Density and Viscosity of Aqueous Solutions of Sodium Dithionite, Sodium Hydroxide, Sodium Dithionite + Sucrose, and Sodium Dithionite + Sodium Hydroxide + Sucrose from 25 °C to 40 °C

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The density and viscosity of aqueous solutions of sodium dithionite, sodium hydroxide, sodium dithionite + sucrose, and sodium dithionite + sodium hydroxide + sucrose were measured at temperatures from (25 to 40) °C. The concentration ranges were (0 to 1.0) mol·dm^{-3} for sodium dithionite, (0 to 1.0) mol·dm^{-3} for sodium hydroxide, and (0 to 171) g·dm^{-3} for sucrose. The experimental values were correlated with the concentration of sucrose. The maximum deviation was always less than 0.2%.

Introduction

Alkaline sodium dithionite solutions are used in the textile industry to reduce dyes and for the manufacture of various chemicals (Bailar et al., 1973; Doraiswamy and Sharma, 1984). The absorption of O_2 in aqueous alkaline sodium dithionite solutions has also been studied by Jhaveri and Sharma (1968) and Schumpe and Deckwer (1980) for application as a model system for determining the mass transfer parameters in gas−liquid contactors.

All these applications require a kinetic understanding of the reactions which take place. Most authors agree on zero order for oxygen, and some authors have even suggested that the reaction is of first order with respect to dithionite in the range of dithionite concentration <0.1 mol·dm^{-3} and of second order in the range of dithionite concentration >0.1 mol·dm^{-3} (Hikita et al., 1978). The absorption rate decreased with an increase of the pH of the solution (Singh et al., 1978) in the pH range of 8−11, while it is independent of the pH between 12.0 and 13.7 (Camacho et al., 1992).

It is known that use of sugar, glycerin, etc. produces a small reduction in the rate of absorption as the viscosity of the solution increases (Jhavery et al., 1968). The addition of sucrose or glycerin was used in a previous paper (Vázquez et al., 1993) to study the influence of viscosity on gas−liquid absorption.

The objective of this work was to measure the density and viscosity of aqueous solutions of sodium dithionite, sodium hydroxide, sodium dithionite + sucrose, and sodium dithionite + sodium hydroxide (1.0 mol·dm^{-3}) + sucrose over the temperature range (25 to 40) °C. The concentration ranges considered in this work were (0 to 1.0) mol·dm^{-3} for aqueous solutions of sodium dithionite and sodium hydroxide, (0 to 0.5) mol·dm^{-3} for sodium dithionite (for sodium dithionite + sucrose and sodium dithionite + sodium hydroxide (1.0 mol·dm^{-3}) + sucrose solutions) and (0 to 171) g·dm^{-3} for sucrose.

Experimental Section

Aqueous solutions of sodium dithionite, sodium hydroxide, sodium dithionite + sucrose, and sodium dithionite + sodium hydroxide (1.0 mol·dm^{-3}) + sucrose were prepared with distilled−deionised water. The solutes were Merck products of nominal purity >87% for sodium dithionite, >99% for sodium hydroxide, and 99.95% for sucrose. All the solutions were prepared by mass with deviations of less than 0.2% from the desired concentrations. The physical properties were measured at temperature ranging from (25 to 40) °C at 5 °C intervals.

Pycnometers of the Gay-Lussac type (nominal internal volume 25 cm^3) and a Shott-Geräte AVS 350 automatic Ubbelohde viscometer were employed to measure the density and kinematic viscosity, respectively. The detailed experimental procedure has been described elsewhere (Vázquez et al., 1995). In general, each measurement was repeated at least 10 times with a maximum deviation of less than 0.01% for density and 0.4% for viscosity. The precision of the temperature control in all these measurements was ±0.05 °C. The dynamic viscosity was calculated by multiplying the kinematic viscosity by the corresponding density.

Table 1. Density and Viscosity of the Aqueous Solutions of Sodium Dithionite and Sodium Hydroxide

		sodium dithionite		sodium hydroxide	
c/(mol·dm^{-3})	t/°C	ρ/(kg·m^{-3})	η/(mPa·s)	ρ/(kg·m^{-3})	η/(mPa·s)
0.00	25	997.0	0.8900	997.0	0.8900
	30	995.6	0.7973	995.6	0.7973
	35	994.0	0.7255	994.0	0.7255
	40	992.2	0.6529	992.2	0.6529
0.05	25	1003.0	0.9041	999.7	0.9017
	30	1001.7	0.8075	998.2	0.8094
	35	1000.2	0.7336	996.7	0.7303
	40	998.3	0.6608	994.8	0.6598
0.10	25	1009.2	0.9189	1002.1	0.9032
	30	1007.8	0.8211	1000.5	0.8108
	35	1006.3	0.7450	998.9	0.7317
	40	1004.4	0.6716	997.1	0.6610
0.25	25	1027.3	0.9727	1008.4	0.9075
	30	1025.9	0.8705	1006.9	0.8150
	35	1024.7	0.7879	1005.2	0.7356
	40	1022.0	0.7121	1003.6	0.6646
0.50	25	1058.0	1.0796	1018.9	0.9145
	30	1056.1	0.9688	1017.2	0.8217
	35	1055.1	0.8756	1015.5	0.7418
	40	1052.7	0.7946	1013.7	0.6704
0.75	25	1088.2	1.2001	1029.0	0.9214
	30	1086.2	1.0796	1027.3	0.8283
	35	1085.1	0.9765	1025.3	0.7480
	40	1082.6	0.8889	1023.4	0.6756
1.00	25	1118.4	1.3302	1039.4	0.9281
	30	1116.1	1.1994	1038.3	0.8349
	35	1114.8	1.0870	1036.1	0.7541
	40	1112.4	0.9918	1033.3	0.6817

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Table 2. Density of the Aqueous Solutions of Sodium Dithionite + Sucrose[a]

		ρ/(kg·m^{-3})					
c_S/(mol·dm^{-3})	t/°C	c/(mol·dm^{-3}) = 0.05	c/(mol·dm^{-3}) = 0.10	c/(mol·dm^{-3}) = 0.25	c/(mol·dm^{-3}) = 0.50	c/(mol·dm^{-3}) = 0.75	c/(mol·dm^{-3}) = 1.00
0.000	25	1003.0	1009.2	1027.3	1058.0	1088.2	1118.4
	30	1001.7	1007.8	1025.9	1056.1	1086.2	1116.1
	35	1000.2	1006.3	1024.7	1055.1	1085.1	1114.8
	40	998.3	1004.4	1022.0	1052.7	1082.6	1112.4
0.047	25	1009.6	1016.3	1034.4	1065.4	1095.4	1128.3
	30	1008.2	1014.7	1032.9	1063.5	1093.4	1126.0
	35	1006.2	1013.1	1031.5	1062.3	1092.1	1124.6
	40	1004.3	1011.2	1028.8	1059.8	1089.5	1122.0
0.146	25	1024.1	1030.6	1049.5	1079.9	1110.2	1149.2
	30	1022.4	1029.0	1047.8	1078.3	1108.6	1147.0
	35	1020.0	1027.4	1046.1	1076.8	1107.0	1145.6
	40	1018.3	1025.4	1043.6	1074.2	1104.7	1142.9
0.205	25	1032.4	1039.1	1058.2	1088.2	1118.8	1161.4
	30	1030.6	1037.6	1056.4	1086.7	1117.4	1159.3
	35	1028.3	1036.0	1054.6	1085.1	1115.7	1157.9
	40	1026.5	1034.1	1052.2	1082.5	1113.6	1155.2
0.251	25	1038.8	1045.9	1064.9	1094.7	1125.5	1171.1
	30	1036.9	1044.3	1063.1	1093.3	1124.3	1169.0
	35	1034.7	1042.7	1061.1	1091.7	1122.6	1167.7
	40	1032.9	1040.9	1058.9	1089.1	1120.4	1165.1
0.313	25	1047.4	1054.9	1073.8	1103.7	1134.5	1184.2
	30	1045.2	1053.3	1072.1	1102.3	1133.4	1182.2
	35	1043.3	1051.7	1070.0	1100.7	1131.7	1181.0
	40	1041.2	1049.9	1067.8	1098.1	1129.6	1178.4
0.395	25	1057.8	1066.9	1085.0	1115.2	1145.8	1201.3
	30	1055.2	1065.3	1083.4	1114.0	1144.7	1199.3
	35	1054.0	1063.7	1081.1	1112.3	1143.0	1198.0
	40	1051.4	1061.9	1078.9	1109.7	1140.8	1195.5
0.500	25	1071.0	1082.3	1099.3	1130.7	1160.3	1224.0
	30	1067.7	1080.7	1097.8	1129.3	1158.9	1222.0
	35	1067.5	1079.1	1095.3	1127.7	1157.2	1220.8
	40	1063.5	1077.3	1092.9	1125.1	1154.6	1218.3

[a] c_S and c are the concentrations of sucrose and sodium dithionite, respectively.

Table 3. Viscosity of the Aqueous Solutions of Sodium Dithionite + Sucrose[a]

		η/(mPa·s)					
c_S/(mol·dm^{-3})	t/°C	c/(mol·dm^{-3}) = 0.05	c/(mol·dm^{-3}) = 0.10	c/(mol·dm^{-3}) = 0.25	c/(mol·dm^{-3}) = 0.50	c/(mol·dm^{-3}) = 0.75	c/(mol·dm^{-3}) = 1.00
0.000	25	0.9041	0.9189	0.9727	1.0796	1.2001	1.3302
	30	0.8075	0.8211	0.8705	0.9688	1.0796	1.1994
	35	0.7336	0.7450	0.7879	0.8756	0.9765	1.0870
	40	0.6608	0.6716	0.7121	0.7946	0.8889	0.9918
0.047	25	0.9309	0.9506	1.0081	1.1143	1.2301	1.3538
	30	0.8366	0.8560	0.9082	1.0033	1.1081	1.2225
	35	0.7604	0.7817	0.8233	0.9106	1.0047	1.1109
	40	0.6878	0.7120	0.7470	0.8338	0.9169	1.0161
0.146	25	1.0246	1.0491	1.1112	1.2174	1.3401	1.4544
	30	0.9307	0.9560	1.0092	1.1057	1.2110	1.3194
	35	0.8454	0.8783	0.9175	1.0111	1.1037	1.2082
	40	0.7681	0.8066	0.8358	0.9387	1.0114	1.1132
0.205	25	1.0931	1.1178	1.1813	1.2880	1.4224	1.5347
	30	0.9971	1.0234	1.0755	1.1756	1.2874	1.3959
	35	0.9051	0.9411	0.9790	1.0788	1.1762	1.2841
	40	0.8230	0.8653	0.8927	1.0073	1.0795	1.1882
0.251	25	1.1513	1.1750	1.2389	1.3463	1.4929	1.6054
	30	1.0527	1.0788	1.1293	1.2333	1.3524	1.4630
	35	0.9551	0.9919	1.0288	1.1345	1.2376	1.3503
	40	0.8684	0.9119	0.9383	1.0629	1.1369	1.2534
0.313	25	1.2355	1.2562	1.3201	1.4285	1.5954	1.7108
	30	1.1322	1.1564	1.2042	1.3147	1.4472	1.5626
	35	1.0263	1.0624	1.0981	1.2127	1.3269	1.4482
	40	0.9324	0.9755	1.0016	1.1403	1.2195	1.3495
0.395	25	1.3551	1.3698	1.4326	1.5429	1.7430	1.8659
	30	1.2437	1.2639	1.3067	1.4278	1.5826	1.7086
	35	1.1262	1.1587	1.1927	1.3208	1.4537	1.5908
	40	1.0215	1.0609	1.0873	1.2463	1.3366	1.4891
0.500	25	1.5207	1.5241	1.5839	1.6971	1.9483	2.0876
	30	1.3960	1.4079	1.4428	1.5803	1.7707	1.9164
	35	1.2624	1.2861	1.3180	1.4658	1.6294	1.7930
	40	1.1415	1.1719	1.2003	1.3868	1.4974	1.6861

[a] c_S and c are the concentrations of sucrose and sodium dithionite, respectively.

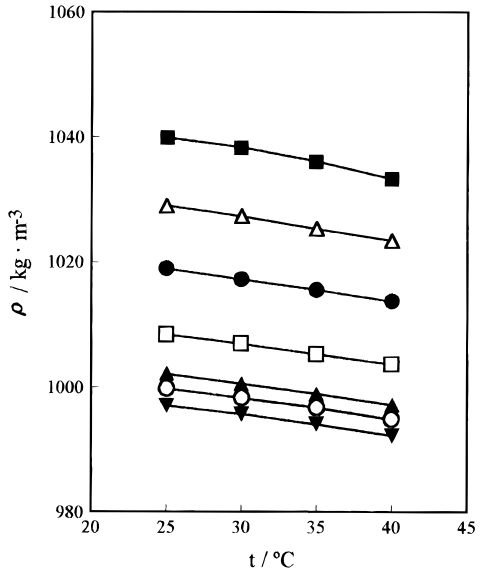

Figure 1. Experimental densities of the aqueous solutions of sodium hydroxide at varius concentrations as a function of temperature: (▼) 0.00 mol·dm^{-3}; (○) 0.05 mol·dm^{-3}; (▲) 0.10 mol·dm^{-3}; (□) 0.25 mol·dm^{-3}; (●) 0.50 mol·dm^{-3}; (△) 0.75 mol·dm^{-3}; (■) 1.00 mol·dm^{-3}.

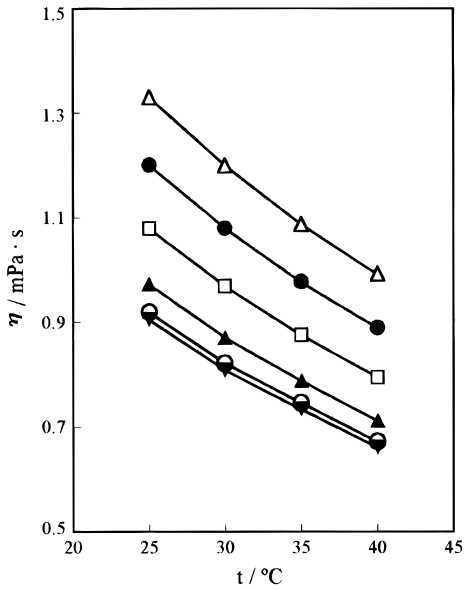

Figure 2. Experimental viscosities of the aqueous solutions of sodium dithionite at various concentrations as a function of temperature: (▼) 0.05 mol·dm^{-3}; (○) 0.10 mol·dm^{-3}; (▲) 0.25 mol·dm^{-3}; (□) 0.50 mol·dm^{-3}; (●) 0.75 mol·dm^{-3}; (△) 1.00 mol·dm^{-3}.

The pycnometers and the viscometer were calibrated with distilled−deionized water. The measured density and kinematic viscosity of water at the working temperatures, all of which were within 0.2% of published values (Marsh, 1987), are listed in Table 1.

Results and Discussion

The density and viscosity of the aqueous solutions of sodium dithionite, sodium hydroxide, sodium dithionite + sucrose, and sodium dithionite + sodium hydroxide (1.0 mol·dm^{-3}) + sucrose, at (25, 30, 35 and 40) °C, are listed in Tables 1−5. For each temperature the density and

Table 4. Density of the Aqueous Solutions of Sodium Dithionite + Sodium Hydroxide (1.0 mol·dm^{-3}) + Sucrose[a]

		ρ/(kg·m^{-3})					
c_S/(mol·dm^{-3})	t/°C	c/(mol·dm^{-3}) = 0.05	c/(mol·dm^{-3}) = 0.10	c/(mol·dm^{-3}) = 0.25	c/(mol·dm^{-3}) = 0.50	c/(mol·dm^{-3}) = 0.75	c/(mol·dm^{-3}) = 1.00
0.000	25	1045.8	1051.9	1071.4	1103.4	1133.0	1159.9
	30	1044.9	1050.1	1069.5	1099.8	1128.8	1156.8
	35	1041.0	1047.7	1067.0	1097.7	1126.9	1154.3
	40	1040.1	1046.8	1066.1	1096.3	1124.4	1150.9
0.047	25	1053.0	1055.4	1076.9	1107.3	1138.1	1162.9
	30	1051.9	1053.5	1074.7	1103.7	1133.7	1159.8
	35	1048.1	1050.9	1072.0	1100.8	1131.9	1157.1
	40	1046.7	1049.7	1070.1	1099.5	1128.8	1153.8
0.146	25	1064.5	1066.9	1088.5	1113.0	1149.1	1169.0
	30	1063.1	1064.6	1086.2	1109.6	1145.4	1166.3
	35	1059.9	1062.3	1083.7	1106.7	1143.9	1163.2
	40	1058.3	1060.2	1081.4	1105.2	1139.9	1160.4
0.205	25	1070.9	1074.7	1095.7	1117.0	1155.6	1173.6
	30	1069.2	1072.0	1093.2	1114.1	1152.7	1171.4
	35	1066.4	1069.8	1091.1	1111.4	1151.2	1168.0
	40	1064.9	1067.2	1088.6	1109.5	1146.9	1165.7
0.251	25	1075.8	1080.9	1101.2	1121.1	1160.9	1178.3
	30	1074.0	1078.0	1098.9	1118.5	1158.3	1176.2
	35	1071.4	1076.0	1096.9	1115.9	1157.0	1172.8
	40	1070.0	1072.9	1094.4	1113.8	1152.5	1170.5
0.313	25	1082.7	1089.4	1109.0	1127.8	1167.9	1185.8
	30	1080.7	1085.9	1106.7	1125.7	1165.7	1183.9
	35	1078.4	1083.9	1104.9	1123.3	1164.3	1180.3
	40	1076.9	1080.4	1102.2	1121.0	1159.7	1178.2
0.395	25	1092.9	1100.4	1119.2	1139.8	1177.6	1198.2
	30	1090.3	1096.1	1117.0	1138.1	1175.7	1196.6
	35	1088.1	1094.4	1115.4	1135.9	1173.8	1192.5
	40	1086.7	1089.7	1112.4	1132.8	1169.1	1190.8
0.500	25	1107.6	1113.8	1132.6	1160.4	1190.1	1218.8
	30	1104.3	1107.8	1130.6	1159.3	1188.0	1217.2
	35	1101.9	1106.3	1128.5	1157.2	1184.7	1212.8
	40	1100.0	1100.2	1125.2	1152.7	1180.2	1210.7

[a] c_S and c are the concentrations of sucrose and sodium dithionite, respectively.

Table 5. Viscosity of the Aqueous Solutions of Sodium Dithionite + Sodium Hydroxide (1.0 mol·dm^{-3}) + Sucrose[a]

		η/(mPa·s)					
c_S/(mol·dm^{-3})	t/°C	c/(mol·dm^{-3}) = 0.05	c/(mol·dm^{-3}) = 0.10	c/(mol·dm^{-3}) = 0.25	c/(mol·dm^{-3}) = 0.50	c/(mol·dm^{-3}) = 0.75	c/(mol·dm^{-3}) = 1.00
0.000	25	0.9425	0.9624	1.0364	1.1862	1.3568	1.5413
	30	0.8475	0.8651	0.9304	1.0628	1.2142	1.3789
	35	0.7645	0.7781	0.8343	0.9496	1.0837	1.2316
	40	0.6904	0.7032	0.7523	0.8551	0.9753	1.1081
0.047	25	0.9753	0.9947	1.0698	1.2056	1.3762	1.5607
	30	0.8786	0.8961	0.9608	1.0802	1.2317	1.3964
	35	0.7951	0.8086	0.8632	0.9666	1.1007	1.2475
	40	0.7197	0.7325	0.7796	0.8712	0.9914	1.1242
0.146	25	1.0753	1.0934	1.1742	1.2831	1.4537	1.6383
	30	0.9720	0.9895	1.0533	1.1478	1.2993	1.4641
	35	0.8859	0.8994	0.9496	1.0304	1.1645	1.3078
	40	0.8043	0.8171	0.8614	0.9311	1.0513	1.1841
0.205	25	1.1443	1.1616	1.2459	1.3432	1.5139	1.6984
	30	1.0361	1.0536	1.1171	1.1994	1.3508	1.5157
	35	0.9480	0.9615	1.0089	1.0785	1.2127	1.3533
	40	0.8615	0.8743	0.9165	0.9761	1.0963	1.2291
0.251	25	1.2015	1.2183	1.3060	1.3955	1.5662	1.7508
	30	1.0891	1.1066	1.1699	1.2440	1.3954	1.5603
	35	0.9993	1.0127	1.0580	1.1200	1.2542	1.3925
	40	0.9084	0.9212	0.9624	1.0147	1.1349	1.2677
0.313	25	1.2826	1.2986	1.3927	1.4727	1.6434	1.8280
	30	1.1640	1.1816	1.2047	1.3094	1.4608	1.6257
	35	1.0717	1.0851	1.1273	1.1805	1.3149	1.4498
	40	0.9744	0.9872	1.0278	1.0712	1.1914	1.3242
0.395	25	1.3956	1.4106	1.5079	1.5852	1.7557	1.9404
	30	1.2682	1.2860	1.3489	1.4040	1.5554	1.7203
	35	1.1721	1.1856	1.2237	1.2677	1.4024	1.5324
	40	1.0657	1.0785	1.1151	1.1524	1.2726	1.4054
0.500	25	1.5484	1.5622	1.6687	1.7439	1.9145	2.0992
	30	1.4088	1.4268	1.4896	1.5369	1.6883	1.8531
	35	1.3089	1.3211	1.3537	1.3897	1.5248	1.6479
	40	1.1882	1.2009	1.2355	1.2658	1.3861	1.5189

[a] c_S and c are the concentrations of sucrose and sodium dithionite, respectively.

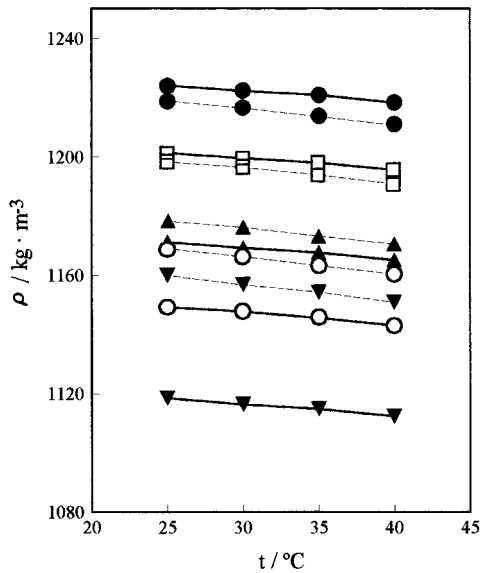

Figure 3. Experimental densities of the sodium dithionite (1.00 mol·dm^{-3}) + sucrose and sodium dithionite (1.00 mol·dm^{-3}) + sodium hydroxide (1.0 mol·dm^{-3}) + sucrose aqueous solutions as a function of temperature: (—) with sodium hydroxide; (- - -) without sodium hydroxide. Concentration of sucrose: (▼) 0.000 mol·dm^{-3}; (○) 0.047 mol·dm^{-3}; (▲) 0.251 mol·dm^{-3}; (□) sucrose 0.395 mol·dm^{-3}; (●) sucrose 0.500 mol·dm^{-3}.

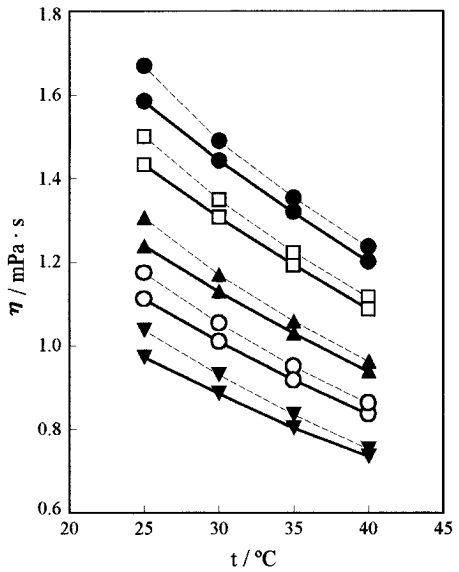

Figure 4. Experimental viscosities of the sodium dithionite (0.25 mol·dm^{-3}) + sucrose and sodium dithionite + sodium hydroxide (1.0 mol·dm^{-3}) + sucrose aqueous solutions as a function of temperature: (—) with sodium hydroxide; (- - -) without sodium hydroxide. Concentration of sucrose: (▼) 0.000 mol·dm^{-3}; (○) 0.146 mol·dm^{-3}; (▲) 0.251 mol·dm^{-3}; (□) 0.395 mol·dm^{-3}; (●) 0.500 mol·dm^{-3}.

viscosity of the aqueous solutions of the sodium dithionite and sodium hydroxide increase with increasing concentration, Figures 1 and 2, and the density and viscosity of the sodium dithionite + sucrose and sodium dithionite + sodium hydroxide (1.0 mol·dm^{-3}) + sucrose increase with increasing sucrose concentration, Figures 3 and 4.

Table 6. Parameters of Eqs 1 and 2 for the Sucrose Concentration Dependence of the Density and Viscosity of the Aqueous Solutions of Sodium Dithionite + Sucrose

		ρ(eq 1)			η(eq 2)	
c/(mol·dm^{-3})	t/°C	A_2	A_3	A_4	m	n
0.05	25	135.366	44.544	−61.714	1.5460	1.326
	30	129.930	59.111	−79.498	1.4195	1.270
	35	112.056	92.098	−85.167	1.2687	1.263
	40	105.644	130.526	−135.036	1.1185	1.218
0.10	25	152.079	−21.958	19.223	1.4372	1.248
	30	147.253	−8.352	8.875	1.3428	1.194
	35	144.379	−0.405	3.000	1.1911	1.138
	40	140.262	13.864	−8.635	1.0461	1.064
0.25	25	152.505	6.103	−25.607	1.4095	1.206
	30	147.291	14.193	−27.015	1.2706	1.151
	35	142.732	18.115	−28.637	1.1721	1.145
	40	137.965	44.097	−54.677	1.0579	1.116
0.50	25	173.180	−92.599	75.395	1.4367	1.218
	30	170.796	−74.435	56.576	1.4204	1.216
	35	163.948	−63.824	52.800	1.3518	1.196
	40	159.851	−54.098	46.428	1.3128	1.149
0.75	25	153.019	−4.770	−10.923	1.9233	1.362
	30	146.788	33.478	−50.153	1.7596	1.348
	35	138.362	49.615	−58.545	1.6400	1.328
	40	132.924	79.687	−90.528	1.5006	1.302
1.00	25	219.118	−42.620	44.509	2.0965	1.469
	30	217.635	−33.432	35.672	1.9615	1.452
	35	212.717	−17.775	23.696	1.9036	1.431
	40	203.466	7.924	5.455	1.8531	1.416

Table 7. Parameters of Eqs 1 and 2 for the Sucrose Concentration Dependence of the Density and Viscosity of the Aqueous Solutions of Sodium Dithionite + Sodium Hydroxide (1.0 mol·dm^{-3}) + Sucrose

		ρ(eq 1)			η(eq 2)	
c/(mol·dm^{-3})	t/°C	A_2	A_3	A_4	m	n
0.05	25	211.666	−328.211	288.088	1.4243	1.233
	30	204.409	−311.636	269.506	1.3105	1.223
	35	199.044	−267.407	223.676	1.2633	1.217
	40	174.648	−192.533	162.622	1.1421	1.198
0.10	25	20.700	295.785	−212.094	1.4129	1.236
	30	13.607	317.202	−244.982	1.3128	1.225
	35	8.025	339.891	−262.206	1.2627	1.218
	40	−2.602	353.557	−281.209	1.1417	1.198
0.25	25	113.735	5.940	8.868	1.4987	1.245
	30	104.044	27.219	−2.223	1.3122	1.230
	35	84.738	104.589	−71.402	1.2121	1.223
	40	54.008	181.793	−128.676	1.1228	1.216
0.50	25	151.033	−425.341	527.516	1.4944	1.422
	30	139.965	−378.208	492.842	1.2474	1.396
	35	110.100	−288.716	426.087	1.1431	1.377
	40	107.957	−277.781	402.484	1.0622	1.371
0.75	25	110.358	−8.769	20.168	1.4937	1.421
	30	89.296	92.484	−72.523	1.2437	1.396
	35	78.935	152.103	−141.766	1.1473	1.379
	40	61.802	169.969	−140.807	1.0627	1.371
1.00	25	97.533	−236.400	374.840	1.4942	1.421
	30	91.084	−197.005	338.044	1.2465	1.394
	35	85.102	−189.897	332.237	1.0830	1.379
	40	74.476	−147.543	288.923	1.0627	1.371

The density of the sodium dithionite + sucrose and sodium dithionite + sodium hydroxide (1.0 mol·dm^{-3}) + sucrose, ρ, was expressed as a function of the concentration of sucrose by an empirical equation of the form (Choudary and Jasra, 1994)

$$\rho/(\mathrm{kg\cdot m^{-3}}) = \rho_d(\mathrm{kg\cdot m^{-3}}) + \sum_{i=2}^{4} A_i(c_S/(\mathrm{mol\cdot dm^{-3}}))^{i/2} \quad (1)$$

where ρ_d is the density of solvent (given by the aqueous solutions of the sodium dithionite or sodium dithionite + sodium hydroxide (1.0 mol·dm^{-3})), c_S is the concentration of sucrose, and A_i are the adjustable coefficients whose values are listed in Tables 6 and 7.

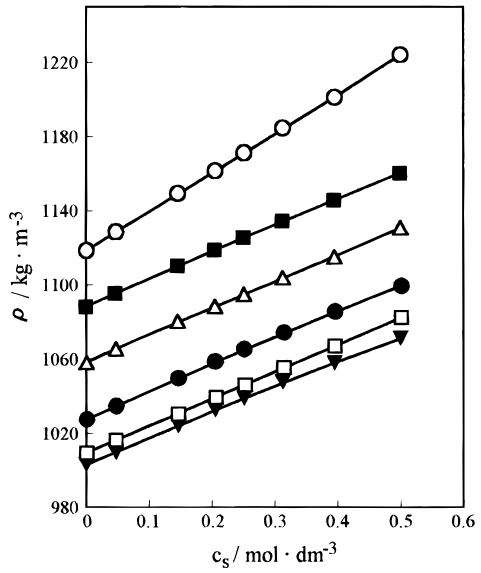

Figure 5. Density of the aqueous solutions of sodium dithionite + sucrose at 25 °C plotted against the sucrose concentration: (—) calculated from eq 1. Concentration of sodium dithionite: (▼) 0.05 mol·dm^{-3}; (□) 0.10 mol·dm^{-3}; (●) 0.25 mol·dm^{-3}; (△) 0.50 mol·dm^{-3}; (□) 0.75 mol·dm^{-3}; (○) 1.00 mol·dm^{-3}.

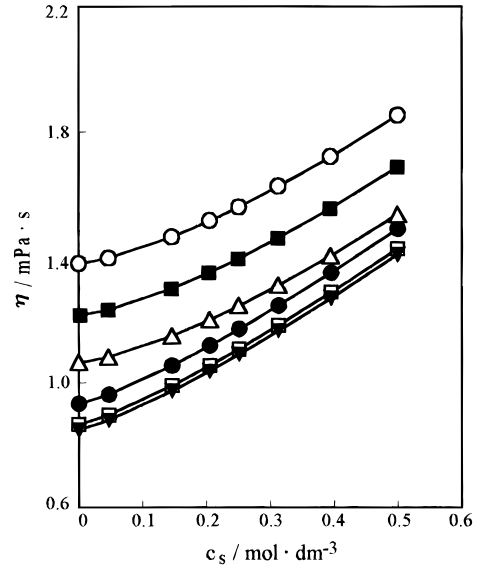

Figure 6. Viscosity of the aqueous solutions of sodium dithionite + sodium hydroxide (1.0 mol·dm^{-3}) + sucrose at 30 °C plotted against the sucrose concentration: (—) calculated from eq 2. Concentration of sodium dithionite: (▼) 0.05 mol·dm^{-3}; (□) 0.10 mol·dm^{-3}; (●) 0.25 mol·dm^{-3}; (●) 0.50 mol·dm^{-3}; (■) 0.75 mol·dm^{-3}; (○) 1.00 mol·dm^{-3}.

The maximum deviation of the estimated density from the experimental density is ±0.1 kg·m^{-3}. The comparison between the experimental densities and those calculated by means of eq 1 at 25 °C are graphically shown in Figure 5.

The variation of the dynamic viscosity of the sodium dithionite + sucrose and sodium dithionite + sodium hydroxide (1.0 mol·dm^{-3}) + sucrose solutions with the concentration was expressed through the following equation:

$$\eta/(\mathrm{mPa\cdot s}) = \eta_d/(\mathrm{mPa\cdot s}) + m(c_S/(\mathrm{mol\cdot dm^{-3}}))^n \quad (2)$$

where η is the viscosity of the solution, η_d is the viscosity of solvent, and c_S is the concentration of sucrose. The

Table 8. Parameters of Eqs 1 and 2 for the Dithionite Concentration Dependence of the Density and Viscosity of the Aqueous Solutions of Sodium Dithionite and Sodium Dithionite + Sodium Hydroxide (1.0 mol·dm^{-3})

		ρ(eq 1)			η(eq 2)	
system	t/°C	A_2	A_3	A_4	m	n
sodium dithionite	25	117.278	−20.065	16.085	0.4371	1.229
	30	113.109	−13.322	15.167	0.4020	1.231
	35	112.182	−12.046	14.465	0.3610	1.268
	40	111.613	−10.564	14.369	0.3390	1.259
sodium dithionite +	25	104.544	70.438	−54.994	0.6139	1.246
sodium hydroxide	30	115.706	22.478	−20.445	0.5441	1.255
(1.0 mol·dm^{-3})	35	139.577	−12.744	−6.651	0.4775	1.288
	40	141.841	−18.049	−6.176	0.4264	1.298

values of the fitted parameters m and n are listed in Tables 6 and 7.

The experimental and estimated viscosities at 30 °C are compared in Figure 6. The maximum differences are always less than 0.2%.

The density and viscosity in absence of sucrose, ρ_d and η_d, were correlated as a function of the concentration of dithionite, c, by means of eqs 1 and 2, respectively (with deviations of less than 0.2%). The values of the fitted parameters are listed in Table 8.

Literature Cited

Bailar, J. C.; Emeleus, H. J.; Nyholm, S. R.; Trotmanm-Dickenson, A. F. *Comprehensive Inorganic Chemistry*; Pergamon Press: Oxford, 1973; Vol. 1.

Camacho, F.; Paez, M. P.; Blázquez, G.; Garrido, J. M. Oxygen Absorption in Alkaline Sodium Dithionite Solutions. *Chem. Eng. Sci.* **1992**, *47*, 4309−4314.

Choudary, N. V.; Jasra, R. V. Densities of Aqueous Solutions of Sodium Bisulfite and Sodium 2-Methylallyl Sulfate. *J. Chem. Eng. Data* **1994**, *39*, 181−183.

Doraiswamy, L. K.; Sharma, M. M. *Heterogeneous Reactions*; Wiley: New York: 1984; Vol. 2.

Hikita, H.; Ishikawa, H.; Sakamoto, N; Esaka, N. Absorption of Oxygen in Aqueous Alkaline Solutions of Sodium Dithionite. *Chem. Eng. Sci.* **1978**, *33*, 392−396.

Jhavery, A. S.; Sharma, M. M. Absorption of Oxygen in Aqueous Alkaline Solutions of Sodium Dithionite. *Chem. Eng. Sci.* **1968**, *23*, 1−8.

Marsh, K. N. *Recommended Reference Materials for the Realization of Physicochemical Properties*; Blackwell Scientific Publications: Oxford, 1987.

Schumpe, A.; Deckwer, W. D. Analysis of Chemical Methods for Determination of Interfacial Areas in Gas-Liquid Dispersions with Non-Uniform Bubble Sizes. *Chem. Eng. Sci.* **1980**, *35*, 2221−2233.

Singh, D. K.; Sharma, R. N.; Srivastava, R. D. Kinetics of Oxidation of Sodium Dithionite By Flow Thermal Method. *AIChE J.* **1978**, *24*, 232−237.

Vázquez G.; Antorrena G.; Navaza J. M.; Santos V.; Rodríquez T. Absorption of CO_2 in Aqueous Solutions of Various Viscosities in the Presence of Induced Turbulence. *Int. Chem. Eng.* **1993**, *33*, 649−655.

Vázquez, G.; Alvarez, E.; Cancela, A.; Navaza, J. M. Density, Viscosity and Surface Tension of Aqueous Solutions of Sodium Sulfite and Sodium Sulfite + Sucrose from 25 to 40 °C. *J. Chem. Eng. Data* **1995**, *40*, 1101−1105.

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