Viscosity and Density of Aqueous Solutions of LiBr, LiCl, $ZnBr_2$, $CaCl_2$, and $LiNO_3$. 2. Two-Salt Solutions

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Experimental data for the viscosity and density of the systems LiBr + LiCl + H_2O, LiBr + $LiNO_3$ + H_2O, LiBr + $CaCl_2$ + H_2O, and LiBr + $ZnBr_2$ + H_2O are presented. The concentrations are three equally spaced salt mole ratios and five total salt:water ratios. The temperature ranges are 25–90 °C for the viscosity and 20–70 °C for the density.

Introduction

Over the last 20 years various multisalt + water solutions have been proposed as the replacement for LiBr + water as the working fluid in absorption heat pumps, heat transformers, and refrigeration machinery. Iyoki and Uemura (*1, 2*) have evaluated some of them. The main advantage of such solutions is that crystallization is suppressed by the addition of a second and possibly a third salt to the solution. One disadvantage of multisalt solutions as working fluids is that the viscosity of the solutions becomes higher when crystallization is suppressed. In a previous paper (*3*), we have measured the viscosity of some single-salt solutions. The scope of this work is measurement of the viscosity of the ternary solutions formed by addition of a second salt to a LiBr + water solution. The aim is to enable correlation of viscosity to salt composition in the multisalt case.

Experimental Section

The materials and methods are the same in part 1 (*3*). Single-salt + water stock solutions were prepared and the compositions determined as in ref 3. The ternaries were prepared by mixing the LiBr stock solution with one of the

Table 1. Experimental Density, ρ, of the System LiBr + LiCl + H_2O as a Function of Temperature, t, Salt Mass Fraction, w, and Molar Ratio of LiBr to LiCl, r (For Each Composition the Density Parameters, d, and Regression Standard Deviation, SD Are Given)

$100w$	r	d_1	d_2	d_3	ρ/(kg m^{-3})	t/°C	SD/(kg m^{-3})
50.35	0.3221				1412.7	18.45	
50.35	0.3221				1408.0	28.56	
50.35	0.3221				1403.3	38.72	
50.35	0.3221				1398.4	48.92	
50.35	0.3221				1393.5	59.12	
50.35	0.3221	1412.0	−0.460 34	−3.3765E−04	1388.4	69.41	0.01
12.73	0.3221				1082.2	19.37	
12.73	0.3221				1079.3	29.35	
12.73	0.3221				1075.7	39.38	
12.73	0.3221				1071.6	49.39	
12.73	0.3221				1067.0	59.51	
12.73	0.3221	1082.1	−0.283 29	−2.4643E−03	1062.0	69.63	0.05
24.80	0.3221				1169.8	18.30	
24.80	0.3221				1166.6	28.43	
24.80	0.3221				1162.8	38.78	
24.80	0.3221				1158.8	49.02	
24.80	0.3221				1154.4	59.28	
24.80	0.3221	1169.3	−0.316 03	−1.5801E−03	1149.8	69.55	0.02
37.27	0.3221				1276.3	19.34	
37.27	0.3221				1272.5	29.34	
37.27	0.3221				1268.5	39.36	
37.27	0.3221				1264.3	49.45	
37.27	0.3221				1260.0	59.56	
37.27	0.3221	1276.1	−0.373 20	−8.3467E−04	1255.5	69.70	0.03
43.58	0.3221				1339.7	19.31	
43.58	0.3221				1335.5	29.28	
43.58	0.3221				1331.2	39.30	
43.58	0.3221				1326.8	49.28	
43.58	0.3221				1322.2	59.42	
43.58	0.3221	1339.4	−0.412 54	−5.7349E−04	1317.6	69.53	0.02
54.69	0.9554				1527.3	18.45	
54.69	0.9554				1521.7	28.67	
54.69	0.9554				1516.2	38.77	
54.69	0.9554				1510.7	48.86	
54.69	0.9554				1505.0	58.97	
54.69	0.9554	1526.4	−0.541 72	−1.9037E−04	1499.3	69.22	0.01
13.62	0.9554				1093.0	19.29	
13.62	0.9554				1089.7	29.36	
13.62	0.9554				1085.6	39.42	
13.62	0.9554				1080.9	49.43	
13.62	0.9554				1075.5	59.60	
13.62	0.9554	1092.8	−0.310 93	−3.1685E−03	1069.5	69.81	0.02
27.23	0.9554				1206.9	19.38	
27.23	0.9554				1203.3	29.37	
27.23	0.9554	1206.7	−0.354 99	−1.7333E−03	1199.2	39.39	0.04
47.67	0.9554				1430.5	19.34	
47.67	0.9554				1425.8	29.36	
47.67	0.9554				1420.8	39.44	
47.67	0.9554				1415.8	49.52	
47.67	0.9554				1410.6	59.69	
47.67	0.9554	1430.2	−0.470 30	−4.9522E−04	1405.4	69.89	0.11
58.36	2.880				1641.5	18.32	
58.36	2.880				1635.0	28.51	
58.36	2.880				1628.6	38.85	
58.36	2.880				1622.2	49.06	
58.36	2.880				1615.7	59.33	
58.36	2.880	1640.4	−0.628 06	−1.5731E−05	1609.2	69.60	0.02
14.67	2.880				1109.5	18.49	
14.67	2.880				1106.3	28.66	
14.67	2.880				1102.5	38.86	
14.67	2.880				1098.1	48.84	
14.67	2.880				1093.2	58.91	
14.67	2.880	1109.1	−0.302 64	−2.6415E−03	1087.9	69.12	0.06
29.25	2.880				1242.7	19.29	
29.25	2.880				1238.9	29.28	
29.25	2.880				1234.6	39.27	
29.25	2.880				1229.9	49.30	
29.25	2.880				1225.0	59.41	
29.25	2.880	1242.5	−0.376 84	−1.7001E−03	1219.6	69.52	0.02
43.76	2.880				1411.6	19.26	
43.76	2.880				1406.9	29.22	
43.76	2.880				1402.0	39.24	
43.76	2.880				1396.9	49.29	
43.76	2.880				1391.6	59.35	
43.76	2.880	1411.3	−0.470 00	−7.6755E−04	1386.2	69.43	0.02
50.99	2.880				1516.9	18.37	
50.99	2.880				1511.4	28.58	
50.99	2.880				1505.9	38.82	
50.99	2.880				1500.3	48.89	
50.99	2.880				1494.5	59.18	
50.99	2.880	1516.0	−0.535 23	−3.5619E−04	1488.7	69.56	0.02

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Table 2. Experimental Density, ρ, of the System $LiBr + CaCl_2 + H_2O$ as a Function of Temperature, t, Salt Mass Fraction, w, and Molar Ratio of LiBr to $CaCl_2$, r (For Each Composition the Density Parameters, d, and Regression Standard Deviation, SD, Are Given)

$100w$	r	d_1	d_2	d_3	ρ/(kg m^{-3})	t/°C	SD/(kg m^{-3})	$100w$	r	d_1	d_2	d_3	ρ/(kg m^{-3})	t/°C	SD/(kg m^{-3})
51.57	0.3399				1533.2	19.27		27.16	1.023				1229.2	49.32	
51.57	0.3399				1526.2	29.35		27.16	1.023				1223.7	59.47	
51.57	0.3399				1519.3	39.50		27.16	1.023	1243.4	−0.446 55	−2.6585E−03	1218.1	69.72	1.73
51.57	0.3399				1512.3	49.71		40.52	1.023				1399.9	18.35	
51.57	0.3399				1507.4	57.03		40.52	1.023				1394.1	28.48	
51.57	0.3399	1532.7	−0.695 30	3.6112E−04	1507.5	56.89	0.01	40.52	1.023				1388.2	38.68	
13.25	0.3399				1110.9	19.13		40.52	1.023				1382.2	48.83	
13.25	0.3399				1107.3	29.26		40.52	1.023				1376.1	59.03	
13.25	0.3399				1103.0	39.42		40.52	1.023	1398.9	−0.567 39	−4,5464E−04	1369.9	69.23	0.01
13.25	0.3399				1098.3	49.57		46.83	1.023				1481.7	19.03	
13.25	0.3399				1095.2	55.58		46.83	1.023				1475.4	29.01	
13.25	0.3399	1110.6	−0.342 24	−2.5331E−03	1095.1	55.89	0.02	46.83	1.023				1469.0	39.05	
25.63	0.3399				1231.2	19.20		46.83	1.023				1462.5	49.07	
25.63	0.3399				1226.5	29.33		46.83	1.023				1455.9	59.24	
25.63	0.3399				1221.5	39.45		46.83	1.023	1481.1	−0.637 69	−1.2977E−04	1449.3	69.40	0.02
25.63	0.3399				1216.2	49.61		57.22	2.908				1644.4	19.10	
25.63	0.3399				1212.8	55.91		57.22	2.908				1637.4	29.14	
25.63	0.3399	1230.9	−0.455 83	−1.2854E−03	1212.7	56.23	0.01	57.22	2.908				1630.5	39.21	
38.43	0.3399				1375.3	18.28		57.22	2.908				1623.7	49.31	
38.43	0.3399				1369.3	28.44		57.22	2.908				1616.8	59.47	
38.43	0.3399				1363.1	38.81		57.22	2.908	1643.8	−0.694 92	−3.0081E−04	1610.0	69.75	0.75
38.43	0.3399				1356.8	49.14		14.71	2.908				1118.3	19.20	
38.43	0.3399				1353.0	55.32		14.71	2.908				1114.9	29.18	
38.43	0.3399	1374.3	−0.588 67	−3.7403E−04	1352.8	55.70	0.01	14.71	2.908				1110.8	39.19	
44.93	0.3399				1452.9	19.04		14.71	2.908				1106.2	49.21	
44.93	0.3399				1446.3	29.14		14.71	2.908				1101.2	59.24	
44.93	0.3399				1439.6	39.30		14.71	2.908	1118.0	−0.330 25	−2.5006E−03	1095.7	69.26	0.05
44.93	0.3399				1432.9	49.48		29.42	2.908				1263.9	18.07	
44.93	0.3399				1428.4	56.25		29.42	2.908				1259.5	28.15	
44.93	0.3399	1452.3	−0.657 41	−2.8474E−05	1428.2	56.54	0.01	29.42	2.908				1254.7	38.40	
54.15	1.023				1581.0	18.66		29.42	2.908				1249.7	48.47	
54.15	1.023				1574.0	28.84		29.42	2.908				1244.4	58.67	
54.15	1.023				1567.1	39.08		29.42	2.908	1263.1	−0.428 22	−1.4126E−03	1238.8	68.87	0.03
54.15	1.023				1560.1	49.37		43.28	2.908				1434.2	19.13	
54.15	1.023				1558.7	51.56		43.28	2.908				1428.7	29.09	
54.15	1.023	1580.0	−0.688 41	−3,6575E−04	1558.4	52.00	0.51	43.28	2.908				1423.1	39.06	
13.69	1.023				1112.5	18.08		43.28	2.908				1417.3	49.03	
13.69	1.023				1109.0	28.43		43.28	2.908				1411.4	59.15	
13.69	1.023				1104.8	38.67		43.28	2.908	1433.7	−0.547 17	−5.7968E−04	1405.4	69.21	0.01
13.69	1.023				1100.2	48.86		50.07	2.908				1532.9	18.09	
13.69	1.023				1095.0	59.13		50.07	2.908				1526.6	28.26	
13.69	1.023	1111.9	−0.329 07	−2.6585E−04	1089.2	69.39	2.95	50.07	2.908				1520.3	38.39	
27.16	1.023				1243.8	19.11		50.07	2.908				1513.8	48.70	
27.16	1.023				1239.2	29.17		50.07	2.908				1507.2	59.02	
27.16	1.023				1234.4	39.18		50.07	2.908	1531.8	−0.620 47	−1.9538E−04	1500.7	69.35	0.00

Table 3. Experimental Density, ρ, of the System of $LiBr + ZnBr_2 + H_2O$ as a Function of Temperature, t, Salt Mass Fraction, w, and Molar Ratio of LiBr to $ZnBr_2$, r (For Each Composition the Density Parameters, d, and Regression Standard Deviation, SD, Are Given)

$100w$	r	d_1	d_2	d_3	ρ/(kg m^{-3})	t/°C	SD/(kg m^{-3})	$100w$	r	d_1	d_2	d_3	ρ/(kg m^{-3})	t/°C	SD/(kg m^{-3})
65.01	3.448				1856.8	18.38		56.95	3.448				1663.0	49.28	
65.01	3.448				1847.5	28.64		56.95	3.448				1655.2	59.36	
65.01	3.448				1838.1	38.86		56.95	3.448	1685.0	−0.732 81	−6.1621E−04	1647.3	69.50	0.02
65.01	3.448				1828.8	49.08		67.44	1.123				1973.7	17.94	
65.01	3.448				1819.4	59.28		67.44	1.123				1962.1	28.12	
65.01	3.448	1855.4	−0.908 76	−1.9060E−04	1809.9	69.46	0.01	67.44	1.123				1950.5	38.45	
16.92	3.448				1147.7	18.59		67.44	1.123				1939.0	48.68	
16.92	3.448				1143.6	28.75		67.44	1.123				1927.5	58.91	
16.92	3.448				1138.7	38.94		67.44	1.123	1971.3	−1.139 3	3.7213E−04	1916.3	69.11	0.01
16.92	3.448				1133.1	49.08		16.66	1.123				1154.6	18.34	
16.92	3.448				1126.8	59.24		16.66	1.123				1145.1	38.91	
16.92	3.448	1147./2	−0.390 79	−3.2076E−03	1120.0	69.49	0.05	16.66	1.123				1139.2	49.10	
31.89	3.448				1302.9	19.30		16.66	1.123				1132.6	59.37	
31.89	3.448				1297.2	29.30		16.66	1.123	1154.0	−0.400 38	−3.5983E−03	1125.2	69.66	0.03
31.89	3.448				1290.9	39.34		32.79	1.123				1337.3	19.37	
31.89	3.448				1284.3	49.41		32.79	1.123				1330.5	29.41	
31.89	3.448				1277.3	59.51		32.79	1.123				1323.2	39.46	
31.89	3.448	1302.5	−0.569 08	−1.7207E−03	1270.1	69.71	0.05	32.79	1.123				1315.3	49.54	
48.33	3.448				1528.9	19.33		32.79	1.123				1307.0	59.66	
48.33	3.448				1522.4	29.31		32.79	1.123	1336.9	−0.657 57	−2.3847E−03	1298.3	69.78	0.05
48.33	3.448				1515.6	39.33		50.43	1.123				1600.0	19.32	
48.33	3.448				1508.6	49.42		50.43	1.123				1591.1	29.31	
48.33	3.448				1501.2	59.56		50.43	1.123				1581.8	39.33	
48.33	3.448	1528.5	−0.646 92	−1.0537E−03	1493.8	69.68	0.02	50.43	1.123				1572.3	49.37	
56.95	3.448				1685.5	19.27		50.43	1.123				1562.4	59.46	
56.95	3.448				1678.2	29.26		50.43	1.123	1599.5	−0.890 19	−1.2010E−03	1552.4	69.59	0.04
56.95	3.448				1670.7	39.28		58.67	1.123				1761.2	18.28	

Table 3 (Continued)

100w	r	d_1	d_2	d_3	ρ/(kg m^{-3})	t/°C	SD/(kg m^{-3})	100w	r	d_1	d_2	d_3	ρ/(kg m^{-3})	t/°C	SD/(kg m^{-3})
58.67	1.123				1751.0	28.57		34.13	0.3879				1365.8	29.14	
58.67	1.123				1740.7	38.68		34.13	0.3879				1358.0	39.16	
58.67	1.123				1730.2	48.90		34.13	0.3879				1349.6	49.24	
58.67	1.123				1719.7	59.06		34.13	0.3879				1340.7	59.31	
58.67	1.123	1759.5	−0.999 72	−5.1593E−04	1709.1	69.24	0.02	34.13	0.3879	1372.4	−0.706 89	−2.5293E−03	1331.4	69.41	0.04
69.10	0.3879				2092.3	17.99		51.75	0.3879				1661.8	18.50	
69.10	0.3879				2065.5	38.35		51.75	0.3879				1651.9	28.63	
69.10	0.3879				2079.0	28.11		51.75	0.3879				1641.8	38.67	
69.10	0.3879				2051.9	48.51		51.75	0.3879				1631.2	48.77	
69.10	0.3879				2038.2	58.66		51.75	0.3879				1620.3	58.88	
69.10	0.3879	2089.7	−1.315 75	−3.7655E−04	2024.5	68.88	0.02	51.75	0.3879	1660.4	−0.965 76	−1.6068E−03	1609.1	69.07	0.04
17.58	0.3879				1171.3	19.13		60.32	0.3879				1851.0	18.03	
17.58	0.3879				1166.8	29.11		60.32	0.3879				1839.7	28.13	
17.58	0.3879				1161.5	39.12		60.32	0.3879				1828.0	38.40	
17.58	0.3879				1155.3	49.20		60.32	0.3879				1816.0	48.63	
17.58	0.3879				1148.3	59.29		60.32	0.3879				1803.8	58.78	
17.58	0.3879	1170.9	−0.410 57	−4.2529E−03	1140.2	69.42	0.07	60.32	0.3879	1848.8	−1.114 71	−1.1653E−03	1791.5	68.94	0.02
34.13	0.3879				1373.0	19.17									

Table 4. Experimental Density, ρ, of the System of LiBr + $LiNO_3$ + H_2O as a Function of Temperature, t, Salt Mass Fraction, w, and Molar Ratio of LiBr to $LiNO_3$, r (For Each Composition the Density Parameters, d, and Regression Standard Deviation, SD, Are Given)

100w	r	d_1	d_2	d_3	ρ/(kg m^{-3})	t/°C	SD/(kg m^{-3})	100w	r	d_1	d_2	d_3	ρ/(kg m^{-3})	t/°C	SD/(kg m^{-3})
57.63	2.595				1615.5	19.45		26.66	0.8501				1185.5	50.04	
57.63	2.595				1608.5	29.57		26.66	0.8501				1179.9	59.74	
57.63	2.595				1601.3	39.76		26.66	0.8501	1200.9	−0.463 87	−1.6501E−03	1179.6	60.14	0.01
57.63	2.595				1594.1	50.01		39.81	0.8501				1331.1	18.77	
57.63	2.595				1587.7	59.06		39.81	0.8501				1325.2	29.06	
57.63	2.595	1615.1	−0.695 89	−1.5226E−04	1587.5	59.33	0.01	39.81	0.8501				1319.2	39.33	
14.33	2.595				1105.4	18.75		39.81	0.8501				1312.9	49.65	
14.33	2.595				1101.9	28.95		39.81	0.8501				1308.0	57.61	
14.33	2.595				1097.7	39.28		39.81	0.8501	1330.4	−0.564 49	−8.8162E−04	1307.4	58.57	0.01
14.33	2.595				1092.9	49.60		47.48	0.8501				1419.8	19.52	
14.33	2.595				1087.9	59.16		47.48	0.8501				1413.4	29.65	
14.33	2.595	1105.0	−0.328 52	−2.7777E−03	1087.7	59.52	0.02	47.48	0.8501				1406.9	39.79	
29.00	2.595				1237.7	19.55		47.48	0.8501				1400.2	50.00	
29.00	2.595				1233.1	29.67		47.48	0.8501				1394.4	58.70	
29.00	2.595				1228.1	39.80		47.48	0.8501	1419.5	−0.627 68	−5.5662E−04	1394.3	58.86	0.01
29.00	2.595				1222.7	50.01		50.83	0.2812				1420.5	19.57	
29.00	2.595				1217.8	58.89		50.83	0.2812				1413.5	29.68	
29.00	2.595	1237.5	−0.439 62	−1.7034E−03	1217.5	59.42	0.02	50.83	0.2812				1406.3	39.83	
43.15	2.595				1398.2	19.55		50.83	0.2812				1399.0	50.04	
43.15	2.595				1392.7	29.69		50.83	0.2812				1392.5	59.09	
43.15	2.595				1386.9	39.82		50.83	0.2812	1420.3	−0.695 20	−3.5528E−04	1392.3	59.43	0.01
43.15	2.595				1380.8	50.07		11.98	0.2812				1077.0	18.38	
43.15	2.595				1375.6	58.80		11.98	0.2812				1073.2	28.57	
43.15	2.595	1398.0	−0.543 45	−8.9241E−04	1375.4	59.07	0.01	11.98	0.2812				1068.7	38.93	
50.30	2.595				1497.3	18.66		11.98	0.2812				1063.7	49.25	
50.30	2.595				1491.1	28.82		11.98	0.2812				1060.1	55.93	
50.30	2.595				1484.8	39.14		11.98	0.2812	1076.4	−0.355 37	−2.6977E−03	1060.0	56.16	0.01
50.30	2.595				1478.3	49.50		24.65	0.2812				1171.4	18.42	
50.30	2.595				1472.0	59.35		24.65	0.2812				1166.3	28.80	
50.30	2.595	1496.5	−0.601 26	−4.9031E−04	1471.8	59.68	0.01	24.65	0.2812				1160.8	39.13	
54.06	0.8501				1506.1	19.55		24.65	0.2812				1155.0	49.49	
54.06	0.8501				1499.2	29.62		24.65	0.2812				1151.0	56.38	
54.06	0.8501				1492.1	39.80		24.65	0.2812	1170.6	−0.482 49	−1.5743E−03	1150.8	56.76	0.01
54.06	0.8501				1484.9	50.00		37.78	0.2812				1285.4	18.73	
54.06	0.8501				1477.6	60.30		37.78	0.2812				1279.3	29.08	
54.06	0.8501	1505.8	−0.687 66	−2.9411E−04	1476.9	61.41	0.01	37.78	0.2812				1273.0	39.37	
13.75	0.8501				1095.1	18.49		37.78	0.2812				1266.4	49.72	
13.75	0.8501				1091.3	28.86		37.78	0.2812				1261.6	57.24	
13.75	0.8501				1086.9	39.19		37.78	0.2812	1284.7	−0.590 82	−8.0060E−04	1261.1	57.92	0.01
13.75	0.8501				1081.9	49.54		37.78	0.2812				1351.7	19.49	
13.75	0.8501				1076.4	59.96		37.78	0.2812				1345.1	29.65	
13.75	0.8501	1094.0	−0.350 59	−2.6320E−03	1076.3	60.19	0.02	37.78	0.2812				1338.4	39.80	
26.66	0.8501				1201.1	19.51		37.78	0.2812				1331.5	50.05	
26.66	0.8501				1196.3	29.58		37.78	0.2812				1326.0	58.16	
26.66	0.8501				1191.1	39.80		37.78	0.2812	1351.4	−0.643 62	−5.5213E−04	1325.8	58.46	0.01

Table 5. Viscosity, η, and Density, ρ, of the System $ZnBr_2$ + LiBr + H_2O as a Function of Salt Mass Fraction, w, Molar Ratio of LiBr to $ZnBr_2$, r, and Temperature, t

100w	r	t/°C	$10^3\eta$/(Pa·s)	ρ/(kg m^{-3})	100w	r	t/°C	$10^3\eta$/(Pa·s)	ρ/(kg m^{-3})
16.92	3.448	24.76	1.13	1145.2	31.89	3.488	29.70	1.28	1296.9
16.92	3.488	29.75	1.01	1143.1	31.89	3.488	39.74	1.05	1290.6
16.92	3.488	39.77	0.84	1138.2	31.89	3.448	49.77	0.89	1284.1
16.92	3.488	24.75	1.13	1145.2	31.89	3.488	24.74	1.41	1299.8
31.89	3.448	24.72	1.43	1299.8	48.33	3.488	24.76	2.02	1525.4

Table 5 (Continued)

100*w*	*r*	*t*/°C	$10^3\eta$/(Pa·s)	ρ/(kg m^{-3})	100*w*	*r*	*t*/°C	$10^3\eta$/(Pa·s)	ρ/(kg m^{-3})
48.33	3.488	29.75	1.82	1522.1	58.67	1.123	29.79	2.43	1749.7
48.33	3.448	39.77	1.51	1515.3	58.67	1.123	39.82	1.97	1739.5
48.33	3.488	49.77	1.28	1508.3	58.67	1.123	49.85	1.64	1729.2
48.33	3.448	59.79	1.10	1501.1	58.67	1.123	59.86	1.38	1718.9
48.33	3.488	24.75	2.01	1525.4	58.67	1.123	69.85	1.20	1708.4
56.95	3.488	24.72	2.85	1681.6	58.67	1.123	24.83	2.73	1754.7
56.95	3.488	29.70	2.57	1677.9	69.10	0.3879	24.82	5.91	2083.3
56.95	3.488	39.74	2.14	1670.3	69.10	0.3879	29.81	5.17	2076.7
56.95	3.448	49.77	1.80	1662.7	69.10	0.3879	39.77	4.01	2063.5
56.95	3.488	59.76	1.56	1654.9	69.10	0.3879	49.81	3.21	2050.1
56.95	3.488	69.75	1.37	1647.0	69.10	0.3879	59.84	2.60	2036.7
56.95	3.488	79.79	1.21	1639.0	69.10	0.3879	69.82	2.15	2023.2
56.95	3.488	89.82	1.08	1630.9	69.10	0.3879	24.81	5.94	2083.3
56.95	3.488	24.74	2.85	1681.6	17.58	0.3879	24.78	1.20	1168.9
67.44	1.123	24.72	4.39	1966.0	17.58	0.3879	29.78	1.08	1166.5
67.44	1.123	29.70	3.90	1960.3	17.58	0.3879	39.78	0.89	1161.1
67.44	1.123	39.74	3.11	1949.0	17.58	0.3879	49.79	0.74	1154.9
67.44	1.123	49.77	2.57	1937.7	17.58	0.3879	24.85	1.20	1168.8
67.44	1.123	59.76	2.15	1926.6	34.13	0.3879	24.82	1.59	1369.0
67.44	1.123	69.75	1.84	1915.6	34.13	0.3879	39.77	1.17	1357.5
67.44	1.123	24.74	4.42	1965.9	34.13	0.3879	49.81	0.98	1349.1
16.66	1.123	24.81	1.18	1152.0	34.13	0.3879	59.84	0.84	1340.3
16.66	1.123	29.79	1.07	1149.7	34.13	0.3879	24.81	1.61	1369.0
16.66	1.123	39.82	0.88	1144.6	51.75	0.3879	24.82	2.37	1655.7
16.66	1.123	49.85	0.79	1138.8	51.75	0.3879	29.81	2.10	1650.7
16.66	1.123	24.83	1.18	1152.0	51.75	0.3879	39.77	1.70	1640.6
32.79	1.123	24.81	1.45	1333.7	51.75	0.3879	49.81	1.39	1630.1
32.79	1.123	29.79	1.30	1330.2	51.75	0.3879	59.84	1.16	1619.3
32.79	1.123	39.82	1.07	1322.9	51.75	0.3879	24.81	2.39	1655.7
32.79	1.123	49.85	0.89	1315.1	60.32	0.3879	24.78	3.36	1843.5
32.79	1.123	24.83	1.47	1333.6	60.32	0.3879	29.78	2.97	1837.8
50.43	1.123	24.78	2.11	1595.2	60.32	0.3879	39.78	2.36	1826.3
50.43	1.123	29.78	1.88	1590.6	60.32	0.3879	49.79	1.93	1814.6
50.43	1.123	39.78	1.53	1581.4	60.32	0.3879	59.79	1.61	1802.6
50.43	1.123	49.79	1.26	1581.4	60.32	0.3879	69.79	1.36	1790.4
50.43	1.123	59.79	1.07	1562.1	60.32	0.3879	79.99	1.17	1777.8
50.43	1.123	24.85	2.12	1595.1	60.32	0.3879	24.85	3.36	1843.4
58.67	1.123	24.81	2.73	1754.7					

Table 6. Viscosity, η, and Density, ρ, of the System LiCl + LiBr + H_2O as a Function of Salt Mass Fraction, *w*, Molar Ratio of LiBr to LiCl, *r*, and Temperature, *t*

100*w*	*r*	*t*/°C	$10^3\eta$/(Pa·s)	ρ/(kg m^{-3})	100*w*	*r*	*t*/°C	$10^3\eta$/(Pa·s)	ρ/(kg m^{-3})
12.73	0.3221	24.78	1.26	1080.7	13.62	0.9554	49.83	0.75	1080.7
12.73	0.3221	29.76	1.14	1079.1	13.62	0.9554	24.78	1.21	1091.3
12.73	0.3221	39.79	0.95	1075.5	27.23	0.9554	24.76	1.78	1205.0
12.73	0.3221	49.83	0.79	1071.4	27.23	0.9554	29.75	1.57	1203.1
12.73	0.3221	24.79	1.28	1080.7	27.23	0.9554	39.79	1.30	1199.0
50.35	0.3221	24.78	13.00	1409.8	27.23	0.9554	49.83	1.09	1194.6
50.35	0.3221	29.76	11.12	1407.5	27.23	0.9554	59.85	0.96	1189.8
50.35	0.3221	39.79	8.95	1402.8	27.23	0.9554	69.88	0.83	1184.7
50.35	0.3221	49.83	6.73	1398.0	27.23	0.9554	24.78	1.76	1205.0
50.35	0.3221	59.83	5.45	1393.1	47.67	0.9554	24.76	5.58	1428.0
50.35	0.3221	69.82	4.50	1388.2	47.67	0.9554	29.75	4.98	1425.6
50.35	0.3221	79.85	3.78	1383.2	47.67	0.9554	39.79	4.02	1420.6
50.35	0.3221	89.89	3.22	1378.2	47.67	0.9554	49.83	3.31	1415.6
50.35	0.3221	24.79	12.81	1409.8	47.67	0.9554	59.85	2.78	1410.6
37.27	0.3221	24.79	3.77	1274.3	47.67	0.9554	69.88	2.37	1405.3
37.27	0.3221	29.74	3.33	1272.3	47.67	0.9554	79.91	2.05	1400.0
37.27	0.3221	39.74	2.70	1268.4	47.67	0.9554	89.96	1.78	1394.6
37.27	0.3221	49.76	2.25	1264.2	47.67	0.9554	24.78	5.60	1427.9
37.27	0.3221	59.85	1.91	1259.9	29.25	2.880	24.75	1.60	1240.6
37.27	0.3221	69.84	1.63	1255.4	29.25	2.880	29.74	1.45	1238.6
37.27	0.3221	79.88	1.41	1250.7	29.25	2.880	39.77	1.20	1234.3
37.27	0.3221	89.91	1.24	1245.9	29.25	2.880	49.79	1.07	1229.7
37.27	0.3221	24.87	3.72	1274.2	29.25	2.880	59.82	0.90	1224.7
54.69	0.9554	24.75	11.47	1523.9	29.25	2.880	69.82	0.81	1219.5
54.69	0.9554	29.74	9.98	1521.1	29.25	2.880	24.78	1.61	1240.6
54.69	0.9554	39.77	7.76	1515.7	43.76	2.880	24.81	2.88	1409.0
54.69	0.9554	49.79	6.21	1510.1	43.76	2.880	29.79	2.61	1406.6
54.69	0.9554	59.82	5.08	1504.6	43.76	2.880	39.76	2.14	1401.7
54.69	0.9554	69.82	4.21	1499.0	43.76	2.880	49.74	1.83	1396.6
54.69	0.9554	79.87	3.80	1493.3	43.76	2.880	59.79	1.53	1391.4
54.69	0.9554	89.89	3.24	1487.6	43.76	2.880	69.80	1.33	1385.9
54.69	0.9554	24.78	11.40	1523.8	43.76	2.880	24.80	2.89	1409.0
13.62	0.9554	24.76	1.20	1091.3	50.99	2.880	24.75	4.91	1413.5
13.62	0.9554	29.75	1.09	1089.5	50.99	2.880	29.74	4.41	1510.8
13.62	0.9554	39.79	0.89	1085.4	50.99	2.880	39.77	3.59	1505.3

Table 6. (Continued)

100w	r	t/°C	$10^3\eta$/(Pa·s)	ρ/(kg m^{-3})	100w	r	t/°C	$10^3\eta$/(Pa·s)	ρ/(kg m^{-3})
50.99	2.880	49.79	2.97	1499.8	50.99	2.880	79.87	1.85	1482.7
50.99	2.880	59.82	2.50	1494.2	50.99	2.880	89.89	1.61	1476.9
50.99	2.880	69.82	2.12	1488.5	50.99	2.880	24.78	4.89	1513.5

Table 7. Viscosity, η, and Density, ρ, of the System $CaCl_2$ + LiBr + H_2O as a Function of Salt Mass Fraction, w, Molar Ratio of LiBr to $CaCl_2$, r, and Temperature, t

100w	r	t/°C	$10^3\eta$/(Pa·s)	ρ/(kg m^{-3})	100w	r	t/°C	$10^3\eta$/(Pa·s)	ρ/(kg m^{-3})
13.25	0.3399	24.89	1.28	1108.9	27.16	1.023	79.92	0.80	1212.0
13.25	0.3399	29.87	1.15	1107.0	27.16	1.023	24.84	1.91	1241.2
13.25	0.3399	39.83	0.96	1102.8	40.52	1.023	24.81	4.18	1396.2
13.25	0.3399	49.89	0.80	1098.1	40.52	1.023	29.78	3.77	1393.3
13.25	0.3399	24.93	1.27	1108.9	40.52	1.023	39.77	3.11	1387.5
25.63	0.3399	24.89	2.06	1228.6	40.52	1.023	49.82	2.57	1381.6
25.63	0.3399	29.87	1.86	1226.2	40.52	1.023	59.82	2.32	1375.6
25.63	0.3399	39.83	1.55	1221.3	40.52	1.023	69.83	2.01	1369.5
25.63	0.3399	49.89	1.32	1216.1	40.52	1.023	79.83	1.68	1363.4
25.63	0.3399	59.88	1.13	1210.6	40.52	1.023	24.87	4.23	1396.2
25.63	0.3399	69.86	1.00	1204.9	57.22	2.908	24.87	13.15	1640.4
25.63	0.3399	79.88	0.91	1198.9	57.22	2.908	29.86	11.57	1636.9
25.63	0.3399	89.89	0.77	1192.7	57.22	2.908	39.74	8.92	1629.9
25.63	0.3399	24.93	2.03	1228.6	57.22	2.908	49.81	7.02	1622.8
54.15	1.023	24.90	17.22	1576.7	57.22	2.908	59.82	5.67	1615.6
54.15	1.023	29.88	14.76	1573.2	57.22	2.908	69.86	4.73	1608.4
54.15	1.023	39.83	11.09	1566.2	57.22	2.908	79.91	4.04	1601.1
54.15	1.023	49.84	9.08	1559.2	57.22	2.908	89.90	3.43	1593.7
54.15	1.023	59.85	7.27	1552.0	57.22	2.908	24.87	13.07	1640.4
54.15	1.023	69.88	5.81	1544.8	29.42	2.908	24.87	1.78	1261.0
54.15	1.023	79.92	4.84	1537.5	29.42	2.908	29.86	1.60	1258.8
54.15	1.023	89.94	4.08	1530.1	29.42	2.908	39.74	1.34	1254.6
54.15	1.023	24.84	17.28	1576.7	29.42	2.908	49.81	1.13	1250.2
13.69	1.023	24.81	1.24	1110.3	29.42	2.908	59.82	0.97	1245.8
13.69	1.023	29.79	1.11	1108.4	29.42	2.908	69.86	0.85	1241.4
13.69	1.023	39.77	0.92	1104.4	29.42	2.908	24.87	1.76	1261.0
13.69	1.023	49.78	0.77	1099.8	43.28	2.908	24.81	3.61	1431.1
13.69	1.023	59.86	0.67	1094.6	43.28	2.908	29.79	3.22	1428.3
13.69	1.023	24.90	1.22	1110.2	43.28	2.908	39.77	2.64	1422.7
27.16	1.023	24.90	1.88	1241.2	43.28	2.908	49.78	2.22	1416.9
27.16	1.023	29.88	1.70	1238.8	43.28	2.908	59.86	1.88	1411.0
27.16	1.023	39.83	1.41	1234.0	43.28	2.908	69.85	1.64	1405.0
27.16	1.023	49.84	1.20	1228.9	43.28	2.908	79.89	1.44	1398.9
27.16	1.023	59.85	1.03	1223.6	43.28	2.908	89.92	1.28	1392.6
27.16	1.023	69.88	0.92	1217.9	43.28	2.908	24.90	3.54	1431.0

Table 8. Viscosity, η, and Density, ρ, of the System $LiNO_3$ + LiBr + H_2O as a Function of Salt Mass Fraction, w, Molar Ratio of LiBr to $LiNO_3$, r, and Temperature, t

100w	r	t/°C	$10^3\eta$/(Pa·s)	ρ/(kg m^{-3})	100w	r	t/°C	$10^3\eta$/(Pa·s)	ρ/(kg m^{-3})
57.63	2.595	24.90	7.28	1611.7	54.06	0.8501	29.88	5.06	1499.0
57.63	2.595	29.89	6.45	1608.2	54.06	0.8501	39.88	4.02	1492.0
57.63	2.595	39.86	5.03	1601.2	54.06	0.8501	49.90	3.52	1485.0
57.63	2.595	49.90	4.09	1594.2	54.06	0.8501	59.92	2.93	1477.9
57.63	2.595	59.93	3.38	1587.1	54.06	0.8501	69.92	2.49	1470.8
57.63	2.595	69.95	2.88	1580.0	54.06	0.8501	79.94	2.06	1463.6
57.63	2.595	79.98	2.43	1572.8	54.06	0.8501	89.97	1.80	1456.3
57.63	2.595	90.01	2.13	1565.7	54.06	0.8501	24.90	5.65	1502.4
57.63	2.595	24.93	7.29	1611.7	13.75	0.8501	24.87	1.12	1092.8
14.33	2.595	24.88	1.12	1103.4	13.75	0.8501	29.86	1.01	1090.9
14.33	2.595	29.88	1.00	1101.5	13.75	0.8501	39.88	0.84	1086.6
14.33	2.595	39.88	0.84	1097.4	13.75	0.8501	49.93	0.71	1081.7
14.33	2.595	49.90	0.71	1092.7	13.75	0.8501	24.89	1.11	1092.8
14.33	2.595	24.90	1.11	1103.4	26.66	0.8501	24.87	1.47	1198.6
29.00	2.595	24.90	1.49	1235.3	26.66	0.8501	29.86	1.32	1196.2
29.00	2.595	29.92	1.36	1232.9	26.66	0.8501	39.88	1.09	1191.0
29.00	2.595	39.88	1.14	1228.0	26.66	0.8501	49.93	0.92	1185.6
29.00	2.595	49.89	0.97	1222.8	26.66	0.8501	59.94	0.80	1179.8
29.00	2.595	59.92	0.86	1217.2	26.66	0.8501	24.89	1.46	1198.6
29.00	2.595	24.90	1.49	1235.3	47.48	0.8501	24.90	3.43	1416.4
43.15	2.595	24.90	2.47	1395.3	47.48	0.8501	29.90	3.03	1413.3
43.15	2.595	29.92	2.25	1392.5	47.48	0.8501	39.85	2.45	1406.9
43.15	2.595	39.88	1.85	1386.8	47.48	0.8501	49.90	2.04	1400.3
43.15	2.595	49.89	1.57	1381.0	47.48	0.8501	59.92	1.74	1393.6
43.15	2.595	59.92	1.36	1374.9	47.48	0.8501	69.93	1.50	1386.8
43.15	2.595	70.01	1.19	1368.6	47.48	0.8501	79.95	1.29	1379.9
43.15	2.595	80.02	1.05	1362.2	47.48	0.8501	24.96	3.44	1416.4
43.15	2.595	90.06	0.94	1355.5	24.65	0.2812	24.83	1.46	1168.3
43.15	2.595	24.90	2.49	1395.3	24.65	0.2812	29.80	1.32	1165.8
54.06	0.8501	24.88	5.68	1502.5	24.65	0.2812	39.78	1.07	1160.5

Table 8 (Continued)

100w	r	t/°C	$10^3\eta$/(Pa·s)	ρ/(kg m^{-3})	100w	r	t/°C	$10^3\eta$/(Pa·s)	ρ/(kg m^{-3})
24.65	0.2812	49.82	0.90	1154.9	44.49	0.2812	49.82	1.84	1331.7
24.65	0.2812	59.82	0.78	1148.9	44.49	0.2812	59.85	1.57	1324.9
24.65	0.2812	24.84	1.45	1168.3	44.49	0.2812	69.86	1.43	1317.9
44.49	0.2812	24.81	3.03	1348.3	44.49	0.2812	79.89	1.24	1310.9
44.49	0.2812	29.81	2.70	1345.0	44.49	0.2812	24.85	3.03	1348.3
44.49	0.2812	39.81	2.21	1338.4					

other stocks in three proportions, aiming at the molar salt ratios 3:1, 1:1, and 1:3. Samples were then prepared by dilution with known amounts of water. Since one additional weighing was incorporated, we estimated the composition to be somewhat more inaccurate in this work than in the previous work. For $ZnBr_2$ + LiBr + water and $CaCl_2$ + LiBr + water we estimated the uncertainty to be ±0.15% by mass, and for the other systems, ±0.10% by mass.

Results and Discussion

The measured densities are presented in Tables 1–4 both as experimental points and as parameters of the equation

$$\rho/(\text{kg m}^{-3}) = d_1 + d_2(t - 20) + d_3(t - 20)^2 \qquad (2)$$

where t is the temperature (°C) and d_i are the density parameters. The viscosities are presented in Tables 5–8, where the dynamic viscosity is calculated from the density parameters in Table 1–4.

For discussion of experimental accuracy, we refer to our work on single-salt solutions (*3*).

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