ScienSage

Journal of Advanced Scientific Research

Available online through http://www.sciensage.info

ISSN
0976-9595
Research Article

STUDY THE TEMPERATURE EFFECT ON APPARENT MOLAR VOLUMES AND VISCOSITY (JONES DOLE COEFFICIENT) OF MAGNESIUM SULPHATE, ALUMINIUM AMMONIUM SULPHATE AND POTASSIUM ALUMINIUM SULPHATE IN BINARY MIXTURE OF AQUEOUS DMF AND AQUEOUS DMSO

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ABSTRACT

The apparent molar volumes (ϕ_v) and viscosity B coefficients (Jones Dole)for Magnesium sulphate, Aluminium ammonium sulphate and Potassium aluminium sulphate in aqueous Dimethylformamide (DMF) and aqueous Dimethyl sulphoxide (DMSO) were evaluated from density (ρ) and viscosity (η) at various temperatures as 308.15, 313.15, 318.15 and 323.15K with help of bicapillary pycnometer and Ubbelohde viscometer instruments respectively. The densitydata for all the solutions were analyzed in limiting apparent molar volume (ϕ_v°) and experimental slopes (S_v) obtained from Masson equation. The viscosity data of solution were analyzed in term of A and B coefficient obtained from Jone-Dole equation.

Keywords: Density, viscosity, Magnesium sulphate, Aluminium ammonium sulphate, Potassium aluminium sulphate, Apparent molar volume, A and B coefficient

1. INTRODUCTION

The up growing use of sulphated fertilizers in the agricultural sector has led to several environmental problems in due course. Due to excess use of fertilizers, residues are present in soil and it could affect man's health. The occurrence of appreciable amounts of certain fertilizers and pesticides in human tissues of general population gives sufficient reason for concern [1] in recent years, an increased awareness of the possible accumulation or persistence of toxic compounds in the environment has stimulated research into the fate of agrochemicals within plant tissues and also into the uptake and distribution of other exogenous materials [2].

On the other hand, the thermodynamics of various liquids is a subject of great importance in chemical engineering and physical chemistry. The properties of all liquid mixtures basically depend on its structure, expressed in terms of volume and packing density. It also changes with composition and temperature of the system. The type and nature of interactions in binary liquid mixtures have been studied in terms of mixing parameters such as excess molar volume [3].

Generally the liquids are viscous in nature due to shearing effect in the liquid which is the movement of liquid layers over each other. The important information regarding solute-solute, solute-solvent and solvent-solvent interactions in an aqueous solution studied is viscometric analyses. The molecular interactions of an electrolyte in binary mixtures of liquids studied by Kapadiand Das [4] has done by viscometric studies 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 [5]. Interactions of electrolytes in binary mixtures of two liquids have been studied in terms of B coefficient of viscosity [6].

The aim of the present study was to understand solvation behavior and molecular interactions of Magnesium sulphate, Aluminium ammonium sulphate and Potassium aluminium sulphate in binary mixture of aqueous DMF and aqueous DMSO at different temperatures.

2. MATERIAL AND METHODS

2.1. General

The chemicals DMSO and DMF employed were of analytical grade purchased from Merck, Germany, were used without further purification. The component

Magnesium sulphate, Aluminium ammonium sulphate and Potassium aluminium sulphate were purified and used to prepare solutions of different proportions.

2.2. Density Measurements

The densities (ρ) of the solvent and solutions were measured by a bicapillary pycnometer having a bulb capacity of 10 ml at various temperatures. The pycnometer was calibrated using distilled water.

2.3. Viscosity measurements

The dynamic viscosities of the solution were evaluated by measuring flow time of solution using an Ubbelohde suspended-level viscometer, calibrated with distill water. The flow time measurements were measured on Electronic digital stopwatch with readability of 0.01 s. At least three repetitions of every data measurement were carried out. Viscosity values of solution were determined using the relation [7, 8].

$$\eta_1/\eta_2 = \rho_1 t_1/\rho_2 t_2 \quad \ldots (1)$$

3. RESULTS AND DISCUSSION

The apparent molar volume of solution was calculated from density data using the given equation [9-12].

$$\Phi_v = [1000(\rho_0 - \rho)/C\rho_0] + [M/\rho_0] \quad \ldots (2)$$

Where, M, C, $\rho_0$and ρare the molar mass of the Magnesium sulphate or Aluminium ammonium sulphate or Potassium aluminium sulphate, concentration of salts in aqueous DMF or DMSO (mol L^{-1}) and the densities of the solvent and solution, respectively.

The 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 [13] and experimental slope by least square method [14].

$$\Phi_v = \Phi_v^\circ + S_v\sqrt{C} \quad \ldots (3)$$

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-Doleequation [15] given as:

$$(\eta_r - 1)/\sqrt{C} = A + B\sqrt{C} \quad \ldots (4)$$

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 [16] 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 [17, 18].

$$\eta_r^2 = M + KC^2 \quad \ldots (5)$$

$$(\rho - \rho_0)/C = R - SC^{1/2} \quad \ldots (6)$$

The values of the viscosities (η), densities (ρ) and apparent molar volumes (ϕ_v) of Magnesium sulphate or Aluminium ammonium sulphate or Potassium aluminium sulphate solution in binary liquid mixture of aqueous DMF and aqueous DMSO at 308.15, 313.15, 318.15 and 323.15 K temperature are shown in Table 1 to Table 7.

Hence the densities of solutions of Magnesium sulphate or Aluminium ammonium sulphate or Potassium aluminium sulphate increase with percentage of DMSO in the binary liquid mixture. The ϕ_v values of Magnesium sulphate or Aluminium ammonium sulphate or Potassium aluminium sulphate for all the system are large and positive which indicate strong solute-solvent interaction [19]. These ϕ_v values increasing slowly with salts concentration increase in binary mixtures.

The 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 Fig. 1 at308.15 K. The similar plots were observed for Magnesium sulphate or Aluminium ammonium sulphate or Potassium aluminium sulphate indifferent compositions of binary liquid mixture of aqueous DMF + aqueous DMSO solutions at various temperatures such as 313.15, 318.15 and 323.15 K. The limiting apparent molar volumes (ϕ_v°) of the solutions were calculated using equation (3) fromthe intercept of linear plots, it is listed in Table 8. The (ϕ_v^o) values provide us the information regarding the solute-solvent interactions in the solution, it is close values to Table 8, shows the positive values of limiting apparent molar volume (ϕ_v^o). The sepositive 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, which indicates an increased solute-solute interaction insolution.

The viscosities (η) of the solution increases with increasing concentration of solution and decreases with rise in temperature. This indicated the existence of molecular interactions occurring in the system. The viscosity data of the solution were analyzed by using

Jones-Dole equation (4). The values of 'A' and 'B' coefficients are recorded in Table 8. All the values of 'A' coefficient are positive showing solute-solute interaction [22-24]. The value of 'A'coefficient increases with increase in concentration of Magnesium 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 Magnesium sulphate or Aluminium ammonium sulphate or 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 [25, 26].

Finally the values of 'R' and 'S' coefficients of Root's equation are recorded in Table 9. 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 9. '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: Concentration (C), Density (ρ), Viscosity (η), apparent molar volume (ϕ_v) of Magnesium sulphate in DMF and 20% 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	0.94828	0.8153	46.52	0.94161	0.7219	54.04	0.93929	0.7293	56.00	0.93215	0.6978	64.55
0.0329	0.95284	0.8182	53.74	0.94814	0.7416	57.37	0.94368	0.7408	62.98	0.93544	0.7106	70.72
0.0577	0.95569	0.8485	58.47	0.95482	0.7987	64.32	0.94723	0.7555	76.20	0.94983	0.7285	75.20
0.0894	0.96443	0.8869	61.82	0.95653	0.8190	69.35	0.95872	0.7744	78.60	0.94703	0.7494	80.71
0.1281	0.96749	0.8918	69.50	0.96416	0.8214	72.40	0.95911	0.7969	84.79	0.95717	0.7726	90.50
20 % DMSO												
		308.15K			313.15K			318.15K			323.15K	
0.0150	0.96257	0.8142	48.12	0.96285	0.8352	57.50	0.95231	0.7717	64.20	0.95519	0.77502	70.18
0.0329	0.96811	0.8534	50.28	0.96422	0.8458	60.20	0.95359	0.8845	70.45	0.95435	0.79542	76.20
0.0577	0.97979	0.9868	62.54	0.96962	0.8694	74.33	0.96487	0.8906	74.30	0.95853	0.84245	84.16
0.0894	0.97851	0.9608	66.50	0.97497	0.8978	78.90	0.96513	0.8902	82.15	0.96297	0.83371	90.74
0.1281	0.98198	0.9497	72.80	0.98714	0.9083	82.35	0.97691	0.8655	90.30	0.96841	0.86759	98.45

Table 2: Concentration (C), Density (ρ), Viscosity (η), apparent molar volume (ϕ_v) of Magnesium sulphate in DMF and 40% and 60% 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	0.99909	1.0398	53.63	0.99338	1.00091	62.25	0.98621	0.9212	67.42	0.98242	0.8183	76.53
0.0329	1.00040	1.0516	60.51	0.99668	1.01303	68.66	0.98923	0.9342	75.63	0.98556	0.8372	82.42
0.0577	1.00485	1.0628	65.70	1.00097	1.02925	74.54	0.99427	0.9512	81.94	0.98965	0.8549	88.61
0.0894	1.01014	1.0838	73.61	1.00608	1.04927	81.74	0.99922	0.9732	88.75	0.99478	0.8752	94.60
0.1281	1.01631	1.1029	80.50	1.01199	1.07489	88.79	1.00423	0.9982	95.86	0.99992	0.9045	103.00
60 % DMSO												
		308.15K			313.15K			318.15K			323.15K	
0.0150	1.02947	1.2295	61.36	1.02477	1.1335	67.51	1.01842	1.0576	73.18	1.01451	1.0189	78.07
0.0329	1.03268	1.2423	68.32	1.02787	1.1478	74.58	1.02143	1.0747	80.13	1.01742	1.0395	85.55
0.0577	1.03689	1.2597	74.96	1.03197	1.1685	80.55	1.02534	1.0977	87.19	1.02121	1.0639	92.49
0.0894	1.04192	1.2813	81.91	1.03686	1.1915	87.21	1.03002	1.1247	94.02	1.02573	1.0994	99.35
0.1281	1.04771	1.3073	88.32	1.04233	1.2196	94.64	1.03526	1.1582	101.34	1.03078	1.1348	106.66

Table 3: Concentration (C), Density (ρ), Viscosity (η), apparent molar volume (ϕ_v) of Magnesium sulphate in DMF and 80% DMSO and 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	1.07469	1.8256	62.50	1.08522	1.6522	71.80	1.07425	1.5241	76.30	1.07125	1.4472	82.42
0.0329	1.08728	1.8642	75.20	1.08525	1.7610	74.60	1.07785	1.5498	80.70	1.07385	1.4772	89.25
0.0577	1.09109	1.9532	83.54	1.08582	1.7328	87.20	1.08098	1.5828	90.70	1.07741	1.5172	97.11
0.0894	1.09822	1.9413	90.90	1.09951	1.7915	92.20	1.08542	1.6255	98.10	1.08186	1.5672	107.81
0.1281	1.10458	1.9699	97.65	1.09124	1.8734	108.10	1.08963	1.6753	108.80	1.08572	1.6186	114.90
DMSO												
		308.15K			313.15K			318.15K			323.15K	
0.0150	1.09778	2.0149	72.13	1.09383	1.8213	76.05	1.08794	1.6482	84.44	1.08503	1.5474	90.82
0.0329	1.10064	2.0395	80.43	1.09659	1.8452	85.18	1.09059	1.6764	92.35	1.08757	1.5801	98.49
0.0577	1.10424	2.0693	89.26	1.10019	1.8767	92.12	1.09393	1.7156	100.59	1.09074	1.6233	106.94
0.0894	1.10852	2.1091	96.70	1.10433	1.9147	100.12	1.09776	1.7615	109.00	1.09422	1.6740	116.82
0.1281	1.11324	2.1602	104.33	1.10876	1.9623	108.92	1.10194	1.8195	117.12	1.09791	1.7342	126.23

Table 4: Concentration (C), Density (ρ), Viscosity (η), apparent molar volume (ϕ_v) of Aluminium ammonium sulphate in DMF and 20% 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	0.98986	0.8125	47.67	0.94685	0.7784	54.82	0.93985	0.7347	61.82	0.93577	0.7085	68.85
0.0329	0.95808	0.8285	50.08	0.95039	0.7874	59.50	0.94384	0.7479	67.35	0.93985	0.7127	74.88
0.0577	0.99548	0.8386	61.08	0.95549	0.8028	67.86	0.94852	0.7656	73.45	0.94431	0.7379	81.31
0.0894	0.98692	0.8475	65.98	0.96174	0.8185	72.82	0.95479	0.7861	79.87	0.95002	0.7599	87.49
0.1281	0.99515	0.8696	72.28	0.96877	0.8386	78.96	0.96157	0.8102	85.89	0.95647	0.7865	93.85
20 % DMSO												
		308.15K			313.15K			318.15K			323.15K	
0.0150	0.96518	0.8887	52.81	0.96085	0.8452	59.50	0.95582	0.7972	68.34	0.95164	0.78516	75.03
0.0329	0.96934	0.8996	58.09	0.96422	0.8558	65.28	0.95963	0.8126	74.71	0.95531	0.80241	81.68
0.0577	0.97452	0.9136	64.65	0.96862	0.8694	72.37	0.96438	0.8307	81.32	0.95982	0.82377	89.21
0.0894	0.98065	0.9306	71.21	0.97397	0.8878	78.92	0.96982	0.8527	89.43	0.96534	0.84936	94.12
0.1281	0.98761	0.9503	77.66	0.98348	0.9203	88.66	0.97613	0.8777	95.57	0.97150	0.88035	100.13

Table 5: Concentration (C), Density (ρ), Viscosity (η), apparent molar volume (ϕ_v) of Aluminium ammonium sulphate in DMF and 80% DMSO and 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	1.08517	1.8702	71.37	1.08167	1.6932	74.81	1.07421	1.5241	74.34	1.07231	1.4597	85.18
0.0329	1.08861	1.8947	79.27	1.08483	1.7181	82.88	1.07706	1.5498	82.77	1.07545	1.4924	93.25
0.0577	1.09278	1.9237	87.22	1.08892	1.7526	90.58	1.08071	1.5828	90.74	1.07918	1.5363	101.89
0.0894	1.09767	1.9623	93.97	1.09359	1.7956	98.24	1.08503	1.6255	98.10	1.08352	1.5876	109.04
0.1281	1.10302	2.0083	101.01	1.09874	1.8440	105.43	1.08965	1.6753	106.84	1.08768	1.6514	119.66
DMSO												
		308.15K			313.15K			318.15K			323.15K	
0.0150	1.09907	2.0263	77.57	1.09513	1.8326	79.83	1.08916	1.6615	88.64	1.08619	1.5627	95.27
0.0329	1.10239	2.0527	84.41	1.09832	1.8597	88.42	1.09221	1.6944	96.14	1.08908	1.6009	103.03
0.0577	1.10633	2.0897	92.76	1.10221	1.8943	95.99	1.09581	1.7385	104.61	1.09249	1.6493	111.36
0.0894	1.11067	2.1344	101.90	1.10655	1.9356	104.22	1.09982	1.7873	113.06	1.09624	1.7022	119.94
0.1281	1.11562	2.1846	108.72	1.11089	1.9873	114.24	1.10393	1.8496	122.21	1.09983	1.7694	130.47

Table 6: Concentration (C), Density (ρ), Viscosity (η), apparent molar volume (ϕ_v) of Potassium aluminium sulphate in DMF and 20% 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	0.91846	0.8252	45.61	0.95461	0.7720	54.25	0.94585	0.7469	60.14	0.94566	0.7054	60.40
0.0329	0.95256	0.8283	50.70	0.95622	0.7754	56.85	0.95623	0.7655	72.20	0.94744	0.7525	70.70
0.0577	0.95956	0.8569	60.00	0.96039	0.7865	59.42	0.96172	0.7844	78.65	0.94950	0.7258	72.85
0.0894	0.96365	0.8678	68.51	0.96549	0.8058	68.92	0.96479	0.7901	71.87	0.95183	0.7561	75.26
0.1281	0.97952	0.8353	72.12	0.97516	0.8242	74.42	0.96811	0.7659	80.60	0.94713	0.7683	88.71
20 % DMSO												
		308.15K			313.15K			318.15K			323.15K	
0.0150	0.99863	1.0443	59.74	0.99485	1.00637	65.65	0.98823	0.9275	72.24	0.98232	0.8183	76.55
0.0329	1.00253	1.0567	66.53	0.99868	1.02065	71.31	0.99189	0.9421	78.87	0.98536	0.8342	82.46
0.0577	1.00738	1.0721	73.40	1.00344	1.03874	77.70	0.99641	0.9620	85.90	0.98935	0.8549	88.64
0.0894	1.01318	1.0924	79.25	1.00896	1.06062	84.88	1.00166	0.9852	93.16	0.99418	0.8792	94.63
0.1281	1.01971	1.1184	85.43	1.01502	1.08865	92.75	1.00762	1.0121	99.59	1.00239	0.9274	105.95

Table 7: Concentration (C), Density (ρ), Viscosity (η), apparent molar volume (ϕ_v) of Potassium aluminium sulphate in DMF and 80% DMSO and 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	1.08217	1.8522	72.37	1.08025	1.6822	70.85	1.07653	1.5856	78.44	1.07245	1.4585	82.17
0.0329	1.09061	1.8047	74.27	1.08345	1.7040	78.65	1.07851	1.5454	86.75	1.07575	1.4985	90.24
0.0577	1.09378	1.9337	85.22	1.08682	1.7328	86.65	1.08752	1.6751	94.85	1.07985	1.5368	104.85
0.0894	1.09567	1.9743	97.97	1.09121	1.7725	94.75	1.08854	1.6754	103.86	1.08386	1.5875	110.04
0.1281	1.10402	2.0283	111.01	1.09874	1.8440	105.85	1.09856	1.7957	111.95	1.08775	1.6585	119.66
DMSO												
		308.15K			313.15K			318.15K			323.15K	
0.0150	1.09924	2.0242	74.56	1.09342	1.8453	77.15	1.09259	1.6785	92.36	1.08247	1.5561	94.45
0.0329	1.10252	2.0553	85.46	1.09858	1.8247	84.42	1.09451	1.6985	96.24	1.08458	1.6049	104.24
0.0577	1.10656	2.0885	90.75	1.10045	1.8427	96.12	1.09753	1.7175	100.46	1.09256	1.6445	112.25
0.0894	1.10882	2.1068	94.73	1.10275	1.8423	94.99	1.09861	1.7385	104.46	1.09445	1.6725	115.85
0.1281	1.11042	2.1345	114.25	1.10485	1.9257	105.12	1.09252	1.7867	113.45	1.09454	1.7242	124.96

Table 8: 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 Magnesium 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	32.84	34.12	41.18	48.49	49.22	54.32
313.15	38.24	45.27	47.84	53.03	57.72	54.57
318.15	40.44	55.13	56.65	54.29	66.92	57.28
323.15	52.17	58.99	62.48	61.25	68.94	63.32
S_V (cm^3.mol$^{-2/3}$.L$^{1/2}$)						
308.15	99.22	102.2	111.8	111.5	123.2	128.6
313.15	102.1	112.8	113.6	114.3	126.3	133.0
318.15	106.3	115.9	118.7	120.1	131.4	139.8
323.15	107.6	109.7	110.6	121.7	133.8	142.9
A (dm$^{3/2}$.mol$^{-1/2}$)						
308.15	0.011	0.012	0.018	0.022	0.022	0.025
313.15	0.024	0.027	0.026	0.029	0.028	0.032
318.15	0.062	0.059	0.061	0.066	0.067	0.068
323.15	0.077	0.071	0.081	0.084	0.084	0.086

			B (dm^3. Mol^{-1})			
308.15	0.494	0.525	0.522	0.526	0.534	0.544
313.15	0.601	0.612	0.604	0.625	0.646	0.657
318.15	0.706	0.718	0.629	0.724	0.742	0.759
323.15	0.811	0.836	0.844	0.858	0.867	0.904

Table 9: Moulik constants (M and K) and Roots parameters (R and S) of Magnesium 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	1.066	1.048	1.046	1.045	1.043	1.045
313.15	1.090	1.056	1.055	1.053	1.053	1.056
318.15	1.120	1.073	1.069	1.073	1.073	1.064
323.15	1.150	1.088	1.089	1.087	1.086	1.089
			K			
308.15	6.387	6.857	6.982	6.999	7.184	7.328
313.15	8.054	8.338	8.175	8.462	8.733	9.087
318.15	10.59	10.39	9.323	10.72	11.14	11.31
323.15	12.38	12.69	12.85	12.96	13.16	13.88
			R			
308.15	-0.236	-0.223	-0.215	-0.208	-0.204	-0.191
313.15	-0.221	-0.214	-0.211	-0.206	-0.198	-0.192
318.15	-0.216	-0.209	-0.206	-0.199	-0.196	-0.194
323.15	-0.211	-0.110	-0.198	-0.196	-0.182	-0.189
			S			
308.15	0.094	0.125	0.115	0.118	0.129	0.138
313.15	0.098	0.128	0.119	0.124	0.123	0.146
318.15	0.099	0.159	0.123	0.126	0.136	0.149
323.15	0.100	0.172	0.129	0.129	0.142	0.156

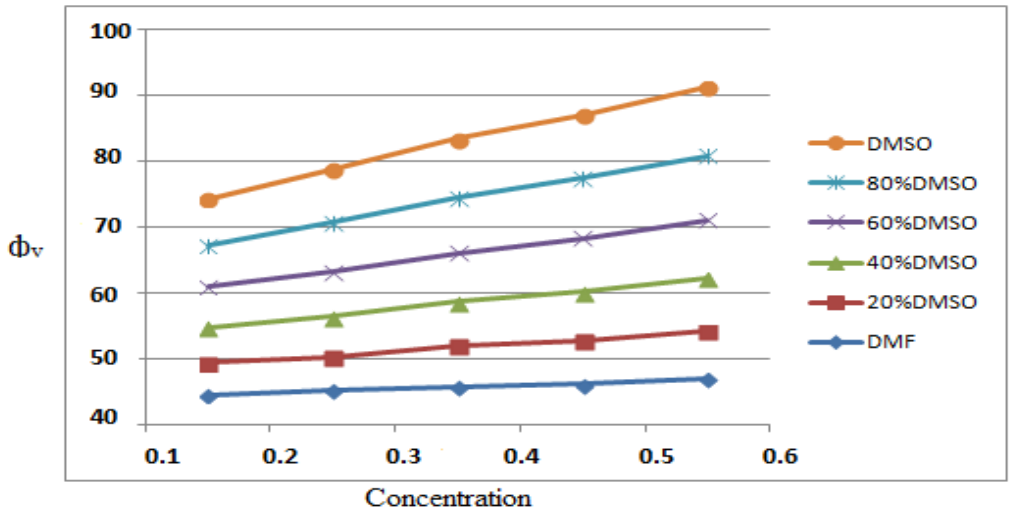

Fig. 1: Plots of apparent molar volume ϕ_v vs. square root of concentration, C for Magnesium sulphate in binary liquid mixture of aqueous DMF + aqueous DMSO solution at 308.15 K

4. CONCLUSION

From the viscosity and density of Magnesium sulphate solutionsin binary mixture of aqueous DMF and aqueous DMSO are at 308.15, 313.15, 318.15 and 323.15 K temperatures. All the values of $\phi_v°$ at all temperatures are positive and higher, suggest the strong solute solvent interactions in binary mixture aqueous DMF + aqueous DMSO. The S_v values are positive and showing strong solute-solute interactions in Magnesium sulphate. The positive values of Jones-Dole coefficient 'B' indicate strong interactions between solute and solvent at high temperature. The B coefficient for the Magnesium sulphate increases with a rise of 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 Magnesium sulphate in binary liquid mixture aqueous DMSO and aqueous DMF.

5. ACKNOWLEDGEMENT

Authors are thankful to Principal of Maulana Azad College, Rouza Bagh, Aurangabad for providing laboratory and library facilities.

Conflict of interests

Authors do not have any potential conflict of interest

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