7469	68.34	0.93945	0.7137	72.84

0.0577	0.99538	0.8306	60.04	0.95549	0.8088	65.87	0.94872	0.7676	72.45	0.94471	0.7389	80.31
0.0894	0.98682	0.8495	66.94	0.96174	0.8175	74.87	0.95449	0.7881	74.88	0.95082	0.7549	88.47
0.1281	0.99505	0.8616	74.20	0.96897	0.8396	74.96	0.96177	0.8142	84.85	0.95677	0.7875	98.89
70 % DMSO												
	308.15K			313.15K			318.15K			323.15K		
0.0150	0.96558	0.8887	57.88	0.96075	0.8472	58.51	0.95522	0.7942	69.30	0.95146	0.7851	76.53
0.0329	0.96944	0.8966	59.04	0.96442	0.8548	66.24	0.95953	0.8156	74.71	0.95531	0.8024	82.65
0.0577	0.97472	0.9156	65.67	0.96852	0.8654	73.35	0.96448	0.8367	82.31	0.95982	0.8237	84.25
0.0894	0.98085	0.9346	74.27	0.97367	0.8878	79.94	0.96982	0.8525	88.44	0.96544	0.8496	91.14
0.1281	0.98751	0.9573	79.67	0.98378	0.9293	89.64	0.97673	0.8757	96.59	0.97170	0.8805	102.13

Table 11 Concentration (C), Density (ρ), Viscosity (η), apparent molar volume (ϕ_v) of potassium aluminium sulphate in aqueous DMF and 80% DMSO and 90% DMSO.

C/ mol/ dm^3	ρ/ g.cm^{-3}	η/ Nm^{-3} s.	ϕ_v/ cm^3 mol^{-1}	ρ/ g.cm^{-3}	η/ Nm^{-3} s.	ϕ_v/ cm^3 mol^{-1}	ρ/ g.cm^{-3}	η/ Nm^{-3} s.	ϕ_v/ cm^3 mol^{-1}	ρ/ g.cm^{-3}	η/ Nm^{-3} s.	ϕ_v/ cm^3 mol^{-1}
80 % DMSO												
	308.15K			313.15K			318.15K			323.15K		
0.0150	1.08567	1.8772	70.39	1.08167	1.6942	75.86	1.07481	1.5251	75.34	1.07251	1.4577	86.18
0.0329	1.08841	1.8967	74.25	1.08483	1.7161	84.87	1.07786	1.5478	82.77	1.07555	1.4925	95.25
0.0577	1.09288	1.9257	84.25	1.08892	1.7576	92.57	1.08041	1.5866	91.74	1.07988	1.5373	104.89
0.0894	1.09777	1.9643	97.95	1.09359	1.7966	99.27	1.08553	1.6275	99.10	1.08372	1.5576	108.04
0.1281	1.10392	2.0013	104.00	1.09874	1.8480	106.43	1.08975	1.6773	106.84	1.08788	1.6714	116.64
90 % DMSO												
	308.15K			313.15K			318.15K			323.15K		
0.0150	1.09507	2.0243	78.57	1.09553	1.8426	78.84	1.08956	1.6645	85.67	1.08419	1.5647	96.27
0.0329	1.10249	2.0557	85.44	1.09842	1.8597	89.44	1.09271	1.6544	94.14	1.08508	1.6079	105.04
0.0577	1.10653	2.0877	93.74	1.10521	1.8973	96.94	1.09581	1.7375	106.64	1.09849	1.6443	115.34
0.0894	1.11467	2.1374	102.94	1.10755	1.9556	107.25	1.09482	1.7853	115.07	1.05624	1.7722	118.94
0.1281	1.11552	2.1886	108.77	1.11059	1.9473	118.24	1.15393	1.8796	124.25	1.08986	1.7644	132.44

Table 12 Concentration (C), Density (ρ), Viscosity (η), apparent molar volume (ϕ_v) of potassium aluminium sulphate in aqueous DMSO.

C/ mol/ dm^3	ρ/ g.cm^3	η/ Nm^{-3} s.	ϕ_v/ cm^3 mol^{-1}	ρ/ g.cm^3	η/ Nm^{-3} s.	ϕ_v/ cm^3 mol^{-1}	ρ/ g.cm^3	η/ Nm^{-3} s.	ϕ_v/ cm^3 mol^{-1}	ρ/ g.cm^3	η/ Nm^{-3} s.	ϕ_v/ cm^3 mol^{-1}
DMSO												
	308.15K			313.15K			318.15K			323.15K		
0.0150	1.09524	2.0242	73.54	1.09542	1.8553	78.12	1.09279	1.6775	93.36	1.08247	1.8561	96.45
0.0329	1.10852	2.0453	86.44	1.09858	1.8287	84.42	1.05551	1.6485	96.24	1.09458	1.6849	109.24
0.0577	1.10556	2.0585	95.77	1.10048	1.8477	98.14	1.09753	1.7675	107.46	1.09456	1.6445	116.24
0.0894	1.10872	2.1078	98.74	1.10575	1.8823	99.99	1.09661	1.7385	109.46	1.09495	1.6765	119.84
0.1281	1.11052	2.1545	118.28	1.10485	1.9957	109.12	1.09852	1.7866	116.45	1.09454	1.7245	128.90

Figure 1: Plots of apparent molar volume ϕ_v vs. solvent percentage for potassium aluminium sulphate in binary liquid mixture of aqueous DMF + aqueous DMSO solution at 308.15 K.

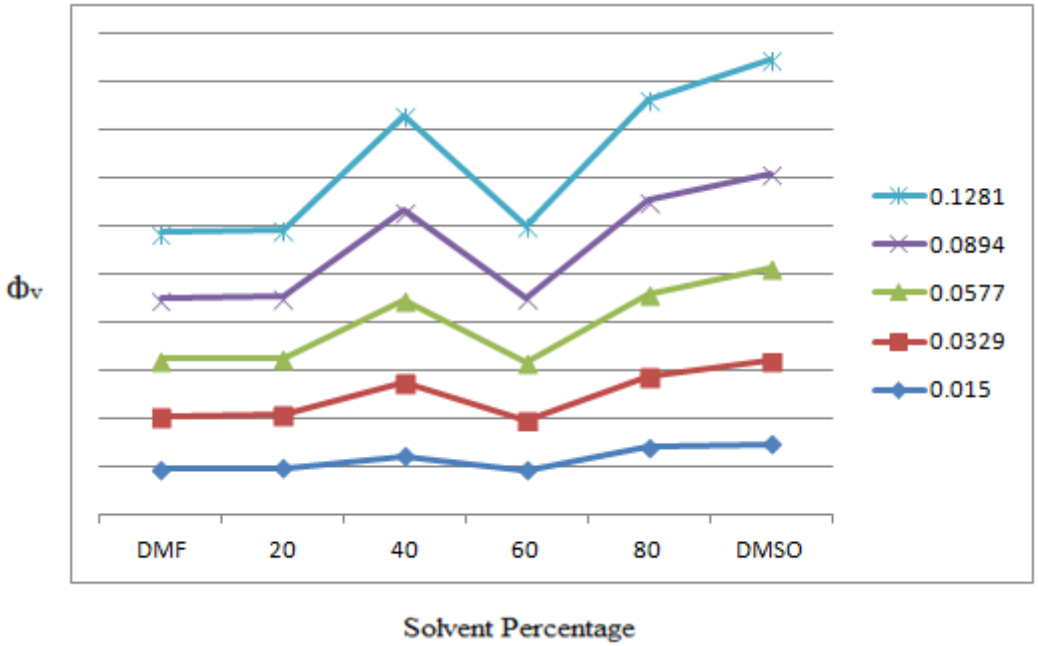

Table 13 ϕ_v^0 ($cm^3.mol^{-1}$), S_V ($cm^3.mol^{-2/3}.L^{1/2}$), A ($dm^{3/2}.mol^{-1/2}$) and B (dm^3. mol^{-1}) of potassium aluminium sulphate in different compositions of aqueous DMF and aqueous DMSO at different temperatures.

Temp. (K)	**DMF**	**20% DMSO**	**40% DMSO**	**60% DMSO**	**80% DMSO**	**DMSO**
	ϕ_v^o ($cm^3.mol^{-1}$)					
308.15	31.80	35.13	42.19	49.46	48.25	55.33
313.15	37.23	46.28	48.85	54.08	58.78	56.58
318.15	41.48	56.14	57.66	57.25	68.94	58.29
323.15	53.18	59.92	63.49	65.24	69.99	64.39
	S_V ($cm^3.mol^{-2/3}.L^{1/2}$)					

308.15	98.52	102.2	112.9	112.5	124.2	129.4
313.15	104.5	113.4	114.7	115.3	127.3	134.5
318.15	107.1	116.4	119.8	121.1	132.4	138.4
323.15	109.7	109.4	111.7	122.7	134.8	143.1
	A ($dm^{3/2}.mol^{-1/2}$)					
308.15	0.013	0.014	0.020	0.024	0.024	0.027
313.15	0.026	0.029	0.028	0.028	0.029	0.033
318.15	0.064	0.057	0.063	0.068	0.069	0.069
323.15	0.079	0.073	0.083	0.086	0.086	0.088
	B (dm^3. Mol^{-1})					
308.15	0.496	0.527	0.524	0.528	0.536	0.546
313.15	0.603	0.614	0.606	0.627	0.648	0.659
318.15	0.708	0.719	0.628	0.726	0.744	0.761
323.15	0.813	0.838	0.846	0.860	0.869	0.906

Table 14 Moulik constants (M and K) and Roots parameters (R and S) of potassium aluminium sulphate in different compositions of aqueous DMF and aqueous DMSO at different temperatures.

Temp. (K)	**DMF**	**20% DMSO**	**40% DMSO**	**60% DMSO**	**80% DMSO**	**DMSO**
	M					
308.15	1.064	1.046	1.044	1.043	1.041	1.043
313.15	1.088	1.054	1.053	1.051	1.051	1.054
318.15	1.118	1.071	1.067	1.071	1.071	1.0642
323.15	1.148	1.086	1.087	1.085	1.084	1.087
	K					
308.15	6.388	6.856	6.983	6.998	7.186	7.329
313.15	8.055	8.337	8.176	8.461	8.735	9.084
318.15	10.60	10.38	9.324	10.71	11.16	11.35
323.15	12.39	12.68	12.86	12.95	13.18	13.84
	R					
308.15	-0.231	-0.228	-0.210	-0.204	-0.204	-0.197
313.15	-0.220	-0.219	-0.216	-0.208	-0.198	-0.195
318.15	-0.211	-0.204	-0.209	-0.197	-0.199	-0.192
323.15	-0.215	-0.115	-0.195	-0.195	-0.184	-0.181
	S					
308.15	0.098	0.124	0.117	0.114	0.124	0.134
313.15	0.096	0.125	0.114	0.124	0.127	0.145
318.15	0.094	0.151	0.126	0.127	0.134	0.144
323.15	0.106	0.176	0.128	0.124	0.149	0.155

4. CONCLUSION

In the summary, density and viscosity of potassium aluminium sulphate solutions in binary mixture of aqueous DMSO and aqueous DMF are at 308.15, 313.15, 318.15 and 323.15 K temperatures is studied. All the values of ϕ_v^0 at various temperatures are higher and positive, these suggest the strong solute - solvent interactions in binary mixture of aqueous DMF +

aqueous DMSO. Values of S_v are positive and also showing strong solute - solute interactions in electrolytic solutions of potassium aluminium sulphate. The positive values of Jones-Dole coefficient 'B' indicate strong interactions between solute and solvent at high temperature. B coefficient of potassium aluminium sulphate increases with temperatures. The Masson's equations and Jones-Dole equations were found to be obeyed for all three salts in binary mixture aqueous DMF + aqueous DMSO. Also the Root's and Moulik equations were found to be obeyed for potassium aluminium sulphate in binary liquid mixture aqueous DMSO and aqueous DMF.

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