Table I. Enthalpy of Solution of Nd_2O_3-Hexagonal in HCl at 298° K.

Mass of Nd_2O_3, G.	Mass of Solvent, G.	Energy Equiv., Cal./Arb. Units	ΔT, Arb. Units	Energy from Solution, Cal./G.	Dev., Cal./G.
Solvent, 2.00*M* HCl Av. temp. rise, 0.34° C.					
0.4597	400.16	15.984	8.886	308.96	0.60
0.4610	401.33	15.953	8.912	308.37	0.01
0.4605	400.84	15.919	8.911	308.07	0.29
0.4595	399.95	15.904	8.921	308.79	0.43
0.4602	400.57	15.927	8.883	307.45	0.91
0.4597	400.16	15.900	8.917	308.40	0.04
			Av.	308.34	0.38
2 × standard deviation of mean					0.44
Solvent, 4.36 molal HCl Av. temp. rise, 0.36° C.					
0.4672	448.01	16.339	8.909	311.57	0.16
0.4667	447.53	16.401	8.845	310.84	0.57
0.4671	447.91	16.245	8.914	310.01	1.40
0.4671	447.91	16.350	8.920	312.23	0.82
0.4666	447.43	16.133	9.035	312.39	0.98
			Av.	311.41	0.79
2 × standard deviation of mean					0.89

$$Nd_2O_3(c) + 6\ HCl\ (4.36\ \text{molal}) \rightarrow 2\ NdCl_3\ (\text{in }4.36\ \text{molal HCl}) + 3\ H_2O \qquad (2)$$

$$3\ H_2O\ (\text{in }4.36\ \text{molal HCl}) \rightarrow 3\ H_2O(1) \qquad (3)$$

$$3\ H_2(g) + 3/2\ O_2(g) \rightarrow 3\ H_2O(1) \qquad (4)$$

$$2\ Nd(c) + 3/2\ O_2(g) \rightarrow Nd_2O_3(c) \qquad (5)$$

$$\Delta H_5 = \Delta H_1 - \Delta H_2 - \Delta H_3 + \Delta H_4$$

ΔH_1 is taken to be −331.56 ± 0.40 kcal., which is twice the enthalpy of solution of Nd metal in 4.36 molal HCl, −165.78 ± 0.20 kcal. per gram atom as reported by Stuve (*8*). Other values for the enthalpy of solution of Nd metal in aqueous HCl are −162.6 kcal. per gram atom in 0.25*M* HCl reported by Spedding and Miller (*7*) for metal not as well characterized as that used by Stuve and probably not as pure, −171.4 kcal. per gram atom in 0.1*N* HCl reported by Bommer and Hohmann (*1*), whose value for the enthalpy of solution of lanthanum metal is known to be in error (*7*), and −163.9 kcal. per mole reported by Polyachenok and Novikov (*6*), who dissolved Nd(c) in 0.2*N* HCl.

ΔH_2 is taken to be −104.76 ± 0.31 kcal. as discussed earlier. ΔH_3 = 204 cal., three times the negative of the partial molal enthalpy of water in 4.36 molal HCl, which is taken to be −68 cal. per mole from data tabulated by Klotz (*4*). ΔH_4 is three times the enthalpy of formation of liquid water = 3 × (−68.315) = −204.945 kcal. (*9*).

Summing as indicated above, ΔH_5 = −431.95 ± 0.51 kcal. per mole. The weighted average of this value and the value from combustion calorimetry is $\Delta H^{\circ}_{f\ 298^{\circ}\ K.}$ (Nd_2O_3-hexagonal) = 432.11 ± 0.22 kcal. per mole.

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Viscosities of Binary Aqueous Solutions of NaCl, KCl, Na_2SO_4, and $MgSO_4$ at Concentrations and Temperatures of Interest in Desalination Processes

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Experimental viscosity and density measurements are reported on binary salt solutions over the range of ionic strength levels from 0.1 to 3.5 and the temperature range from 25° to 150° C. The estimated precision for the viscosity data is 0.1 to 0.2% and for densities, 0.02%. The data were correlated by using Othmer's rule, yielding an over-all precision of 0.4 to 0.5%. Literature data were reviewed and compared with the correlation.

UNDER a continuing program to establish the property values of aqueous electrolyte solutions encountered in desalination processes, viscosity measurements were made on these solutions over the temperature range from 25° to 150° C. The first part of this investigation, covering the viscosities of the four major sea water components in their binary aqueous solutions, is presented here.

Measured rather than calculated densities were used in converting kinematic viscosities to dynamic viscosities to avoid excessive extrapolations from our previous set of density data (*2*). Determined viscosities were correlated and compared with other sources. At elevated temperatures, though, the comparison was hindered by the lack of relevant literature information.

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EXPERIMENTAL

Densities of liquids were determined in Lipkin pycnometers up to 75° C., and sealed glass dilatometer tubes consisting of a bulb and a long, uniform-bore capillary stem were used in the 75° to 150° C. temperature range. Details of the measurements were reported previously (*2*).

Viscosity measurements were made in Cannon master glass capillary instruments. Open viscometers, fully immersed in a water-filled thermostat, were used up to 60° C. To reduce evaporative losses, the receiving side arm tube was narrowed to 0.3 cm. I.D. Closed end viscometers pressurized with hydrogen were used for the measurements above 75° C. to avoid liquid evaporation and boiling. A special high temperature assembly was developed to receive the latter viscometers, and provision was made to facilitate the liquid movement in the closed pressurized system by diffusing hydrogen through a palladium-silver membrane. The entire unit was submerged in an oil bath. Details of the apparatus and procedure were described elsewhere (*9*).

Results obtained with water confirmed that varying the pressure up to 200 p.s.i.g. had no significant effect on the efflux times measured. Repeated measurements with electrolyte solutions (Table I) showed this effect to be negligible in this case also.

All compounds used in the experiments were analytical grade reagents dissolved in double-distilled, degassed water. Temperatures were measured with NBS-calibrated mercury in glass thermometers graduated into 0.01° C. divisions, and maintained in the thermostat bath with ±0.001-0.003° C. precision. The glass capillary viscometers used for the tests were individually calibrated with degassed double distilled water at 20° C. (*9*). All viscosity measurements are related to the 1.002-centipoise absolute water viscosity value at 20° C. as the accepted primary standard in viscometry.

RESULTS

The experimental results are given in Tables II–V. Kinetic energy and driving head corrections were made as described elsewhere (*9*). In addition, concentration adjustments to correct for water evaporation into the vapor

Table I. Kinematic Viscosity of Electrolyte Solutions in Centistokes Measured at Atmospheric and at Elevated Pressures

Salt Dissolved	Concentration, Molality	Pressure, P.S.I.G.	Temperature	
			40° C.	60° C.
NaCl	0.0999	Atmospheric[a]	0.6627	0.4786
		100	. . .	0.4788
		150	. . .	0.4789
		200	. . .	0.4785
NaCl	0.7069	Atmospheric	0.6880	0.5009
		100	0.6885	0.5005
		200	0.6879	0.5005
NaCl	3.5345	Atmospheric	0.8524	0.6258
		100	0.8526	0.6259
		200	0.8524	0.6254
KCl	0.7069	Atmospheric	0.6481	0.4758
		100	0.6484	0.4760
		200	0.6478	0.4758
KCl	3.5348	Atmospheric	0.6405	0.4920
		100	0.6410	0.4926
		200	0.6406	0.4920
Na_2SO_4	1.1779	Atmospheric	0.9576	0.6828
		100	0.9583	0.6827
		200	0.9579	. . .
$MgSO_4$	0.8848	Atmospheric	1.0397	0.7335
		100	1.0394	. . .
		200	1.0385	0.7331

[a] Atmospheric measurements were made in the open viscometers.

Table II. Measured Viscosities and Densities of Binary Aqueous NaCl Solutions

Temp., ° C.	Molality	Density	ν, Cs.	η_R	
				Exptl.	Calcd.
25	0.0999	1.0011	0.8980	1.010	1.009
	0.7069	1.0253	0.9243	1.065	1.065
	1.4138	1.0514	0.9636	1.138	1.140
	3.5345	1.1226	1.1358	1.432	1.431
40	0.0999	0.9961	0.6627	1.011	1.010
	0.7069	1.0197	0.6880	1.075	1.074
	1.4138	1.0453	0.7212	1.155	1.154
	3.5345	1.1154	0.8524	1.457	1.456
60	0.0999	0.9871	0.4786	1.013	1.012
	0.7069	1.0104	0.5009	1.085	1.084
	1.4138	1.0356	0.5277	1.171	1.170
	3.5345	1.1047	0.6258	1.482	1.482
75	0.1001	0.9786	0.3920	1.014	1.013
	0.7083	1.0016	0.4118	1.090	1.090
	1.4166	1.0272	0.4352	1.181	1.181
	3.5408	1.0969	0.5170	1.499	1.500
100	0.1004	0.9623	0.2981	1.017	1.014
	0.7103	0.9855	0.3143	1.098	1.099
	1.4207	1.0113	0.3333	1.195	1.195
	3.5502	1.0813	0.3976	1.525	1.526
125	0.1009	0.9434	0.2396	1.019	1.015
	0.7144	0.9671	0.2535	1.105	1.106
	1.4289	0.9935	0.2695	1.207	1.208
	3.5686	1.0644	0.3225	1.547	1.550
150	0.1020	0.9221	0.2015	1.024	1.017
	0.7217	0.9466	0.2134	1.113	1.113
	1.4438	0.9738	0.2273	1.220	1.220
	3.6024	1.0469	0.2724	1.571	1.573
				S.D. =	0.17%

Table III. Measured Viscosities and Densities of Binary Aqueous KCl Solutions

Temp., ° C.	Molality	Density	ν, Cs.	η_R	
				Exptl.	Calcd.
25	0.0999	1.0017	0.8889	1.000	1.000
	0.7069	1.0289	0.8631	0.997	1.000
	1.4139	1.0584	0.8406	0.999	1.002
	3.5347	1.1369	0.8147	1.040	1.046
40	0.0999	0.9968	0.6569	1.003	1.003
	0.7069	1.0235	0.6481	1.016	1.017
	1.4139	1.0526	0.6410	1.034	1.030
	3.5347	1.1301	0.6405	1.109	1.107
60	0.0999	0.9878	0.4752	1.006	1.006
	0.7069	1.0139	0.4758	1.034	1.036
	1.4139	1.0431	0.4776	1.068	1.061
	3.5347	1.1200	0.4920	1.181	1.177
75	0.1001	0.9795	0.3893	1.008	1.008
	0.7083	1.0062	0.3931	1.045	1.048
	1.4166	1.0348	0.3976	1.087	1.081
	3.5415	1.1118	0.4180	1.228	1.223
100	0.1004	0.9632	0.2959	1.011	1.011
	0.7104	0.9900	0.3021	1.060	1.065
	1.4207	1.0190	0.3088	1.116	1.109
	3.5517	1.0968	0.3325	1.293	1.292
125	0.1009	0.9444	0.2379	1.012	1.013
	0.7144	0.9717	0.2449	1.072	1.079
	1.4287	1.0012	0.2526	1.140	1.134
	3.5718	1.0806	0.2765	1.346	1.354
150	0.1020	0.9232	0.1999	1.017	1.015
	0.7218	0.9512	0.2068	1.084	1.092
	1.4433	0.9818	0.2149	1.162	1.155
	3.6082	1.0632	0.2384	1.396	1.414
				S.D. =	0.43%

Table IV. Measured Viscosities and Densities of Binary Aqueous Na_2SO_4 Solutions

Temp., °C.	Molality	Density	ν, Cs.	η_R	
				Exptl.	Calcd.
25	0.0333	1.0014	0.9029	1.015	1.015
	0.2356	1.0262	0.9578	1.104	1.108
	0.4712	1.0540	1.0285	1.217	1.216
	1.1779	1.1313	1.3129	1.668	1.667
40	0.0333	0.9964	0.6658	1.016	1.016
	0.2356	1.0208	0.7076	1.107	1.109
	0.4712	1.0480	0.7603	1.221	1.216
	1.1779	1.1242	0.9576	1.649	1.651
60	0.0333	0.9873	0.4804	1.017	1.016
	0.2356	1.0113	0.5115	1.109	1.111
	0.4712	1.0383	0.5493	1.222	1.216
	1.1779	1.1134	0.6828	1.630	1.633
75	0.0333	0.9792	0.3930	1.017	1.017
	0.2360	1.0031	0.4184	1.109	1.112
	0.4721	1.0303	0.4489	1.222	1.216
	1.1802	1.1051	0.5547	1.620	1.625
100	0.0334	0.9630	0.2979	1.017	1.017
	0.2367	0.9869	0.3175	1.111	1.114
	0.4734	1.0140	0.3396	1.221	1.217
	1.1836	1.0887	0.4165	1.608	1.613
125	0.0336	0.9440	0.2390	1.017	1.018
	0.2381	0.9683	0.2545	1.111	1.116
	0.4761	0.9956	0.2726	1.223	1.218
	1.1904	1.0710	0.3314	1.599	1.607
150	0.0340	0.9225	0.2005	1.019	1.018
	0.2405	0.9474	0.2131	1.112	1.118
	0.4810	0.9752	0.2284	1.227	1.220
	1.2026	1.0519	0.2758	1.598	1.607
				S.D. =	0.35%

Table V. Measured Viscosities and Densities of Binary Aqueous $MgSO_4$ Solutions

Temp., °C.	Molality	Density	ν, Cs.	η_R	
				Exptl.	Calcd.
25	0.0250	1.0001	0.9060	1.018	1.017
	0.1770	1.0182	0.9791	1.120	1.123
	0.3539	1.0388	1.0738	1.253	1.254
	0.8848	1.0975	1.4385	1.773	1.777
40	0.0250	0.9952	0.6673	1.017	1.017
	0.1770	1.0131	0.7202	1.118	1.121
	0.3539	1.0334	0.7872	1.246	1.242
	0.8848	1.0916	1.0397	1.739	1.740
60	0.0250	0.9863	0.4818	1.019	1.018
	0.1770	1.0039	0.5177	1.114	1.118
	0.3539	1.0242	0.5636	1.237	1.228
	0.8848	1.0822	0.7335	1.702	1.701
75	0.0250	0.9782	0.3930	1.016	1.018
	0.1773	0.9964	0.4228	1.113	1.117
	0.3546	1.0157	0.4584	1.230	1.220
	0.8865	1.0748	0.5911	1.679	1.680
100	0.0251	0.9618	0.2985	1.018	1.018
	0.1778	0.9802	0.3191	1.109	1.115
	0.3556	0.9996	0.3444	1.221	1.209
	0.8890	1.0591	0.4382	1.646	1.651
125	0.0253	0.9430	0.2397	1.019	1.018
	0.1788	0.9613	0.2548	1.104	1.113
	0.3577	0.9810	0.2737	1.210	1.200
	0.8940	1.0408	0.3444	1.615	1.633
150	0.0255	0.9211	0.2010	1.020	1.019
	0.1806	0.9400	0.2127	1.102	1.113
	0.3615	0.9600	0.2275	1.203	1.194
	0.9032	1.0206	0.2838	1.596	1.628
				S.D. =	0.68%

space of the apparatus became necessary above 75° C. With known water activities, the density of the saturated water vapor above the solutions was calculated, and a water material balance was made. Knowing, also, the volumes of the solutions and the inner space of the apparatus at each temperature level, contraction coefficients were derived, and these in turn yielded the concentration change.

Liquid densities corresponding to the adjusted concentrations were used in the driving head corrections. Similarly, in calculating the gas densities for these corrections, the partial pressure of water vapor above the solutions at their adjusted concentration levels were taken into account. Partial pressures of the other two gaseous components, air and hydrogen, were also calculated and the density of the gas mixture was established from that of the individual components at their respective partial pressures.

Young and Grinstead's (*19*) surface tension data on strong electrolytes were used to calculate the surface tension corrections. These authors found a linear relationship, when the difference of surface tension between solution and water was plotted as a function of concentration. The slopes of these lines were found to be almost temperature independent.

The precision of measured kinematic viscosities reported in Tables II–V is estimated to be 0.1 to 0.2%. Dynamic viscosities (η) are easily obtained from the tables by simple multiplication with the densities listed. In the calculation of relative viscosities ($\eta_{\text{soln}}/\eta_{H_2O}$), water viscosities reported previously (*9*) were used. After comparing the experimental and calculated relative viscosities, both values were rounded to three decimal places.

CORRELATION OF DATA

Since all measurements were made well above the range of dilute solutions, the entire evaluation of the viscosity data was based on the application of the Othmer rule (*11*), which states that the logarithm of the relative viscosity of an aqueous solution of a given concentration can be expressed as a linear function of the logarithm of the viscosity of water at the same temperature:

$$\log \eta_R = A_0 + B_0 \log \eta_{H_2O} \tag{1}$$

where

$$\eta_R = \eta_{\text{soln}}/\eta_{H_2O} \quad (\eta \text{ in centipoises})$$

The temperature independent constants A_0 and B_0 were expressed as functions of ionic strength in the form:

$$A_0 = A_1 I + A_2 I^2 + A_3 I^3 \tag{2}$$

$$B_0 = B_1 I + B_2 I^2 + B_3 I^3 \tag{3}$$

In these equations, the ionic strength rather than molarity was used to express the solute concentration to eliminate the temperature dependence of the molarity. Furthermore, the first term of a correlation for dilute solutions containing a square root concentration expression was dropped, since the correlation was applied only to concentrated solutions.

The constants of Equations 2 and 3 were calculated from our experimental data. To carry out this calculation, the measured viscosity data at 75° to 150° C. were re-adjusted, as if they were made at uniform concentrations corresponding to those of the low temperature measurements. The increase of solute concentration with the increase of the temperature was caused by water evaporation within the closed viscometer. The A_0 and B_0 values calculated by the method of least squares were then correlated by Equations 2 and 3 to determine the constants.

Table VI gives the constants for the four salts investigated. The calculated viscosity values using these constants are given in the last columns of Tables II to V. The standard deviations for the systems are 0.17% for NaCl, 0.43% for KCl, 0.35% for Na_2SO_4, and 0.68% for $MgSO_4$. Considering that a single set of constants was used to cover the 25° to 150° C. temperature range and the 0.1 to 3.5 ionic strength range, the fit of the data is quite satisfactory.

COMPARISON WITH LITERATURE DATA

The experimental data and the developed correlations were compared with available literature data. Tables VII to X give the average deviations of viscosity measurements from the present correlation. The tables give the average deviation in per cent and, in parentheses, the number of datum points given by the author at the appropriate temperature level. Since the correlation does not pertain to dilute solutions or to low temperatures, all data below an ionic strength of 0.1 and below 20° C. were omitted. Generally, the literature data agree well with the correlation,

Table VI. Constants for the Correlation of Viscosity by the Othmer Rule (Equations 2 and 3)

Compound	A_1	A_2	A_3	B_1	B_2	B_3
NaCl	0.03550	0.00231	−0.00003	−0.04753	0.01598	−0.00194
KCl	−0.00522	0.00175	0.00016	−0.09677	0.03215	−0.00547
Na_2SO_4	0.06672	−0.00721	0.00176	−0.01547	0.01356	−0.00189
$MgSO_4$	0.07341	−0.00278	0.00063	−0.01104	0.03467	−0.00740

Table VII. Average Deviations of Viscosity Measurements for NaCl from Present Correlation (in Per Cent)

Temp., ° C.	References									Present Data
	(5)	*(7)*	*(1)*	*(10)*	*(16)*	*(4)*	*(12)*	*(15)*	*(8)*	
20				0.16 (5)	0.15 (1)			0.35 (4)	0.04 (3)	
25	0.14 (6)[a]	0.20 (5)	0.16 (2)	0.15 (5)		0.85 (4)		0.15 (4)	0.06 (3)	0.09 (4)
30				0.09 (5)	0.42 (1)		0.32 (5)	0.48 (3)	0.05 (3)	
35							0.94 (5)		0.08 (3)	
40	0.11 (6)		0.33 (2)	0.14 (5)			0.34 (5)	0.14 (4)	0.09 (3)	0.07 (4)
45							0.44 (5)			
50					0.88 (1)		0.16 (5)	0.54 (3)		
55							0.36 (5)			
60	0.11 (6)		0.30 (2)							0.08 (4)
70						0.91 (4)				
75										0.07 (4)
80	0.27 (6)		1.06 (1)		4.61 (1)					
100	0.73 (6)									0.10 (4)
125										0.15 (4)
150										0.21 (4)

[a] Number of datum points.

Table VIII. Average Deviation of Viscosity Measurements for KCl from Present Correlation (in Per Cent)

Temp., ° C.	References										Present Data
	(5)	*(10)*	*(1)*	*(8)*	*(13)*	*(16)*	*(14)*	*(4)*	*(15)*	*(6)*	
20		0.61 (7)[a]		0.07 (3)						0.82 (1)	0.30 (4)
25	0.40 (3)	0.19 (5)	0.26 (14)	0.12 (3)					0.72 (6)	0.17 (2)	
30		0.21 (6)		0.08 (3)					0.52 (5)	0.27 (3)	
35	0.25 (9)			0.06 (3)	0.41 (4)		0.39 (3)				
40		0.53 (7)	0.93 (4)	0.12 (3)	0.85 (5)						0.18 (4)
45	0.59 (9)				0.89 (5)						
50					1.23 (5)	2.37 (1)			0.62 (5)	0.93 (3)	
55					0.97 (5)						
60			0.92 (4)					1.20 (4)			0.33 (4)
70											
75							0.80 (3)				0.35 (4)
80						0.90 (2)				2.00 (3)	
100											0.33 (4)
125											0.55 (4)
150											0.85 (4)

[a] Number of datum points.

Table IX. Average Deviations of Viscosity Measurements for Na_2SO_4 from Present Correlation (in Per Cent)

Temp., ° C.	References			Present data
	(5)	*(3)*	*(4)*	
25	0.67 (4)[a]	0.56 (8)		0.15(4)
30			0.53 (2)	
40	0.83 (5)	0.58 (8)		0.23 (4)
60				0.30 (4)
75				0.35 (4)
100				0.30 (4)
125				0.48 (4)
150				0.58 (4)

[a] Number of datum points

Table X. Average Deviations of Viscosity Measurements for $MgSO_4$ from Present Correlation (in Per Cent)

Temp., ° C.	References				Present Data
	(5)	*(17)*	*(8)*	*(1)*	
18	0.26 (5)[a]			0.42 (4)	
25	0.65 (5)	9.15 (7)	0.30 (4)		0.22 (4)
30			0.29 (4)		
35			0.28 (4)		
40			0.24 (4)	0.61 (1)	0.20 (4)
60					0.38 (4)
75					0.42 (4)
100					0.58 (4)
125					0.95 (4)
150					1.32 (4)

[a] Number of datum points.

Table XI. Relative Viscosity of NaCl Solutions

Molality	Temperature, ° C.					
	25	50	75	100	125	150
0.1	1.009	1.011	1.013	1.014	1.015	1.016
0.2	1.018	1.022	1.026	1.028	1.030	1.032
0.3	1.027	1.033	1.038	1.042	1.045	1.048
0.4	1.036	1.045	1.051	1.056	1.060	1.064
0.5	1.046	1.056	1.064	1.070	1.075	1.079
0.6	1.055	1.067	1.076	1.084	1.090	1.095
0.7	1.065	1.078	1.089	1.097	1.104	1.110
0.8	1.075	1.090	1.102	1.111	1.119	1.125
0.9	1.085	1.101	1.114	1.125	1.133	1.140
1.0	1.095	1.113	1.127	1.138	1.147	1.155
1.2	1.116	1.137	1.153	1.165	1.176	1.185
1.4	1.138	1.161	1.178	1.192	1.204	1.214
1.6	1.161	1.185	1.204	1.220	1.232	1.243
1.8	1.184	1.211	1.231	1.247	1.261	1.272
2.0	1.209	1.236	1.258	1.275	1.290	1.302
2.2	1.234	1.263	1.286	1.304	1.319	1.332
2.4	1.261	1.291	1.314	1.333	1.349	1.362
2.6	1.288	1.319	1.344	1.364	1.380	1.394
2.8	1.316	1.349	1.374	1.395	1.412	1.426
3.0	1.346	1.380	1.406	1.428	1.445	1.460
3.2	1.377	1.412	1.440	1.462	1.480	1.496
3.4	1.409	1.446	1.475	1.498	1.517	1.533
3.6	1.442	1.481	1.511	1.536	1.556	1.573

Table XII. Relative Viscosity of KCl Solutions

Molality	Temperature, ° C.					
	25	50	75	100	125	150
0.1	1.000	1.005	1.008	1.011	1.013	1.015
0.2	1.000	1.009	1.016	1.021	1.025	1.029
0.3	1.000	1.013	1.023	1.031	1.037	1.043
0.4	1.000	1.016	1.029	1.040	1.048	1.055
0.5	1.000	1.020	1.036	1.048	1.059	1.067
0.6	1.000	1.023	1.042	1.056	1.068	1.079
0.7	1.000	1.026	1.047	1.064	1.078	1.089
0.8	1.000	1.029	1.052	1.071	1.087	1.100
0.9	1.000	1.032	1.058	1.078	1.095	1.109
1.0	1.001	1.035	1.062	1.085	1.103	1.119
1.2	1.001	1.040	1.072	1.097	1.118	1.136
1.4	1.002	1.046	1.080	1.108	1.132	1.152
1.6	1.004	1.051	1.089	1.119	1.145	1.167
1.8	1.005	1.056	1.097	1.130	1.158	1.182
2.0	1.008	1.062	1.106	1.142	1.172	1.198
2.2	1.011	1.069	1.116	1.154	1.186	1.214
2.4	1.014	1.076	1.126	1.167	1.202	1.232
2.6	1.018	1.084	1.138	1.182	1.220	1.252
2.8	1.022	1.094	1.152	1.200	1.240	1.275
3.0	1.028	1.105	1.167	1.219	1.264	1.302
3.2	1.034	1.117	1.185	1.242	1.291	1.333
3.4	1.041	1.132	1.207	1.269	1.323	1.369
3.6	1.049	1.149	1.231	1.301	1.360	1.412

Table XIII. Relative Viscosity of Na_2SO_4 Solutions

Molality	Temperature, ° C.					
	25	50	75	100	125	150
0.1	1.046	1.048	1.049	1.050	1.051	1.052
0.2	1.092	1.094	1.096	1.098	1.099	1.100
0.3	1.137	1.139	1.141	1.143	1.144	1.145
0.4	1.183	1.184	1.185	1.186	1.186	1.187
0.5	1.230	1.229	1.229	1.228	1.228	1.228
0.6	1.279	1.276	1.273	1.271	1.268	1.269
0.7	1.331	1.324	1.320	1.316	1.313	1.310
0.8	1.387	1.377	1.370	1.364	1.359	1.355
0.9	1.450	1.436	1.425	1.417	1.410	1.405
1.0	1.519	1.501	1.488	1.477	1.468	1.461
1.1	1.598	1.578	1.559	1.546	1.536	1.527
1.2	1.688	1.662	1.643	1.627	1.615	1.605

Table XIV. Relative Viscosity of $MgSO_4$ Solutions

Molality	Temperature, ° C.					
	25	50	75	100	125	150
0.1	1.069	1.069	1.068	1.068	1.068	1.068
0.2	1.140	1.134	1.130	1.127	1.125	1.123
0.3	1.213	1.199	1.189	1.181	1.174	1.168
0.4	1.291	1.266	1.247	1.232	1.220	1.210
0.5	1.374	1.336	1.308	1.286	1.268	1.254
0.6	1.463	1.414	1.377	1.349	1.326	1.307
0.7	1.562	1.504	1.461	1.427	1.401	1.379
0.8	1.672	1.611	1.565	1.530	1.502	1.479
0.9	1.797	1.742	1.701	1.669	1.643	1.622
1.0	1.940	1.905	1.880	1.859	1.843	1.830

and we feel that they support the general validity of the estimation technique developed.

For convenience, a computer program was prepared and printouts were made at round molality values and at a series of temperature levels. These recommended values are given in Tables XI to XIV. Because of the estimated error of about 0.4%, the data are given only to three decimal places.

Additional tables on salt and sea water solutions which contain density, vapor pressure, and viscosity data as functions of temperature (° C., ° F.) and concentration (molality, molarity, weight per cent, chlorinity, etc.) were prepared by the authors for the Office of Saline Water (*18*).

NOMENCLATURE

Molality = gram moles of salt/1000 grams of H_2O

ν = Kinematic viscosity, centistokes

η = Dynamic viscosity, centipoises

ν_R = Relative viscosity $\eta_{\text{soln}} / \eta_{H_2O}$

Density = g./cc.

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