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Molar volume, viscosity and conductance studies of zinc sulphate in water and aqueous mannitol

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ABSTRACT

Molar volume, viscosity and conductance of zinc sulphate in water and 2, 4 and 6 wt. % of aqueous mannitol solutions have been evaluated from density, viscosity and conductance data respectively at temperatures 303.15K, 308.15K, 313.15K and 318.15K. The solute-solvent interactions for zinc sulphate in water and various compositions of aqueous mannitol have been inferred from ϕ_v^o *, B-coefficient of Jones-Dole equation and* Λ_m^o *values. The structure making/breaking behavior of zinc sulphate is inferred from the sign of* $[\partial^2 \phi_v^o / \partial T^2]_p$*, dB/dT and temperature coefficient of Walden product i.e.* $d(\Lambda_m^o \eta_o)/dT$ *values. It has been found that zinc sulphate behaves as structure-breaker in water as well as in 2, 4 and 6 wt. % of aqueous mannitol solutions from molar volume, viscosity and conductance studies. The energy of activation for zinc sulphate in different compositions of aqueous mannitol is calculated from conductance and viscosity data and it has found that* E_Λ *is less than* E_η*.*

Key Words: Molar volume, viscosity, conductance, zinc sulphate, mannitol-water system.

INTRODUCTION

The study of apparent molar volumes of electrolytes at infinite dilution, B parameter of Jones-Dole equation and their dependence on temperature, molar conductance at infinite dilution and Walden product studies can furnish useful information on the nature of solute – solvent interactions. The behavior of electrolytes in aqueous carbohydrates and carbohydrates containing small quantity of ions which are present in body fluids have recently been subject of interest [1-7]. Increasing concern over the toxicity of metals in environment has led to increase research activity to identify the fate of these metal ions in the organisms. Zinc is very important for proper functioning of the enzyme system of animals. Human body contains about 2g of zinc. There are more than 20 zinc containing enzymes in the body which are responsible for proper absorption of CO_2 by red blood cells in muscles and other tissues and for maintaining proper pH in the muscles and tissues. Beside this, zinc containing enzymes are also involved in the energy release processes, sugar metabolism and metabolism of alcohol in body. The study of zinc sulphate in water and 2, 4 and 6 wt. % of aqueous mannitol at 303.15, 308.15, 313.15 and 318.15K temperatures was carried out to understand the nature of solute-solute and solute–solvent interactions by measuring the density, molar volume, molar conductance and viscosity of their solutions.

MATERIALS AND METHODS

Double distilled water used for solutions had specific conductance in range $0.1 \times 10^{-6}\ \Omega^{-1}cm^{-1}$ to $1.0 \times 10^{-6}\ \Omega^{-1}cm^{-1}$. Zinc sulphate and mannitol (Anala R) were dried over anhydrous calcium chloride for more than 48hr and used as such. All the solutions were prepared by weight and conversion of molality to molarity was done by using the standard expression [8]. The concentration range of zinc sulphate in water and 2, 4 and 6 wt. % aqueous mannitol solutions was 0.01 to 0.12 M. The density was measured with the help of DSA (Density and Sound Analyser) 5000, Antor Paar, GmbH, Garz, Austria. Viscosity was determined with the help of capillary type Viscometer [9]. The conductance was measured with the help of calibrated Digital conductivity meter, CM 180, Elico Limited. All measurements were made in a water bath maintained at 30, 35, 40, 45^{0}C (±0.05).

RESULTS AND DISCUSSION

3.1 Molar Volume Studies

The apparent molar volume of zinc sulphate in water and 2, 4 and 6 wt. % of aqueous mannitol solutions have been calculated from density data (Table 1) by using eq.(1)

$$\phi_v = \frac{M_2}{d^o} - \frac{1000(d-d^o)}{mdd^o} \qquad (1)$$

Where d^0 is the density of solvent, d is the density of solution, m the molality of solution and M$_2$ the molecular weight of zinc sulphate. Errors in ϕ_v were calculated from eq. (2).

$$\Delta\phi_v = (2\Delta d/d^2)\,\{1000/(m+M_2)\} \qquad (2)$$

Eq. (2) assumes error to be associated with the density of solution (d) and solvent (d^0). Moreover, errors associated with determination of solution concentration are not the limiting factor while calculating the apparent molar volumes. The error in apparent molar volume as derived from eq. (2) was estimated to range from ±0.06 cm^3 mol^{-1} at 0.01M concentration to ±0.10cm^3 mol^{-1} at 0.12M concentration. The densities of various solutions of zinc sulphate in water and 2, 4 and 6 wt.% of aqueous mannitol obey Root's equation and justify the use of Masson's eq.(3) for the estimation of the limiting apparent molar volume.

$$\phi_v = \phi_v^o + S_v\sqrt{C} \qquad (3)$$

Where ϕ_v^o and S$_V$ are calculated from the intercept and slope from the extrapolation of the plots of ϕ_v versus $\sqrt{C}$. The values of limiting apparent molar volume and slopes S$_V$ are recorded in Table 2. The slope S$_V$ in Masson's equation may be attributed to be as a measure of ion-ion or solute- solute interactions [10-12], low and positive values accounts for weak solute-solute interactions in water and 2, 4 and 6 wt. % of aqueous mannitol solutions. There is a decrease in inter ionic interactions with increase in temperature for zinc sulphate in water and 2, 4 and 6 wt. % of aqueous mannitol solutions which may be due to more solvation of metal ions with rise in temperature.

The ϕ_v^o is a measure of solute-solvent interactions [13]. The ϕ_v^o values for zinc sulphate in water are higher than ϕ_v^o values for zinc sulphate in 2, 4 and 6 wt.% of aqueous mannitol solutions, shows that solute – solvent interactions are more in water than in aqueous mannitol solutions. The ϕ_v^o values for zinc sulphate in water increases with increase in temperature and it may be due to decrease in hydrogen bonding between water molecules with increase in temperature, thus making more free water molecules available for solvation of metal ions and hence solute-solvent interactions increases with increase in temperature. The solute- solvent interactions for zinc sulphate in 2, 4 and 6 wt. % of aqueous mannitol also increases with increase in temperature.

The temperature dependence of ϕ_v^o for zinc sulphate in water and 2, 4 and 6 wt. % of aqueous mannitol solutions can be expressed as:

$$\phi_v^o = -246.59 + 2.033T - 0.0027T^2 \qquad (4)$$

for : ($ZnSO_4$ $7H_2O$ in water)

$$\phi_v^o = -553.13 + 3.684T - 0.0051T^2 \qquad (5)$$

for: ($ZnSO_4$ $7H_2O$ in 2 wt.% aq. mannitol)

$$\phi_v^o = -361.73 + 2.579T - 0.0035T^2 \qquad (6)$$

for: ($ZnSO_4$ $7H_2O$ in 4 wt.% aq. mannitol)
and

$$\phi_v^o = -315.84 + 2.734T - 0.0039T^2 \qquad (7)$$

for: ($ZnSO_4$ $7H_2O$ in 6 wt.% aq. mannitol)
Where 'T' is the temperature in Kelvin.

The limiting apparent molar expansibility, $\phi_E^o = (\partial\, \phi_v^o / \partial\, T)_{P,}$ calculated for zinc sulphate from Eqs. (4)- (7) is given in Table 2. The values of ϕ_E^o decreases with increase in temperature for zinc sulphate in water and 2, 4 and 6 wt. % of mannitol in water, which indicates the absence of "caging effect" and its behavior is just like common electrolytes[14-16].

The structure making/ breaking capacity of zinc sulphate may be interpreted with the help of Hepler's reasoning [17], i.e. on the basis of sign of $(\partial^2 \phi_v^o / \partial\, T^2)_P$. It has been shown from general thermodynamic eq.(8)

$$(\partial\, \overline{C}_P^0 / \partial\, P)_T = -T\, (\partial^2 \phi_v^o / \partial\, T^2)_P \qquad (8)$$

Where $\overline{C}_P^0$ is the partial molar heat capacity at infinite dilution. From eq. (8), it is clear that structure making electrolytes should have a positive value of $(\partial^2 \phi_v^o / \partial\, T^2)_P$ and structure breaking electrolytes should have negative value of $(\partial^2 \phi_v^o / \partial\, T^2)_P$. For zinc sulphate the sign of $(\partial^2 \phi_v^o / \partial\, T^2)_P$ has been found to be negative in water as well as in 2, 4 and 6 wt. % of aqueous mannitol . It suggests that zinc sulphate acts as structure breaker in water and in 2, 4 and 6 wt. % of aqueous mannitol solutions.

The limiting excess molar volume of zinc sulphate for different compositions of mannitol have been estimated from eq. (9)

$$\Delta \phi_v^o \text{ (excess)} = \phi_v^o \text{(A)} - \phi_v^o \text{(B)} \qquad (9)$$

Where ϕ_v^o (A) is the limiting apparent molar volume of zinc sulphate in different compositions of aqueous mannitol and ϕ_v^o (B) is the limiting apparent molar volume of zinc sulphate in water. The negative value of excess molar volume of zinc sulphate in aqueous mannitol solution may be attributed to decrease in solute –solvent interactions at infinite dilution.

3.2 Viscosity Studies

The viscosity data (Table 1) has been analyzed on the basis of Jones- Dole equation [18].

$$\eta_s / \eta_0 = 1 + A\sqrt{C} + BC \qquad (10)$$

Where η_s and η_0 are viscosities of solution and solvent respectively, C is the molar concentration and A and B are constants. The values of A and B have been determined from the intercept and slope of linear plots of $(\eta_s/\eta_0\ -1)/\sqrt{C}$ versus $\sqrt{C}$. The values of A and B of different solutions are recorded in Table 3.

Parameter A of Jones-Dole equation represents the contribution from solute-solute interactions [19]. The values of A, shows that ion-ion interactions for zinc sulphate in water, 2, 4 and 6 wt. % of mannitol in water decreases with increase in temperature, which may be due to more solvation of metal ions..

The B parameter which measures the structure making/breaking capacity of an electrolyte in a solution also contain a contribution from structural effects and is responsible for solute-solvent interactions in a solvent[20]. It has been emphasized by a number of workers that dB/dT is more important criteriafor determining solute-solvent interactions, as positive B-coefficient obtained from aqueous mannitol can be interpreted as merely due to large size ion [2]. Viscosity study of a number of electrolytes has shown that structure-maker will have negative dB/dT and structure-breaker will have positive dB/dT. The temperature effect on B-coefficient for zinc sulphate in water and in

2, 4, and 6 wt. % of aqueous mannitol shows a positive sign of dB/dT, showing thereby that zinc sulphate behaves as structure-breaker in water and in 2, 4 and 6 wt. % of aqueous mannitol solutions.

The effect of temperature on the viscosity is given by eq.(11)

$$\eta \quad = \quad A\ e^{E\eta/RT} \qquad (11)$$

Where A is a constant and E_η is the activation energy for the viscous flow [21] and other symbols has their usual significance. The values of E_η for zinc sulphate in water and 2, 4 and 6 wt. % of aqueous mannitol solutions were calculated from the slope of the linear plots of log η versus 1/T, and order of activation varies from 15.24 $KJmol^{-1}$ to 16.53 $KJmol^{-1}$ for viscous flow of solutions of different concentration (0.01m-0.12 m) of zinc sulphate in 2, 4 and 6 Wt. % of mannitol. The data of activation for 0.04 m concentration of zinc sulphate in 2, 4 and 6 Wt. % of mannitol is given in table 4.

3.3 Conductance Studies

The limiting molar conductance Λ_m^o for zinc sulphate in water and 2, 4 and 6 wt. % of aqueous mannitol solutions were obtained by extrapolating the linear plots of Λ_m (Table 1) versus $\sqrt{C}$ to zero concentration. The limiting molar conductance for zinc sulphate in water and 2, 4 and 6 wt. % aqueous mannitol solutions at 303.15, 308.15, 313.15 and 318.15 K temperatures are recorded in Table 3, shows that limiting molar conductance increases with increase in temperature, which may be due to increase in ionic mobility with increase in temperature .
Since in the state of infinite dilution, the motion of an ion is limited solely by its interaction with surrounding solvent molecules, there are no other ions with in a finite distance. Therefore evaluation of Λ_m^o should give equally reliable information regarding ion-solvent interactions [22]. Greater value of Λ_m^o may therefore be interpreted as a measure of greater ion-solvent interactions. The order of solute-solvent interactions for zinc sulphate in aqueous mannitol solutions follow as:

Water > 2 wt. % aq. mannitol > 4 wt. % aq. mannitol > 6 wt. % aq. mannitol.

It may be due to more solvation of metal ions in water than water-mannitol system. The Walden product data ($\Lambda_m^o \eta_0$) have been recorded in Table 3. The structure making/ breaking nature of electrolyte have been determined from temperature coefficient of Walden product [23] i.e. [d $(\Lambda^0{}_m\eta_0)$ / dT]. The negative temperature coefficient of Walden product for zinc sulphate in water and 2, 4, and 6 Wt. % of aqueous mannitol suggests an increase in the ion-solvent interactions which indicates that zinc sulphate behaves as structure-breaker in water and in 2, 4 and 6 wt. % of aqueous mannitol.

The effect of temperature on conductance is given by equation [24]:

$$\Lambda_m = \Lambda_m^o e^{-E_\Lambda/RT} \qquad (12)$$

Where E_Λ is the activation energy for conduction and other symbols have their usual significance. The values of E_Λ for zinc sulphate (0.01m-0.12m) in water and 2, 4 and 6 wt. % aqueous mannitol were calculated from the slope of the linear plots of log Λ_m^o versus 1/T and it varies from 12.02 $K.J.mol^{-1}$to 14.50 $K.J.mol^{-1}$. The data of activation for 0.04 m concentration of zinc sulphate in 2, 4 and 6 Wt. % of mannitol is given in table 4.

A sample plot of activation energy versus percentage composition of aqueous mannitol for viscous flow Eη for zinc sulphate (0.04m) and energy of activation for conduction E_Λ is shown in The energy of activation obtained from conductance data E_Λ should be less than energy of activation obtained from viscosity data Eη. It has been found that E_Λ < Eη for zinc sulphate in water and 2, 4, and 6 wt. % of mannitol- water system.

CONCLUSION

Zinc sulphate behaves as structure-breaker in water and 2, 4 and 6 wt. % of aqueous mannitol solutions with negative sign of $(\partial^2 \phi_v^o / \partial T^2)_P$ and positive sign of dB/dT. And the negative temperature coefficient of Walden products supports these results. The activation energies obtained from conductance data E_Λ are less than those obtained from viscosity data Eη.

Table 1: Densities (d), apparent molar volumes (ϕ_v), relative viscosities (η_s/η_o) and molar conductance (Λ_m) of zinc sulphate in different compositions of aqueous mannitol at different temperatures

Concentration C X 10^2 (mol l^{-1})	Density d (g cm^{-3})	Apparent molar volume, ϕ_v (cm^3mol^{-1})	Relative Viscosity η_s/η_o	Molar Conductance Λ_m ($\Omega^{-1}cm^2mol^{-1}$)
		Water		
Temperature=303.15K		**d_0=0.995670**	**η_o=0.79730 cP**	
0.9945	0.997371	118.49	1.00635	133.73
1.9867	0.999058	118.99	1.01270	125.84
3.9640	1.002395	119.87	1.02575	113.52
5.9319	1.005700	120.44	1.03883	104.18
7.8902	1.008968	120.98	1.05126	95.81
9.8391	1.012200	121.51	1.06472	88.42
11.7785	1.015411	121.91	1.07755	82.35
Temperature=308.15K		**do=0.994060**	**ηo=0.71900 cP**	
0.9930	0.99575	120.06	1.00570	146.04
1.9834	0.997426	120.56	1.01176	136.13
3.9575	1.000747	121.29	1.02390	121.29
5.9244	1.004037	121.85	1.03717	111.40
7.8814	1.007300	122.26	1.04936	102.77
9.8294	1.010536	122.63	1.06307	96.65
11.7684	1.013738	123.04	1.07606	87.52
Temperature =313.15K		**d_o=0.992240**		**η_o=0.65260 cP**
0.9911	0.993920	121.59	1.00486	159.42
1.9798	0.995587	122.04	1.01012	149.51
3.9501	0.998890	122.75	1.02303	134.17
5.9110	1.002159	123.28	1.03517	124.01
7.8624	1.005402	123.68	1.04773	114.47
9.8042	1.008614	124.07	1.06154	107.10
11.7367	1.011803	124.40	1.07457	100.54
Temperature=318.15K		**d_o=0.990250**		**η_o=0.59720 cP**
0.9891	0.991921	123.07	1.00383	171.88
1.9760	0.993580	123.47	1.00896	161.96
3.9421	0.996869	124.10	1.02136	145.35
5.8990	1.000123	124.63	1.03379	132.57
7.8463	1.003352	125.02	1.04582	124.90
9.7842	1.006556	125.34	1.05962	115.49
11.7126	1.009728	125.69	1.07258	108.43
		2% Aqueous Mannitol		
Temperature=303.15K		**d_o=1.002160**		**η_o=0.84075 cP**
1.0011	1.004005	102.23	1.00817	119.87
2.0001	1.005798	104.64	1.01568	114.99
3.9912	1.009276	108.24	1.02937	105.11
5.9728	1.012649	110.93	1.04303	97.11
7.9447	1.01593	113.22	1.05634	91.88
9.9065	1.019139	115.16	1.03964	86.81
11.8582	1.022285	116.84	1.08293	82.64
Temperature=308.15K		**d_o=1.000390**	**η_o=0.75458cP**	
0.9993	1.00222	104.24	1.00600	130.58
1.9965	1.004005	106.29	1.01233	124.72
3.9841	1.007485	109.28	1.02461	115.21
5.9624	1.010872	111.56	1.03756	107.34
7.9311	1.014178	113.51	1.05082	100.87
9.8899	1.01742	115.16	1.06338	96.06
11.8386	1.020593	116.71	1.07593	91.23
Temperature=313.15K		**d_o=0.99854**		**η_o=0.68480 cP**
0.9975	1.000355	106.37	1.00410	141.15
1.9928	1.002126	108.32	1.01006	134.48
3.9766	1.005587	111.03	1.02119	123.22
5.9511	1.008968	113.01	1.03421	115.94
7.9160	1.012253	114.99	1.04719	108.64
9.8712	1.015505	116.36	1.05943	103.00
11.8163	1.018665	117.90	1.07279	98.17
Temperature=318.15K		**d_o=0.996586**		**η_o=0.62320cP**
0.9955	0.998384	108.53	1.00344	151.68
1.9888	1.000141	110.39	1.00894	144.81
3.9686	1.003575	113.02	1.02073	133.55
5.9391	1.00692	115.12	1.03291	124.60
7.8999	1.010201	116.77	1.04550	117.72
9.8510	1.01342	118.22	1.05808	110.65
11.7922	1.016587	119.49	1.07193	106.00
		4% Aqueous Mannitol		

Temperature=303.15K		**d_o=1.009423**		**η_o=0.88644 cP**
1.0083	1.011254	101.56	1.00756	118.01
2.0147	1.013027	104.26	1.01417	110.20
4.0212	1.016477	107.71	1.02766	101.99
6.0188	1.019824	110.31	1.04050	94.76
8.0067	1.023042	113.02	1.05296	88.75
9.9852	1.026248	114.61	1.06546	83.20
11.9537	1.029295	116.85	1.07878	78.73
Temperature=308.15K		**d_o=1.00771**		**η_o=0.79557 cP**
1.0066	1.009529	103.25	1.00643	127.16
2.0110	1.011296	105.65	1.01253	120.34
4.0127	1.014736	108.90	1.02602	109.65
6.0048	1.018068	111.51	1.03880	102.42
7.9867	1.021312	113.72	1.05121	95.16
9.9583	1.024469	115.75	1.06393	89.37
11.9197	1.027583	117.33	1.07666	83.90
Temperature=313.15K		**d_o=1.005805**		**η_o=0.7204 cP**
1.0047	1.00761	105.19	1.00507	138.84
2.0072	1.009361	107.69	1.01119	130.03
4.0050	1.012775	110.84	1.02375	119.85
5.9932	1.016098	113.14	1.03629	111.79
7.9711	1.019312	115.45	1.04950	104.13
9.9389	1.022466	117.27	1.06161	97.59
11.8959	1.025528	119.12	1.07405	92.47
Temperature=318.15K		**d_o=1.003697**		**η_o=0.65722 cP**
1.0026	1.005492	106.79	1.00417	149.61
2.0029	1.007239	108.99	1.00987	140.04
3.9966	1.010638	112.16	1.02243	129.61
5.9804	1.013926	114.81	1.03453	120.39
7.9542	1.017144	116.80	1.04702	111.89
9.9178	1.020299	118.47	1.05990	104.86
11.8707	1.023358	120.24	1.07234	99.40
		6% Aqueous Mannitol		
Temperature=303.15K		**d_o=1.016627**		**η_o=0.93588 cP**
1.0155	1.018454	99.94	1.00844	98.96
2.0288	1.02022	102.79	1.01539	93.65
4.0480	1.02365	106.46	1.02866	85.72
6.0573	1.026963	109.36	1.04217	79.24
8.0562	1.030189	111.70	1.05565	74.48
10.0447	1.033356	113.52	1.06768	69.69
12.0222	1.036415	115.50	1.07994	65.71
Temperature=308.15K		**d_o=1.014871**		**η_o=0.83934 cP**
1.0138	1.016683	101.93	1.00650	106.53
2.0252	1.018447	104.13	1.01303	101.22
4.0410	1.021859	107.83	1.02633	91.81
6.0467	1.025161	110.62	1.03895	86.00
8.0420	1.028378	112.87	1.05186	80.82
10.0269	1.031518	114.83	1.06378	75.80
12.0009	1.034582	116.64	1.0760	71.66
Temperature=313.15K		**d_o=1.012932**		**η_o=0.75607 cP**
1.0118	1.014735	103.37	1.00563	117.61
2.0213	1.016486	105.77	1.01191	109.31
4.0332	1.019887	109.19	1.02477	101.66
6.0350	1.023167	112.08	1.03722	92.66
8.0264	1.026380	114.15	1.05072	87.21
10.0073	1.029509	116.08	1.06242	81.94
11.9776	1.032571	117.78	1.07447	77.64
Temperature=318.15K		**d_o=1.010822**		**η_o=0.6875 cP**
1.0097	1.012617	104.76	1.00445	128.75
2.0171	1.014362	107.06	1.010	118.98
4.0247	1.017757	110.26	1.02218	109.32
6.0223	1.021036	113.02	1.03470	101.29
8.0098	1.024251	114.99	1.04758	94.88
9.9865	1.027362	117.04	1.06004	89.12
11.9527	1.030425	118.68	1.07250	83.66

Table 2: Limiting apparent molar volume (ϕ_v^o), S_v, apparent molar expansibility (ϕ_E^o) and excess molar volume ($\Delta\ \phi_v^o$) of zinc sulphate in different compositions of aqueous mannitol at different temperatures.

Mannitol Wt.%	Temp(T) (K)	ϕ_v^o (cm^3mol^{-1})	S_v ($cm^3l^{1/2}mol^{-3/2}$)	ϕ_E^o ($cm^3mol^{-1}K^{-1}$)	$\Delta\phi_v^o$
0	303.15	117.04	0.142	0.214	-
0	308.15	118.86	0.122	0.184	-
0	313.15	120.43	0.116	0.154	-
0	318.15	121.97	0.108	0.124	-
2	303.15	96.19	0.602	0.652	-20.85
2	308.15	99.09	0.511	0.602	-19.77
2	313.15	101.65	0.471	0.553	-18.78
2	318.15	104.04	0.452	0.502	-17.93
4	303.15	95.40	0.616	0.457	-21.64
4	308.15	97.42	0.577	0.422	-21.44
4	313.15	99.57	0.563	0.387	-20.86
4	318.15	101.24	0.550	0.352	-20.73
6	303.15	93.76	0.628	0.309	-23.28
6	308.15	95.71	0.604	0.269	-23.15
6	313.15	97.42	0.590	0.229	-23.01
6	318.15	98.99	0.569	0.189	-22.98

Table 3: Values of parameters of Jones-Dole equation, limiting molar conductance, Λ_m^o and Walden Product for zinc sulphate in different compositions of aqueous mannitol at different temperatures.

Mannitol Wt.%	Temperature (K)	A ($l\ mol^{-1})^{1/2}$	B ($l\ mol^{-1}$)	Λ^o_m ($\Omega^{-1}cm^2mol^{-1}$)	$\Lambda^o_m\ \eta_o$ ($\Omega^{-1}cm^2mol^{-1}$ poise)
0	303.15	-0.341	0.667	155.55	1.24
0	308.15	-1.191	0.676	169.19	1.22
0	313.15	-2.382	0.700	183.41	1.20
0	318.15	-3.516	0.718	198.13	1.18
2	303.15	1.802	0.646	136.15	1.14
2	308.15	-0.670	0.661	147.39	1.11
2	313.15	-2.905	0.697	159.07	1.09
2	318.15	-3.735	0.712	171.25	1.07
4	303.15	1.277	0.610	133.52	1.18
4	308.15	-0.138	0.648	145.21	1.15
4	313.15	-1.633	0.673	157.45	1.13
4	318.15	-2.715	0.690	169.94	1.12
6	303.15	2.245	0.603	112.85	1.06
6	308.15	0.228	0.631	121.03	1.02
6	313.15	-0.877	0.653	133.03	1.01
6	318.15	-2.516	0.680	145.65	1.00

Table 4: Values of E_η and E_Λ for Zinc Sulphate (0.04m) in different compositions of aqueous mannitol.

% Composition of aqueous mannitol	E_η (KJ mol^{-1})	E_Λ (KJ mol^{-1})
0	15.33	12.31
2	15.86	12.35
4	15.95	12.63
6	16.46	13.02

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