Densities of Aqueous Solutions of Sodium Bisulfite and Sodium 2-Methylallyl Sulfate

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Densities of aqueous solutions of sodium 2-methylallyl sulfate and sodium bisulfite have been measured at six temperatures in the range 283.15–303.15 K. The measured density values are represented by an empirical equation. The fitting of the experimental results for sodium 2-methylallyl sulfate is excellent, whereas in the case of sodium bisulfite the fitted data are in reasonably good agreement with the experimental values.

Introduction

In commercial processes acrylic fiber is manufactured by suspension polymerization with water as the suspension medium in the presence of a redox catalyst. In the catalyst preparation, aqueous solutions of sodium nitrite, potassium cyanate, sodium bisulfite, and sulfuric acid are used. In these processes, sodium 2-methylallyl sulfate is used as a comonomer to enhance the dyeability of the fiber. Catalyst batch preparation requires frequent monitoring of concentrations of aqueous solutions of these compounds. One of the simplest ways of obtaining the concentration of a solution is to measure the density of the solution. The density of aqueous solutions of sulfuric acid (*1–3*), sodium nitrite (*1, 4*), and potassium cyanate (*1*) are available in the published literature. However, no published literature values are available for densities of aqueous solutions of sodium 2-methylallyl sulfate and sodium bisulfite. In the present paper, we report densities of aqueous solutions of sodium 2-methylallyl sulfate and sodium bisulfite as a function of concentration and temperature from 283.15 to 313.15 K.

Experimental Section

Densities are measured with an Anton Paar digital density meter, model DMA 602H. The density determination is based on measuring the time period of oscillation of a vibrating U-shaped glass sample tube which is filled with the sample liquid. The following relationship exists between the time period of vibration of the glass tube and the density of the solution filled in the vibrating tube:

$$\rho = A(t^2 - B) \qquad (1)$$

where t is the time period and A and B are instrument constants which are determined by calibration with fluids of precisely known densities, viz., water and air. The density values obtained in the present study were accurate to ±0.01 kg·m^{-3}.

Table 1. Density, ρ, of Sodium 2-Methylallyl Sulfate at 283.75, 288.15, 293.15, 298.15, 303.15, and 313.15 K

	ρ/(kg·m^{-3})			ρ/(kg·m^{-3})	
c/(mol·kg^{-1})	T = 283.75 K	T = 288.15 K	c/(mol·kg^{-1})	T = 283.75 K	T = 288.15 K
0.0078	1000.172	999.617	0.9193	1054.374	1053.242
0.0345	1001.932	1001.362	0.9520	1056.170	1055.062
0.0643	1003.888	1003.427	0.9713	1057.185	1055.976
0.2983	1018.604	1017.922	1.0061	1058.977	1057.896
0.6331	1038.188	1037.401	1.1288	1065.663	1064.349
0.7528	1045.089	1044.169	1.2633	1072.791	1071.394
0.8803	1052.193	1051.151			

	ρ/(kg·m^{-3})			ρ/(kg·m^{-3})	
c/(mol·kg^{-1})	T = 293.15 K	T = 298.15 K	c/(mol·kg^{-1})	T = 293.15 K	T = 298.15 K
0.0065	998.658	997.453	0.8803	1049.569	
0.0302	1000.175	998.963	0.9163	1051.476	1049.497
0.0643	1002.347	1001.107	0.9538	1053.393	1051.427
0.2983	1016.809		0.9787	1054.756	1052.698
0.3209		1016.321	1.0080	1056.290	1054.237
0.6283	1035.851	1033.839	1.1331	1062.660	1060.988
0.7574	1042.964	1040.787	1.2902	1070.519	1069.135

	ρ/(kg·m^{-3})			ρ/(kg·m^{-3})	
c/(mol·kg^{-1})	T = 303.15 K	T = 313.15 K	c/(mol·kg^{-1})	T = 303.15 K	T = 313.15 K
0.0078	996.157	992.720	0.9193	1047.886	1043.809
0.0345	997.846	994.376	0.9520	1049.663	1045.493
0.0643	999.705	996.193	0.9713	1050.639	1046.431
0.2983	1013.750	1010.038	1.0061	1052.387	1048.278
0.6331	1032.618	1028.715	1.1288	1058.746	1054.541
0.7528	1039.141	1035.069	1.2633	1065.555	1061.205
0.8803	1045.874	1041.820			

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Table 2. Density, ρ, of Sodium Bisulfite at 293.75, 288.15, 293.15, 298.15, 303.15, and 313.15 K

	ρ/(kg·m^{-3})		
c/(mol·kg^{-1})	T = 283.15 K	T = 288.15 K	T = 293.15 K
0.0099	1000.802	1000.129	999.154
0.0483	1003.981	1003.297	1002.144
0.0985	1008.214	1007.315	1006.269
0.1179	1009.338	1008.553	1007.493
0.4536	1034.275	1033.229	1032.164
0.8981	1068.218	1066.456	1064.980
1.3988	1105.329	1102.998	1099.893
1.9151	1136.683	1134.862	1132.093
2.1883	1152.982	1150.374	1147.724
2.4717	1168.626	1166.720	1164.472
2.5478	1173.825	1171.504	1168.685
2.6895	1182.093	1179.693	1177.580
2.7636	1186.924	1184.467	1182.070
2.8919	1195.432	1192.322	1190.227
2.9155	1196.573	1193.965	1191.757
3.0844	1209.897	1205.794	1203.555

	ρ/(kg·m^{-3})		
c/(mol·kg^{-1})	T = 298.15 K	T = 303.15 K	T = 313.15 K
0.0099	997.818	996.786	993.307
0.0483	1000.867	998.143	996.402
0.0985	1004.655	1003.617	
0.1179	1006.084	1004.903	1003.564
0.4536	1031.084	1031.483	1028.076
0.8981	1062.635	1063.736	1059.745
1.3988	1096.236		
1.9151	1129.815	1127.921	1123.935
2.1883	1145.639	1143.596	
2.4717	1163.119	1159.090	1153.810
2.5478	1167.487	1163.112	1157.427
2.6895	1175.799	1171.112	1164.676
2.7636	1179.925	1175.313	1167.278
2.8919	1187.104	1181.469	1172.282
2.9155	1188.344	1182.547	1173.601
3.0844	1197.812	1191.244	1180.415

Table 3. Standard Deviation σ (ρ) and Values of Constants in Equation 2 for Sodium 2-Methylalyl Sulfate at Various Temperatures

T/K	A_2	A_3	A_4	A_5	A_6	$\sigma(\rho)$/(kg·m^{-3})
283.75	68.341	-9.012	-0.237			0.05
288.15	65.034	20.083	-75.372	74.062	-25.299	0.07
293.15	68.537	-10.953				0.06
298.15	64.355	-7.468				0.06
303.15	66.063	-10.560	0.984			0.03
313.15	64.418	-8.663				0.04

The temperature of the measuring cell was maintained within ±0.001 K with the help of a circulating thermostat whose temperature was controlled by an M/S TRONIC precision temperature controller, model PTC-41.

Sodium 2-methylallyl sulfate and sodium bisulfate were Analar grade and were used without further purification. Sodium 2-methylallyl sulfate contained 200 ppm each Cl^- and sodium sulfite as impurities. On the other hand sodium bisulfite contained 10 ppm Cl^- and 15 ppm Fe^{3+} as impurities. Aqueous solutions of various known concentrations were prepared by mass using triple-distilled water. Solutions of low concentrations were prepared by successive dilutions.

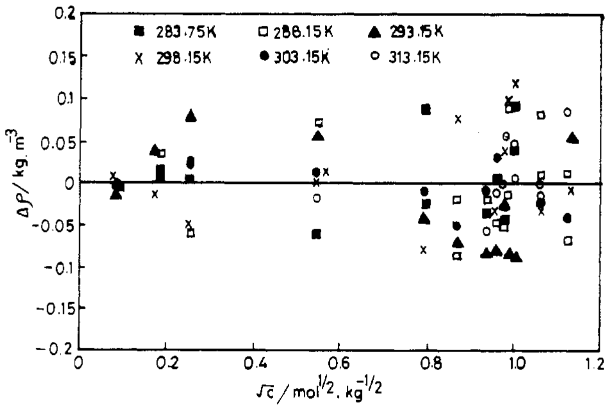

Figure 1. Deviation of the estimated density (from eq 2) from the experimental density plotted as a function of the square root of concentration for sodium 2-methylallyl sulfate.

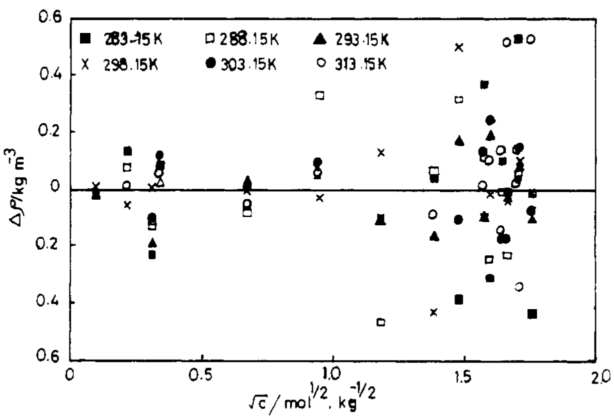

Figure 2. Deviation of the estimated density (from eq 2) from the experimental density plotted as a function of the square root of concentration for sodium bisulfite.

Results and Discussion

Experimental density values for sodium 2-methylallyl sulfate and sodium bisulfite measured at 283.15, 288.15, 293.15, 298.15, 303.15, and 313.15 K are given in Tables 1 and 2. The values of density may be expressed by an empirical equation of the form given below:

$$\rho_T/(\mathrm{kg\cdot m^{-3}}) = \rho_W/(\mathrm{kg\cdot m^{-3}}) + \sum_{i=2}^{n} A_i(c/(\mathrm{mol\cdot kg^{-1}}))^{i/2} \quad (2)$$

where ρ_T is the density of the solution at temperature T, ρ_W is the density of water, c is the concentration of the solution (mol·kg^{-1}), and A_i are adjustable parameters. The values of adjustable parameters obtained by least-squares regression along with the standard deviation $\sigma(\rho)$ calculated using eq 3,

$$\sigma(\rho) = \left[\frac{(\rho_{\mathrm{calcd}} - \rho_{\mathrm{exptl}})^2}{(n-p)}\right]^{1/2} \quad (3)$$

where n is the number of data and p is the number of adjustable parameters, are given in Tables 3 and 4. The

Table 4. Standard Deviation $\sigma(\rho)$ and Vlaues of Constants in Equation 2 for Sodium Bisulfite at Various Temperatures

T/K	A_2	A_3	A_4	A_5	A_6	A_7	$\sigma(\rho)$/(kg·m^{-3})
283.15	1.226	111.890	-170.777	276.037	-184.613	42.463	0.324
288.15	0.560	111.739	-167.838	267.297	-176.678	40.188	0.248
293.15	0.454	99.581	-112.779	182.207	-124.243	28.990	0.147
298.15	0.155	78.125	-3.359	-2.342			0.206
303.15	7.910	22.761	147.078	-167.222	78.415	-13.787	0.169
313.15	5.524	46.510	93.865	-125.931	69.373	-14.818	0.352

deviation of the estimated density from the experimental density for both the components is plotted in Figures 1 and 2. As can be seen from these figures the fitting is excellent in the case of sodium 2-methylallyl sulfate. The deviation was less than ±0.1 $kg{\cdot}m^{-3}$. However, in the case of sodium bisulfite the deviation for most of the data points was within ±0.2 $kg{\cdot}m^{-3}$ with a maximum deviation of ±0.53 $kg{\cdot}m^{-3}$

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