Effect of NaCl or KCl on the Excess Enthalpies of Alkanol + Water Mixtures at Various Temperatures and Salt Concentrations

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Excess enthalpies of methanol, ethanol, 1-propanol, or 2-propanol + aqueous solution of NaCl or KCl were measured using flow-mix calorimetry at various temperatures. Mixtures with all alkanols were investigated at 285.65, 298.15, 308.15, and 323.15 K; those with ethanol and both propanols were additionally investigated at 338.15 K. Furthermore, mixtures with 1-propanol were investigated at 353.15 K. The concentration of the salt water component was varied between 0 and 10 wt % salt in water. Due to the calorimetric flow-mix setup, the total salt concentration in the mixture decreases with increasing mole fraction of alkanol. The reliability of the experimental setup has already been verified in a previous work (Friese et al., 1998) by comparison with literature data. The measured excess enthalpies of alkanol (1) + (water (2) + salt (3)), h^E_{1+23}, are given along with a formula for calculating the excess enthalpies h^E_{123} occuring when mixing the three components in their reference states, that is pure liquids and infinitely diluted salt, respectively.

Introduction

In many chemical engineering processes one has to be aware of the influence of electrolytes on the phase equilibria. Apart from processes where electrolyte solutions occur as unwanted byproducts which demand further treatment, for example neutralization reactions or gas scrubbing, the purposeful use of electrolytes in separation techniques is of increasing interest. For example, the relative volatility of mixed solvent systems is affected by the addition of salt (salting-in or salting-out) (Mock et al., 1986). Regarding azeotropic mixtures, this change in phase equilibrium can be used to design more effective and more economical distillation operations because the azeotrope can be shifted or can even be broken by using salt as extractive agent (Gironi and Lamberti, 1995). Therefore, appropriate thermodynamic models are required in order to predict phase equilibria of liquid mixtures under the influence of inorganic salts. Most of the g^E models in the literature are semiempirical; that is, they contain parameters that have to be fitted to experimental data. For salt-free systems, parameters are usually fitted not only to vapour−liquid equilibrium (VLE) data but also to activity coefficients at infinite dilution as well as to excess enthalpy data in order to increase the thermodynamic consistency of the model. Against this background, the parameters of g^E models for the prediction of the salt effect on the behavior of liquid mixtures should be fitted to several kinds of experimental data, as well. However, only VLE data are available in the literature to a satisfying extent. Thus, there is a demand for further data for the systems mentioned, especially concerning excess enthalpy data (Loehe and Donohue, 1997; Renon, 1996; Achard et al., 1994). In order to create such a data base, the focus of this work was to investigate the influence of salt on the excess enthalpy of alkanol + water over a wide temperature range.

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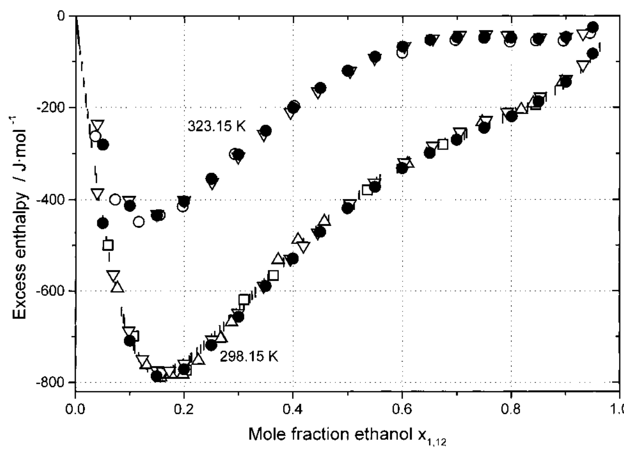

Figure 1. Comparison of salt-free excess enthalpy isotherms of ethanol (1) + water (2) with the literature: (|) Costigan et al., 1980; (□) Boyne and Williamson, 1967; (△) Chand and Fenby, 1978; (▽) Löwen, 1995; (○) Larkin, 1975; (●) this laboratory (Friese et al., 1998).

Table 1. Solvents and Salts

component	supplier	purity (as reported by the supplier)
methanol	Roth, Roti Solv. HPLC	≥99.9%
ethanol	Fluka, puriss. p.a.	≥99.8%
1-propanol	Roth, Rotipuran	≥99.5%
2-propanol	Merck, gradient grade	≥99.8%
sodium chloride	Fluka, puriss. p.a.	≥99.5%
potassium chloride	Fluka, puriss. p.a.	≥99.5%

Experimental Section

Materials. Table 1 displays the substances of interest along with their respective suppliers and purities. Before the salt water solution was prepared, the salts were dried under vacuum for at least 24 h at 240 °C. Water was distilled and filtered four times (conductivity ≤ 1 μS·cm^{-1}). The organic solvents were used without further purification. They were dried with molecular sieves of 3 Å pore diameter supplied by Fluka (Dehydrat Fluka with indica-

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Table 2. Excess Enthalpies of Methanol (1) + (Water (2) + NaCl (3))

$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}
				T = 285.65 K, $w_{3,23}$ = 1.00 wt %					
0.050	−367.9	0.250	−945.6	0.450	−894.1	0.650	−710.1	0.850	−392.6
0.100	−635.7	0.300	−958.5	0.500	−857.9	0.700	−645.0	0.900	−279.9
0.150	−804.7	0.350	−951.3	0.550	−813.9	0.750	−571.7	0.950	−149.2
0.200	−900.5	0.400	−926.1	0.600	−765.4	0.800	−488.6		
				T = 285.65 K, $w_{3,23}$ = 5.00 wt %					
0.040	−279.1	0.200	−846.5	0.360	−904.9	0.520	−816.2	0.680	−662.8
0.080	−507.0	0.240	−893.3	0.400	−890.9	0.560	−782.7	0.720	−611.8
0.120	−668.6	0.280	−910.2	0.440	−868.5	0.600	−748.0	0.760	−555.0
0.160	−780.9	0.320	−914.1	0.480	−846.1	0.640	−706.7	0.800	−489.2
				T = 285.65 K, $w_{3,23}$ = 10.00 wt %					
0.035	−227.2	0.175	−748.2	0.315	−853.5	0.455	−815.8	0.595	−722.8
0.070	−411.0	0.210	−796.6	0.350	−851.6	0.490	−796.8	0.630	−690.4
0.105	−555.2	0.245	−829.1	0.385	−845.6	0.525	−774.7	0.665	−659.1
0.140	−667.5	0.280	−847.9	0.420	−832.9	0.560	−751.1	0.700	−618.5
				T = 298.15 K, $w_{3,23}$ = 1.00 wt %					
0.050	−324.7	0.250	−859.8	0.450	−835.1	0.650	−667.2	0.850	−355.2
0.100	−558.9	0.300	−884.4	0.500	−805.3	0.700	−617.1	0.900	−276.3
0.150	−718.4	0.350	−881.4	0.550	−770.1	0.750	−549.3	0.950	−145.0
0.200	−815.3	0.400	−864.2	0.600	−724.6	0.799	−472.4		
				T = 308.15 K, $w_{3,23}$ = 1.00 wt %					
0.035	−210.6	0.246	−794.5	0.456	−778.4	0.631	−652.9	0.806	−437.9
0.070	−388.7	0.281	−810.7	0.491	−757.4	0.666	−619.0	0.841	−379.9
0.105	−531.1	0.316	−815.5	0.526	−736.6	0.701	−581.4	0.876	−309.7
0.141	−637.2	0.351	−816.0	0.561	−712.1	0.736	−538.9	0.911	−234.6
0.176	−711.7	0.386	−806.7	0.596	−685.0	0.771	−491.6	0.945	−150.9
0.211	−763.5	0.421	−793.3						
				T = 308.15 K, $w_{3,23}$ = 5.00 wt %					
0.035	−200.1	0.246	−742.8	0.456	−742.9	0.631	−632.2	0.806	−439.8
0.070	−366.3	0.280	−763.4	0.491	−725.7	0.666	−603.7	0.841	−380.3
0.105	−494.9	0.315	−770.4	0.526	−708.0	0.701	−569.2	0.876	−317.4
0.140	−591.7	0.351	−770.5	0.561	−685.6	0.736	−531.4	0.911	−244.3
0.175	−666.9	0.386	−765.4	0.595	−660.7	0.770	−490.7	0.945	−154.8
0.211	−714.9	0.421	−757.8						
				T = 308.15 K, $w_{3,23}$ = 10.00 wt %					
0.035	−177.3	0.245	−676.4	0.421	−696.0	0.596	−623.7	0.771	−475.0
0.070	−329.4	0.281	−694.6	0.456	−684.7	0.631	−600.8	0.806	−428.9
0.105	−446.2	0.316	−702.5	0.491	−675.8	0.666	−574.3	0.840	−376.0
0.140	−537.1	0.351	−707.2	0.526	−660.5	0.700	−545.8	0.876	−313.4
0.175	−602.5	0.386	−703.6	0.561	−640.9	0.735	−515.0	0.910	−241.4
0.211	−647.5								
				T = 323.15 K, $w_{3,23}$ = 1.00 wt %					
0.035	−175.8	0.210	−646.6	0.385	−687.5	0.560	−618.7	0.700	−495.8
0.070	−371.6	0.245	−669.2	0.420	−687.6	0.595	−592.5	0.735	−475.1
0.105	−461.2	0.280	−681.3	0.455	−669.9	0.630	−560.6	0.840	−332.0
0.140	−553.3	0.315	−695.7	0.490	−658.1	0.665	−536.7	0.874	−283.1
0.175	−617.9	0.350	−687.3	0.525	−626.6				

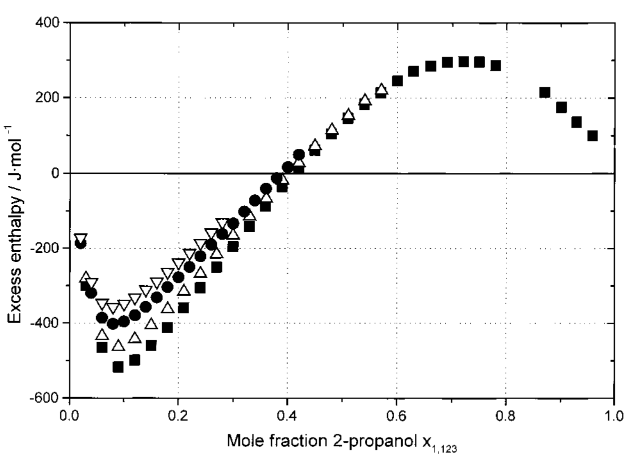

Figure 2. Effect of NaCl on the excess enthalpy of 2-propanol (1) + (water (2) + NaCl (3)) at 308.15 K: (△) 2.50 wt % $w_{3,23}$(NaCl); (●) 5.00 wt % $w_{3,23}$(NaCl); (▽) 7.50 wt % $w_{3,23}$(NaCl); (■) salt-free system.

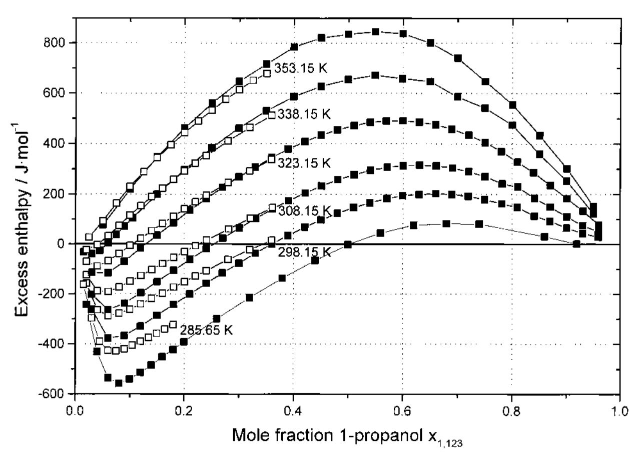

Figure 3. Temperature dependence of the excess enthalpy of 1-propanol (1) + (water (2) + NaCl (3)) at constant salt concentration $w_{3,23}$(NaCl): (□) 5.00 wt %; (■) salt-free system.

tor). Prior to the measurements, all organic liquids were degassed by use of a water-jet vacuum pump.

Experimental Procedure. The experimental setup has been described in detail previously (Friese et al., 1998). Salt water solutions were prepared by mass using a Sartorius

Table 3. Excess Enthalpies of Methanol (1) + (Water (2) + KCl (3))

$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}
				T = 285.65 K, $w_{3,23}$ = 1.00 wt %					
0.050	−365.1	0.250	−946.5	0.450	−895.8	0.650	−703.9	0.851	−382.3
0.100	−635.6	0.300	−959.9	0.500	−855.4	0.700	−642.2	0.900	−277.1
0.150	−804.7	0.350	−950.0	0.550	−812.5	0.750	−568.6	0.950	−143.8
0.200	−901.5	0.400	−927.4	0.600	−762.7	0.800	−485.2		
				T = 285.65 K, $w_{3,23}$ = 5.00 wt %					
0.030	−219.5	0.150	−774.6	0.270	−928.0	0.390	−916.0	0.480	−857.0
0.060	−409.7	0.180	−834.6	0.300	−933.7	0.420	−897.2	0.510	−838.8
0.090	−561.8	0.210	−884.1	0.330	−932.7	0.450	−879.9	0.540	−809.6
0.120	−681.2	0.240	−911.7	0.360	−927.7				
				T = 285.65 K, $w_{3,23}$ = 7.50 wt %					
0.030	−216.7	0.150	−754.3	0.240	−896.6	0.330	−917.8	0.420	−885.0
0.060	−399.4	0.180	−820.3	0.270	−908.4	0.360	−913.6	0.450	−868.4
0.090	−547.5	0.210	−866.9	0.300	−917.9	0.390	−900.1	0.480	−848.4
0.120	−669.9								
				T = 298.15 K, $w_{3,23}$ = 1.00 wt %					
0.040	−265.5	0.200	−822.6	0.360	−882.1	0.520	−795.9	0.680	−638.4
0.080	−481.7	0.240	−861.5	0.400	−865.7	0.560	−759.1	0.720	−587.7
0.120	−638.4	0.280	−881.6	0.440	−848.0	0.600	−725.0	0.760	−536.8
0.160	−746.5	0.320	−888.6	0.480	−820.3	0.640	−683.9		
				T = 298.15 K, $w_{3,23}$ = 5.00 wt %					
0.020	−130.6	0.140	−674.6	0.260	−849.2	0.380	−851.1	0.480	−803.5
0.040	−254.3	0.160	−725.3	0.280	−855.8	0.400	−847.1	0.500	−795.5
0.060	−368.1	0.180	−759.2	0.300	−860.5	0.420	−839.2	0.520	−781.6
0.080	−462.9	0.200	−793.5	0.320	−861.3	0.440	−826.5	0.540	−769.5
0.100	−548.2	0.220	−818.6	0.340	−856.9	0.460	−814.0	0.560	−745.6
0.120	−618.5	0.240	−834.5	0.360	−852.7				
				T = 298.15 K, $w_{3,23}$ = 7.50 wt %					
0.020	−130.6	0.120	−600.6	0.220	−795.5	0.320	−839.7	0.400	−824.5
0.040	−244.8	0.140	−654.7	0.240	−810.5	0.340	−834.4	0.420	−818.5
0.060	−358.3	0.160	−702.9	0.260	−825.7	0.360	−835.9	0.440	−807.7
0.080	−449.9	0.180	−742.6	0.280	−832.6	0.380	−831.3	0.460	−801.0
0.100	−532.1	0.200	−773.6	0.300	−836.4				
				T = 308.15 K, $w_{3,23}$ = 1.00 wt %					
0.025	−164.0	0.176	−711.2	0.326	−814.1	0.476	−765.8	0.626	−654.3
0.050	−293.7	0.201	−749.5	0.351	−814.9	0.501	−751.3	0.651	−628.1
0.075	−412.0	0.226	−776.8	0.376	−810.0	0.526	−733.3	0.676	−602.7
0.100	−509.7	0.251	−796.2	0.401	−802.2	0.551	−715.9	0.701	−576.5
0.125	−594.6	0.276	−807.7	0.426	−791.6	0.576	−696.7	0.726	−544.7
0.151	−660.5	0.301	−814.4	0.451	−780.4	0.601	−676.2	0.750	−514.2
				T = 308.15 K, $w_{3,23}$ = 5.00 wt %					
0.020	−120.0	0.140	−618.8	0.260	−783.6	0.380	−796.0	0.481	−752.3
0.040	−233.6	0.160	−665.5	0.281	−795.6	0.401	−789.4	0.501	−740.6
0.060	−334.0	0.180	−701.3	0.300	−800.6	0.420	−782.3	0.521	−732.4
0.080	−421.9	0.200	−732.2	0.321	−801.0	0.441	−772.7	0.541	−718.4
0.100	−498.4	0.220	−755.4	0.341	−802.6	0.460	−765.0	0.561	−703.3
0.120	−565.6	0.241	−772.1	0.361	−800.1				
				T = 308.15 K, $w_{3,23}$ = 7.50 wt %					
0.020	−116.6	0.120	−539.2	0.220	−725.5	0.321	−772.3	0.400	−761.2
0.040	−222.1	0.140	−593.5	0.240	−742.6	0.341	−773.7	0.421	−755.9
0.060	−319.5	0.160	−637.4	0.260	−754.5	0.361	−772.2	0.440	−749.2
0.080	−406.5	0.180	−673.8	0.280	−763.8	0.380	−768.8	0.461	−740.2
0.100	−478.5	0.200	−703.1	0.300	−769.9				
				T = 323.15 K, $w_{3,23}$ = 1.00 wt %					
0.025	−126.9	0.175	−606.1	0.325	−685.0	0.475	−658.7	0.625	−573.4
0.050	−258.4	0.200	−622.7	0.350	−694.0	0.500	−647.3	0.650	−551.0
0.075	−382.1	0.225	−660.0	0.375	−700.1	0.525	−628.3	0.675	−530.3
0.100	−452.7	0.250	−677.6	0.400	−691.0	0.550	−619.8	0.700	−507.8
0.125	−509.9	0.275	−677.1	0.425	−687.9	0.575	−606.9	0.725	−482.4
0.150	−570.3	0.300	−684.5	0.450	−673.8	0.600	−589.5	0.750	−458.0
				T = 323.15 K, $w_{3,23}$ = 5.00 wt %					
0.040	−185.6	0.160	−583.3	0.280	−674.0	0.380	−660.7	0.480	−636.0
0.060	−267.6	0.180	−598.3	0.300	−671.9	0.400	−666.5	0.500	−617.1
0.080	−339.3	0.200	−609.2	0.320	−676.8	0.420	−658.1	0.520	−612.9
0.100	−401.9	0.220	−621.2	0.340	−673.7	0.440	−653.3	0.540	−597.9
0.120	−502.5	0.240	−640.3	0.360	−667.7	0.460	−647.0	0.560	−596.9
0.140	−542.3	0.260	−663.3						
				T = 323.15 K, $w_{3,23}$ = 7.50 wt %					
0.020	−92.1	0.120	−501.5	0.240	−609.8	0.320	−652.1	0.400	−643.5
0.040	−182.6	0.140	−527.8	0.260	−621.0	0.340	−656.6	0.420	−633.9
0.060	−296.6	0.160	−563.4	0.280	−638.3	0.360	−650.2	0.440	−631.0
0.080	−401.6	0.200	−585.7	0.300	−650.0	0.380	−650.1	0.460	−621.8
0.100	−456.0	0.220	−594.6						

Table 4. Excess Enthalpies of Ethanol (1) + (Water (2) + NaCl (3))

$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}
T = 285.65 K, $w_{3,23}$ = 1.00 wt %									
0.025	−280.5	0.150	−933.2	0.250	−858.4	0.380	−677.8	0.540	−483.3
0.050	−519.4	0.175	−934.7	0.275	−825.0	0.420	−623.0	0.580	−445.1
0.075	−707.3	0.200	−914.6	0.300	−789.3	0.460	−574.3	0.620	−407.1
0.100	−835.2	0.225	−889.8	0.340	−733.5	0.500	−526.2	0.660	−375.7
0.125	−905.6								
T = 285.65 K, $w_{3,23}$ = 3.96 wt %									
0.020	−211.1	0.100	−770.0	0.180	−853.3	0.260	−778.6	0.340	−682.1
0.040	−402.4	0.120	−823.0	0.200	−841.1	0.280	−756.7	0.360	−657.4
0.060	−561.0	0.140	−850.6	0.220	−824.2	0.300	−731.8	0.380	−633.1
0.080	−682.6	0.160	−858.1	0.240	−801.5	0.320	−707.4		
T = 285.65 K, $w_{3,23}$ = 5.00 wt %									
0.025	−255.5	0.150	−827.3	0.275	−737.3	0.375	−621.6	0.475	−511.0
0.050	−472.1	0.175	−827.4	0.300	−711.1	0.400	−592.7	0.500	−485.2
0.075	−637.9	0.200	−813.9	0.325	−680.2	0.425	−565.1	0.525	−460.8
0.100	−746.0	0.225	−792.6	0.350	−651.4	0.450	−538.4	0.550	−437.2
0.125	−806.2	0.250	−767.9						
T = 285.65 K, $w_{3,23}$ = 5.98 wt %									
0.020	−199.0	0.080	−646.4	0.140	−798.5	0.200	−788.8	0.260	−732.8
0.040	−381.3	0.100	−726.2	0.160	−803.7	0.220	−772.3	0.280	−712.9
0.060	−532.7	0.120	−773.4	0.180	−800.2	0.240	−754.9	0.300	−690.5
T = 285.65 K, $w_{3,23}$ = 10.00 wt %									
0.020	−181.1	0.100	−640.3	0.180	−698.2	0.240	−662.5	0.300	−611.4
0.040	−341.7	0.120	−677.5	0.200	−689.7	0.260	−646.9	0.320	−593.4
0.060	−476.4	0.140	−695.7	0.220	−676.8	0.280	−630.1	0.340	−574.7
0.080	−573.7	0.160	−700.4						
T = 298.15 K, $w_{3,23}$ = 1.00 wt %									
0.050	−440.2	0.250	−697.3	0.450	−459.7	0.650	−294.7	0.850	−188.3
0.100	−688.6	0.300	−636.7	0.500	−409.0	0.700	−267.5	0.900	−149.8
0.150	−762.8	0.350	−575.5	0.550	−364.7	0.750	−243.1	0.950	−85.6
0.200	−745.8	0.400	−515.5	0.600	−326.1	0.801	−217.8		
T = 298.15 K, $w_{3,23}$ = 10.00 wt %									
0.020	−151.2	0.120	−541.6	0.220	−528.0	0.320	−451.1	0.420	−369.4
0.040	−285.8	0.140	−553.1	0.240	−515.2	0.340	−434.6	0.440	−353.3
0.060	−385.7	0.160	−554.3	0.260	−499.2	0.360	−418.2	0.460	−337.6
0.080	−453.4	0.180	−550.1	0.280	−483.8	0.380	−401.1	0.480	−323.7
0.100	−513.9	0.200	−540.7	0.300	−468.4	0.400	−384.4	0.500	−312.3
T = 308.15 K, $w_{3,23}$ = 1.00 wt %									
0.040	−306.8	0.241	−557.2	0.442	−342.8	0.641	−201.2	0.801	−149.6
0.080	−508.3	0.281	−514.4	0.482	−306.5	0.681	−185.2	0.841	−141.2
0.121	−597.9	0.321	−470.0	0.522	−274.5	0.721	−172.2	0.881	−113.1
0.161	−614.2	0.361	−425.0	0.561	−247.0	0.762	−160.1	0.921	−84.0
0.201	−593.3	0.402	−383.2	0.601	−220.7				
T = 308.15 K, $w_{3,23}$ = 5.00 wt %									
0.030	−218.1	0.151	−535.7	0.271	−456.2	0.392	−342.2	0.511	−244.9
0.060	−379.2	0.181	−527.1	0.301	−427.5	0.421	−316.2	0.541	−225.4
0.091	−480.0	0.211	−507.4	0.331	−398.5	0.451	−290.8	0.572	−207.7
0.121	−524.6	0.241	−483.6	0.361	−370.3	0.481	−266.8	0.601	−192.2
T = 308.15 K, $w_{3,23}$ = 10.00 wt %									
0.020	−129.9	0.121	−431.3	0.221	−403.9	0.301	−345.2	0.381	−281.7
0.040	−240.0	0.141	−436.5	0.241	−390.4	0.321	−328.7	0.401	−265.4
0.060	−323.4	0.161	−434.0	0.261	−375.8	0.341	−312.5	0.421	−251.4
0.080	−380.2	0.181	−427.0	0.281	−360.2	0.361	−297.2	0.442	−236.5
0.100	−414.9	0.201	−416.5						
T = 323.15 K, $w_{3,23}$ = 1.00 wt %									
0.040	−228.0	0.240	−349.8	0.440	−154.1	0.639	−51.4	0.799	−48.2
0.080	−363.4	0.280	−308.4	0.480	−123.7	0.680	−45.2	0.840	−50.9
0.120	−415.6	0.320	−266.5	0.520	−98.4	0.720	−43.7	0.879	−50.9
0.160	−412.9	0.360	−226.6	0.560	−77.2	0.760	−44.4	0.921	−43.7
0.200	−386.1	0.400	−188.7	0.600	−62.0				
T = 323.15 K, $w_{3,23}$ = 5.00 wt %									
0.030	−160.4	0.150	−356.4	0.270	−267.1	0.390	−158.9	0.510	−76.8
0.060	−274.1	0.180	−341.4	0.300	−238.4	0.420	−135.4	0.540	−62.4
0.090	−337.5	0.210	−319.4	0.330	−210.2	0.450	−113.9	0.570	−50.1
0.120	−357.7	0.240	−294.0	0.360	−184.1	0.480	−93.6	0.600	−40.2
T = 323.15 K, $w_{3,23}$ = 10.00 wt %									
0.020	−95.8	0.120	−281.2	0.220	−229.4	0.300	−169.4	0.380	−108.7
0.040	−173.5	0.140	−277.7	0.240	−216.2	0.320	−153.2	0.400	−94.7
0.060	−227.5	0.160	−268.9	0.260	−201.1	0.340	−138.7	0.420	−80.9
0.080	−260.6	0.180	−258.0	0.280	−185.7	0.360	−123.2	0.440	−68.2
0.100	−276.9	0.200	−244.7						

Table 4 (Continued)

$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}
				T = 338.15 K, $w_{3,23}$ = 1.00 wt %					
0.040	−156.9	0.240	−150.9	0.440	38.2	0.600	103.9	0.799	62.2
0.080	−234.5	0.280	−108.2	0.480	62.4	0.639	101.8	0.840	38.0
0.120	−249.0	0.320	−67.3	0.519	81.8	0.680	101.0	0.879	31.9
0.160	−231.0	0.360	−29.0	0.560	95.8	0.720	86.6	0.921	26.6
0.200	−194.5	0.400	7.9						
				T = 338.15 K, $w_{3,23}$ = 5.00 wt %					
0.030	−109.1	0.150	−191.1	0.270	−77.5	0.390	24.9	0.510	93.7
0.060	−177.3	0.180	−166.8	0.300	−50.7	0.420	46.3	0.540	103.9
0.090	−209.1	0.210	−137.9	0.330	−22.5	0.450	65.0	0.570	109.2
0.120	−205.5	0.240	−109.3	0.360	1.3	0.480	80.4	0.600	114.4
				T = 338.15 K, $w_{3,23}$ = 10.00 wt %					
0.020	−62.6	0.120	−146.3	0.220	−67.1	0.300	5.9	0.380	67.4
0.040	−109.9	0.140	−133.2	0.240	−45.8	0.320	21.6	0.400	79.4
0.060	−139.7	0.160	−122.3	0.260	−30.0	0.340	38.0	0.419	92.8
0.080	−151.5	0.180	−102.1	0.280	−11.1	0.360	54.4	0.439	104.8
0.100	−153.3	0.200	−83.6						

Table 5. Excess Enthalpies of Ethanol (1) + (Water (2) + KCl (3))

$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}
				T = 285.65 K, $w_{3,23}$ = 1.00 wt %					
0.025	−285.2	0.150	−942.6	0.275	−833.0	0.375	−687.8	0.475	−559.5
0.050	−525.9	0.175	−943.1	0.300	−796.1	0.400	−653.5	0.500	−530.5
0.075	−713.4	0.200	−925.8	0.325	−760.9	0.425	−620.8	0.525	−501.3
0.100	−841.6	0.225	−898.9	0.350	−724.0	0.450	−590.1	0.550	−476.0
0.125	−912.9	0.250	−865.9						
				T = 285.65 K, $w_{3,23}$ = 5.00 wt %					
0.020	−214.1	0.100	−781.2	0.180	−867.1	0.260	−798.0	0.340	−697.9
0.040	−405.4	0.120	−837.0	0.200	−859.5	0.280	−773.5	0.360	−675.9
0.060	−568.6	0.140	−865.5	0.220	−842.0	0.300	−751.1	0.380	−649.3
0.080	−692.0	0.160	−873.9	0.240	−819.3	0.320	−725.3		
				T = 285.65 K, $w_{3,23}$ = 7.50 wt %					
0.020	−204.6	0.080	−665.2	0.140	−826.5	0.200	−821.1	0.260	−767.9
0.040	−392.3	0.100	−747.8	0.160	−835.1	0.220	−805.8	0.280	−747.3
0.060	−546.0	0.120	−799.5	0.180	−834.1	0.240	−788.0	0.300	−726.5
				T = 298.15 K, $w_{3,23}$ = 1.00 wt %					
0.030	−276.6	0.150	−757.7	0.270	−670.4	0.390	−528.6	0.510	−398.3
0.060	−499.4	0.180	−754.4	0.300	−635.4	0.420	−491.9	0.540	−371.6
0.090	−648.2	0.210	−733.7	0.330	−594.9	0.450	−457.5	0.570	−346.5
0.120	−727.7	0.240	−704.5	0.360	−562.3	0.480	−426.8	0.600	−325.4
				T = 298.15 K, $w_{3,23}$ = 5.00 wt %					
0.030	−257.2	0.120	−668.2	0.210	−668.7	0.300	−585.7	0.390	−487.5
0.060	−459.2	0.150	−689.2	0.240	−645.1	0.330	−553.6	0.420	−454.0
0.090	−575.5	0.180	−687.9	0.270	−615.0	0.360	−517.9	0.450	−423.6
				T = 298.15 K, $w_{3,23}$ = 7.50 wt %					
0.020	−173.0	0.100	−603.3	0.180	−657.8	0.240	−622.2	0.300	−567.5
0.040	−322.3	0.120	−638.1	0.200	−652.1	0.260	−604.2	0.320	−545.6
0.060	−443.3	0.140	−658.8	0.220	−638.4	0.280	−585.3	0.340	−515.7
0.080	−543.8	0.160	−664.6						
				T = 308.15 K, $w_{3,23}$ = 1.00 wt %					
0.030	−240.9	0.151	−623.5	0.271	−533.9	0.391	−399.7	0.511	−289.8
0.060	−426.8	0.181	−616.2	0.301	−499.2	0.421	−368.7	0.542	−266.3
0.091	−546.2	0.211	−595.4	0.331	−465.5	0.452	−340.6	0.572	−245.9
0.121	−606.5	0.241	−565.8	0.362	−430.9	0.481	−315.0	0.602	−227.6
				T = 308.15 K, $w_{3,23}$ = 5.00 wt %					
0.020	−155.1	0.121	−555.1	0.221	−534.8	0.321	−439.7	0.402	−361.5
0.040	−288.0	0.141	−567.0	0.241	−517.0	0.342	−419.5	0.422	−342.3
0.060	−396.4	0.161	−567.4	0.261	−498.1	0.361	−399.7	0.442	−324.5
0.080	−473.4	0.181	−560.9	0.281	−478.9	0.381	−380.0	0.461	−308.1
0.101	−525.4	0.201	−549.3	0.301	−459.0				
				T = 308.15 K, $w_{3,23}$ = 7.50 wt %					
0.020	−147.3	0.101	−495.8	0.181	−526.3	0.241	−485.7	0.301	−432.3
0.040	−275.8	0.121	−521.7	0.201	−515.3	0.261	−468.4	0.321	−414.4
0.060	−376.0	0.141	−532.6	0.221	−501.4	0.281	−450.4	0.341	−396.8
0.080	−449.2	0.161	−532.8						
				T = 323.15 K, $w_{3,23}$ = 1.00 wt %					
0.030	−187.4	0.150	−424.2	0.270	−326.2	0.390	−203.2	0.510	−108.3
0.060	−313.0	0.180	−409.9	0.300	−293.3	0.420	−176.2	0.540	−90.6
0.090	−389.1	0.210	−386.5	0.330	−263.8	0.450	−151.4	0.570	−76.4
0.120	−421.6	0.240	−357.0	0.360	−231.7	0.480	−128.2	0.599	−64.5

Table 5 (Continued)

$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}
T = 323.15 K, $w_{3,23}$ = 5.00 wt %									
0.020	−118.0	0.120	−382.5	0.220	−335.9	0.320	−243.1	0.400	−171.4
0.040	−214.7	0.140	−383.8	0.240	−318.6	0.340	−224.0	0.420	−155.2
0.060	−289.3	0.160	−378.0	0.260	−299.8	0.360	−206.0	0.440	−139.8
0.080	−339.1	0.180	−367.5	0.280	−280.8	0.380	−188.2	0.460	−125.3
0.100	−368.8	0.200	−352.5	0.300	−262.0				
T = 323.15 K, $w_{3,23}$ = 7.50 wt %									
0.020	−111.9	0.100	−344.2	0.180	−339.0	0.240	−292.6	0.300	−239.7
0.040	−204.6	0.120	−355.1	0.200	−325.5	0.260	−275.4	0.320	−221.8
0.060	−272.7	0.140	−356.2	0.220	−309.7	0.280	−257.4	0.340	−204.2
0.080	−319.1	0.160	−349.5						
T = 338.15 K, $w_{3,23}$ = 1.00 wt %									
0.030	−128.9	0.150	−239.2	0.270	−122.7	0.390	−3.9	0.510	76.6
0.060	−202.3	0.180	−214.1	0.300	−90.5	0.419	20.8	0.540	89.1
0.090	−248.1	0.210	−186.7	0.330	−59.4	0.449	42.8	0.569	98.6
0.120	−250.2	0.240	−155.7	0.360	−30.2	0.480	61.7	0.599	103.9
T = 338.15 K, $w_{3,23}$ = 5.00 wt %									
0.025	−98.8	0.125	−221.4	0.225	−141.0	0.325	−42.2	0.400	21.1
0.050	−174.2	0.150	−208.2	0.250	−116.1	0.350	−19.8	0.425	40.4
0.075	−208.7	0.175	−188.9	0.275	−92.6	0.375	1.9	0.450	55.9
0.100	−224.0	0.200	−164.9	0.300	−64.8				
T = 338.15 K, $w_{3,23}$ = 7.50 wt %									
0.020	−75.2	0.100	−202.6	0.180	−163.8	0.240	−107.3	0.300	−51.8
0.040	−134.2	0.120	−200.0	0.200	−143.4	0.260	−88.9	0.320	−34.1
0.060	−172.7	0.140	−188.6	0.220	−125.1	0.280	−69.8	0.340	−6.5
0.080	−199.2	0.160	−178.9						

Table 6. Excess Enthalpies of 1-Propanol (1) + (Water (2) + NaCl (3))

$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}
T = 285.65 K, $w_{3,23}$ = 1.00 wt %									
0.020	−236.8	0.120	−485.4	0.235	−323.6	0.375	−138.6	0.515	6.9
0.040	−419.4	0.140	−459.8	0.270	−274.7	0.410	−98.1	0.549	32.1
0.060	−517.0	0.160	−429.7	0.305	−227.2	0.445	−60.0	0.584	53.8
0.080	−529.0	0.180	−401.5	0.340	−180.8	0.480	−24.5	0.620	69.5
0.100	−511.8	0.200	−373.8						
T = 285.65 K, $w_{3,23}$ = 3.00 wt %									
0.020	−224.1	0.100	−458.0	0.160	−386.3	0.220	-308.4	0.280	−234.8
0.040	−391.0	0.120	−436.0	0.180	−361.9	0.240	−284.9	0.300	−211.0
0.060	−471.4	0.140	−412.1	0.200	−334.8	0.260	−259.8	0.320	−187.8
0.080	−475.9								
T = 285.65 K, $w_{3,23}$ = 5.00 wt %									
0.015	−161.8	0.060	−426.6	0.105	−405.2	0.135	−373.5	0.165	−339.7
0.030	−296.7	0.075	−428.2	0.120	−389.4	0.150	−357.4	0.180	−322.6
0.045	−390.1	0.090	−419.6						
T = 298.15 K, $w_{3,23}$ = 1.00 wt %									
0.030	−253.5	0.150	−268.4	0.270	−105.3	0.390	39.6	0.510	144.8
0.060	−355.8	0.180	−227.0	0.300	−69.6	0.420	68.8	0.540	165.9
0.090	−343.2	0.210	−186.0	0.330	−32.2	0.450	99.3	0.571	179.8
0.120	−307.5	0.240	−146.5	0.360	3.7	0.481	123.3		
T = 298.15 K, $w_{3,23}$ = 3.00 wt %									
0.020	−170.9	0.100	−295.6	0.160	−223.2	0.240	−123.5	0.360	12.7
0.040	−285.7	0.120	−273.1	0.180	−198.3	0.280	−76.9	0.400	54.5
0.060	−322.9	0.140	−249.2	0.200	−174.5	0.320	−30.9	0.440	95.7
0.080	−315.5								
T = 298.15 K, $w_{3,23}$ = 5.00 wt %									
0.020	−157.7	0.080	−278.0	0.140	−217.8	0.200	−151.2	0.280	−62.3
0.040	−263.9	0.100	−262.3	0.160	−196.5	0.220	−128.5	0.320	−21.6
0.060	−288.1	0.120	−239.9	0.180	−173.1	0.240	−106.8	0.360	15.3
T = 308.15 K, $w_{3,23}$ = 1.00 wt %									
0.030	−194.2	0.151	−119.6	0.271	39.3	0.392	174.6	0.512	272.2
0.060	−241.4	0.181	−77.3	0.301	76.2	0.421	203.2	0.542	287.7
0.090	−207.7	0.211	−37.2	0.331	110.2	0.452	229.7	0.571	298.8
0.121	−162.2	0.241	1.9	0.361	143.1	0.481	252.2		
T = 308.15 K, $w_{3,23}$ = 3.00 wt %									
0.020	−134.2	0.100	−179.0	0.161	−100.1	0.241	3.9	0.361	144.8
0.040	−209.8	0.121	−152.9	0.181	−74.1	0.281	54.6	0.401	184.2
0.060	−220.5	0.141	−126.4	0.201	−47.4	0.321	100.5	0.441	216.2
0.080	−203.3								

Table 6 (Continued)

$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}
				T = 308.15 K, $w_{3,23}$ = 5.00 wt %					
0.020	−124.7	0.080	−172.8	0.141	−102.1	0.201	−30.1	0.281	60.6
0.040	−188.2	0.100	−150.0	0.161	−78.3	0.221	−6.9	0.321	103.9
0.060	−191.0	0.121	−126.4	0.181	−53.8	0.241	16.7	0.361	145.5
				T = 323.15 K, $w_{3,23}$ = 1.00 wt %					
0.030	−109.5	0.150	41.9	0.270	226.0	0.390	375.7	0.510	467.1
0.060	−106.5	0.180	89.9	0.300	268.4	0.420	404.2	0.540	479.4
0.090	−59.3	0.210	138.7	0.330	307.7	0.450	429.4	0.570	485.3
0.120	−8.7	0.240	184.1	0.360	343.3	0.480	451.0		
				T = 323.15 K, $w_{3,23}$ = 3.00 wt %					
0.020	−78.5	0.100	−24.3	0.160	70.0	0.240	189.9	0.360	339.9
0.040	−104.1	0.120	7.4	0.180	101.2	0.280	244.3	0.400	380.7
0.060	−87.4	0.140	39.7	0.200	131.6	0.320	294.5	0.440	416.6
0.080	−57.1								
				T = 323.15 K, $w_{3,23}$ = 5.00 wt %					
0.020	−70.7	0.080	−37.8	0.140	52.3	0.200	140.2	0.280	245.7
0.040	−88.7	0.100	−7.0	0.160	82.8	0.220	167.8	0.320	293.0
0.060	−68.0	0.120	22.6	0.180	111.1	0.240	194.9	0.360	337.4
				T = 338.15 K, $w_{3,23}$ = 1.00 wt %					
0.015	−32.5	0.090	69.0	0.240	353.6	0.359	524.3	0.480	623.6
0.030	−40.2	0.105	101.9	0.270	400.6	0.389	555.1	0.509	638.8
0.045	−25.4	0.150	191.4	0.299	445.1	0.420	583.1	0.540	644.5
0.060	4.2	0.180	250.2	0.330	485.8	0.449	605.6	0.570	647.1
0.075	37.2	0.210	302.4						
				T = 338.15 K, $w_{3,23}$ = 3.00 wt %					
0.020	−34.9	0.100	98.2	0.160	214.1	0.240	351.1	0.360	515.3
0.040	−22.2	0.120	139.3	0.180	250.5	0.280	411.9	0.399	558.9
0.060	15.0	0.140	177.1	0.200	284.7	0.320	466.9	0.439	595.1
0.080	56.8								
				T = 338.15 K, $w_{3,23}$ = 5.00 wt %					
0.020	−22.7	0.080	74.6	0.140	189.7	0.200	290.7	0.280	410.9
0.040	−3.8	0.100	115.5	0.160	223.1	0.220	322.5	0.320	463.8
0.060	31.9	0.120	152.6	0.180	257.7	0.240	352.9	0.360	511.7
				T = 353.15 K, $w_{3,23}$ = 1.00 wt %					
0.030	26.2	0.150	349.0	0.270	590.4	0.390	754.7	0.510	827.3
0.060	108.7	0.180	417.0	0.300	639.1	0.420	782.8	0.540	830.5
0.090	197.1	0.210	477.5	0.330	682.2	0.450	802.6	0.570	823.6
0.120	276.4	0.240	536.3	0.360	720.1	0.480	817.3		
				T = 353.15 K, $w_{3,23}$ = 3.00 wt %					
0.025	20.8	0.125	288.4	0.225	499.1	0.325	662.3	0.400	749.9
0.050	85.8	0.150	346.6	0.250	543.8	0.350	694.9	0.425	772.4
0.075	158.1	0.175	401.0	0.275	587.1	0.375	723.2	0.450	789.6
0.100	225.7	0.200	452.3	0.300	626.3				
				T = 353.15 K, $w_{3,23}$ = 5.00 wt %					
0.025	26.7	0.100	229.8	0.175	395.2	0.250	532.8	0.325	650.3
0.050	93.0	0.125	288.1	0.200	443.0	0.275	574.6	0.350	678.5
0.075	163.2	0.150	343.3	0.225	490.1	0.300	613.7		

Table 7. Excess Enthalpies of 1-Propanol (1) + (Water (2) + KCl (3))

$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}
				T = 285.65 K, $w_{3,23}$ = 1.00 wt %					
0.020	−239.9	0.100	−519.6	0.180	−410.4	0.305	−230.8	0.445	−61.3
0.040	−422.6	0.120	−495.1	0.200	−387.7	0.340	−184.6	0.480	−25.6
0.060	−521.0	0.140	−464.2	0.235	−328.6	0.375	−140.4	0.514	3.6
0.080	−538.8	0.160	−439.5	0.270	−279.0	0.410	−98.7	0.550	30.9
				T = 285.65 K, $w_{3,23}$ = 3.00 wt %					
0.020	−228.4	0.100	−482.1	0.160	−406.7	0.220	−326.9	0.280	−249.1
0.040	−402.1	0.120	−459.9	0.180	−380.4	0.240	−301.1	0.300	−225.0
0.060	−489.8	0.140	−432.8	0.200	−353.6	0.260	−275.1	0.320	−201.0
0.080	−499.4								
				T = 285.65 K, $w_{3,23}$ = 5.00 wt %					
0.015	−168.7	0.060	−458.8	0.105	−438.1	0.135	−405.3	0.165	−371.2
0.030	−310.0	0.075	−463.8	0.120	−422.3	0.150	−388.9	0.180	−352.3
0.045	−411.8	0.090	−454.1						
				T = 298.15 K, $w_{3,23}$ = 1.00 wt %					
0.020	−183.3	0.120	−317.9	0.230	−166.5	0.350	−12.6	0.471	111.2
0.040	−312.3	0.140	−289.2	0.260	−126.5	0.380	21.6	0.500	137.4
0.060	−364.2	0.170	−246.9	0.290	−88.6	0.411	57.0	0.531	156.3
0.080	−362.0	0.200	−206.7	0.320	−47.1	0.440	84.3	0.561	174.5
0.100	−341.6								

Table 7 (Continued)

$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}
T = 298.15 K, $w_{3,23}$ = 3.00 wt %									
0.020	−176.5	0.100	−314.1	0.160	−242.8	0.240	−139.3	0.360	−0.1
0.040	−295.9	0.120	−291.2	0.180	−215.5	0.280	−90.7	0.400	41.4
0.060	−338.7	0.140	−266.4	0.200	−190.8	0.320	−44.1	0.441	79.2
0.080	−332.7								
T = 298.15 K, $w_{3,23}$ = 5.00 wt %									
0.020	−169.5	0.080	−305.7	0.140	−243.7	0.200	−174.5	0.280	−86.5
0.040	−279.9	0.100	−287.7	0.160	−220.5	0.220	−154.3	0.320	−41.4
0.060	−314.3	0.120	−266.9	0.180	−193.3	0.240	−132.6	0.360	2.5
T = 308.15 K, $w_{3,23}$ = 1.00 wt %									
0.020	−144.5	0.120	−187.3	0.231	−24.9	0.351	127.1	0.471	244.0
0.040	−232.8	0.141	−159.1	0.261	14.6	0.381	159.1	0.501	266.2
0.060	−254.8	0.171	−108.3	0.291	54.8	0.411	190.5	0.531	281.9
0.080	−239.8	0.201	−66.4	0.321	92.4	0.442	219.0	0.561	295.4
0.100	−214.9								
T = 308.15 K, $w_{3,23}$ = 3.00 wt %									
0.020	−139.3	0.101	−194.5	0.161	−114.9	0.241	−8.1	0.362	134.7
0.040	−219.7	0.121	−168.3	0.181	−88.0	0.281	41.4	0.402	176.2
0.060	−233.0	0.141	−141.9	0.201	−61.4	0.321	89.5	0.441	211.9
0.080	−219.0								
T = 308.15 K, $w_{3,23}$ = 5.00 wt %									
0.020	−132.3	0.080	−196.2	0.141	−123.3	0.201	−48.7	0.281	44.7
0.040	−205.2	0.100	−173.1	0.161	−98.2	0.221	−23.2	0.321	88.9
0.060	−214.2	0.120	−149.3	0.181	−73.3	0.241	−1.2	0.361	133.5
T = 323.15 K, $w_{3,23}$ = 1.00 wt %									
0.020	−85.8	0.120	−12.7	0.230	165.5	0.350	330.0	0.470	443.2
0.040	−121.6	0.140	21.2	0.260	211.0	0.380	363.3	0.500	461.5
0.060	−110.2	0.170	71.2	0.290	253.2	0.410	394.2	0.530	476.1
0.080	−79.9	0.200	119.3	0.320	292.4	0.440	421.2	0.560	483.9
0.100	−46.5								
T = 323.15 K, $w_{3,23}$ = 3.00 wt %									
0.020	−81.0	0.100	−33.1	0.160	62.3	0.240	180.6	0.360	333.6
0.040	−110.3	0.120	−1.1	0.180	93.4	0.280	236.2	0.400	373.0
0.060	−96.1	0.140	30.5	0.200	122.4	0.320	286.3	0.440	409.3
0.080	−65.7								
T = 323.15 K, $w_{3,23}$ = 5.00 wt %									
0.020	−76.9	0.080	−53.6	0.140	39.5	0.200	127.4	0.280	235.5
0.040	−101.2	0.100	−22.7	0.160	68.2	0.220	155.9	0.320	283.9
0.060	−83.2	0.120	8.0	0.180	97.6	0.240	183.5	0.360	324.3
T = 338.15 K, $w_{3,23}$ = 1.00 wt %									
0.020	−37.4	0.120	130.9	0.230	337.8	0.350	513.2	0.470	623.1
0.040	−33.0	0.140	171.4	0.260	387.0	0.380	548.1	0.500	638.0
0.060	1.0	0.170	229.7	0.290	433.1	0.410	578.5	0.530	647.7
0.080	44.9	0.200	285.4	0.320	475.2	0.439	602.2	0.559	650.0
0.100	88.9								
T = 338.15 K, $w_{3,23}$ = 3.00 wt %									
0.020	−33.7	0.100	95.3	0.160	208.9	0.240	348.0	0.359	513.2
0.040	−26.0	0.120	132.9	0.180	246.5	0.280	410.1	0.400	557.1
0.060	7.8	0.140	171.5	0.200	281.0	0.320	465.5	0.440	587.1
0.080	53.3								
T = 338.15 K, $w_{3,23}$ = 5.00 wt %									
0.020	−30.7	0.080	58.7	0.140	173.6	0.200	279.1	0.280	402.4
0.040	−19.6	0.100	97.9	0.160	210.4	0.220	312.0	0.320	454.8
0.060	18.8	0.120	137.6	0.180	244.9	0.240	343.0	0.359	502.9
T = 353.15 K, $w_{3,23}$ = 1.00 wt %									
0.020	7.2	0.120	279.8	0.230	527.5	0.350	725.5	0.470	830.6
0.040	57.7	0.140	330.8	0.260	585.8	0.380	760.5	0.500	845.5
0.060	107.3	0.170	401.9	0.290	636.3	0.410	791.4	0.530	846.8
0.080	170.2	0.200	466.4	0.320	682.3	0.440	815.8	0.560	848.5
0.100	227.3								
T = 353.15 K, $w_{3,23}$ = 3.00 wt %									
0.030	29.7	0.120	276.6	0.210	478.2	0.300	635.7	0.390	753.7
0.060	112.0	0.150	351.7	0.240	536.6	0.330	683.1	0.420	785.7
0.090	196.8	0.180	416.7	0.270	590.8	0.360	720.2	0.450	806.9
T = 353.15 K, $w_{3,23}$ = 5.00 wt %									
0.025	20.6	0.100	226.0	0.175	404.1	0.250	542.1	0.325	659.8
0.050	88.0	0.125	287.3	0.200	449.2	0.275	584.2	0.350	693.6
0.075	157.1	0.150	344.4	0.225	496.6	0.300	622.1		

Table 8. Excess Enthalpies of 2-Propanol (1) + (Water (2) + NaCl (3))

$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}
T = 285.65 K, $w_{3,23}$ = 2.50 wt %									
0.020	−285.9	0.100	−793.3	0.180	−686.5	0.275	−504.2	0.375	−316.3
0.040	−524.4	0.120	−777.2	0.200	−647.6	0.300	−456.8	0.400	−271.9
0.060	−694.9	0.140	−754.8	0.225	−602.3	0.325	−409.0	0.425	−228.7
0.080	−773.6	0.160	−721.7	0.250	−553.1	0.350	−361.2		
T = 285.65 K, $w_{3,23}$ = 5.98 wt %									
0.015	−197.1	0.074	−664.1	0.119	−658.3	0.164	−610.2	0.208	−537.6
0.030	−372.9	0.089	−679.2	0.134	−644.8	0.179	−582.0	0.223	−516.0
0.045	−523.3	0.104	−674.2	0.149	−623.4	0.193	−558.7	0.238	−491.5
0.059	−617.7								
T = 285.65 K, $w_{3,23}$ = 7.50 wt %									
0.015	−192.3	0.075	−621.9	0.120	−612.6	0.165	−559.5	0.210	−493.9
0.030	−361.3	0.090	−628.6	0.135	−599.9	0.180	−540.1	0.225	−473.3
0.045	−510.6	0.105	−628.6	0.150	−579.6	0.195	−518.7	0.240	−454.0
0.060	−579.2								
T = 298.15 K, $w_{3,23}$ = 2.50 wt %									
0.030	−338.7	0.151	−544.5	0.271	−340.7	0.392	−145.4	0.512	55.2
0.060	−540.5	0.181	−486.5	0.301	−288.8	0.422	−94.0	0.542	82.4
0.090	−593.1	0.211	−450.4	0.331	−238.4	0.452	−48.2	0.572	122.8
0.121	−582.6	0.241	−402.0	0.361	−182.8	0.482	−0.3		
T = 298.15 K, $w_{3,23}$ = 5.00 wt %									
0.020	−222.9	0.120	−511.3	0.201	−411.2	0.281	−286.4	0.361	−156.3
0.040	−391.8	0.140	−490.5	0.221	−380.6	0.301	−256.4	0.381	−127.8
0.060	−491.5	0.161	−465.6	0.241	−351.4	0.321	−223.7	0.401	−97.3
0.080	−524.7	0.181	−437.7	0.261	−330.6	0.341	−188.3	0.421	−65.5
0.100	−524.0								
T = 298.15 K, $w_{3,23}$ = 7.50 wt %									
0.020	−204.3	0.080	−467.4	0.140	−431.6	0.201	−359.9	0.241	−307.2
0.040	−361.3	0.100	−463.3	0.161	−408.1	0.221	−332.7	0.261	−274.4
0.060	−442.9	0.120	−450.9	0.181	−385.0				
T = 308.15 K, $w_{3,23}$ = 2.50 wt %									
0.030	−280.6	0.150	−405.7	0.270	−215.7	0.390	−17.9	0.510	152.9
0.060	−434.3	0.180	−362.3	0.300	−164.9	0.420	28.3	0.541	191.5
0.090	−463.3	0.210	−315.3	0.330	−114.6	0.450	72.1	0.571	219.8
0.120	−442.7	0.240	−267.3	0.360	−66.1	0.480	114.2		
T = 308.15 K, $w_{3,23}$ = 5.00 wt %									
0.020	−186.3	0.120	−378.9	0.200	−277.2	0.280	−161.1	0.360	−40.0
0.040	−319.4	0.140	−356.6	0.220	−249.6	0.300	−132.8	0.380	−12.3
0.060	−385.7	0.160	−330.9	0.240	−220.8	0.320	−101.3	0.400	16.7
0.080	−402.1	0.180	−303.7	0.260	−189.5	0.340	−72.0	0.420	49.4
0.100	−395.4								
T = 308.15 K, $w_{3,23}$ = 7.50 wt %									
0.020	−172.5	0.080	−357.1	0.140	−310.9	0.200	−238.2	0.260	−158.3
0.040	−291.2	0.100	−348.7	0.160	−289.6	0.220	−212.8	0.280	−130.7
0.060	−346.7	0.120	−332.0	0.180	−264.1	0.240	−185.9		
T = 323.15 K, $w_{3,23}$ = 2.50 wt %									
0.030	−198.9	0.150	−204.3	0.270	−16.9	0.390	164.8	0.510	315.1
0.060	−276.5	0.180	−159.3	0.300	29.0	0.420	208.4	0.540	342.3
0.090	−276.1	0.210	−113.8	0.330	75.4	0.450	246.5	0.571	368.1
0.120	−244.6	0.240	−66.0	0.360	121.7	0.480	282.7		
T = 323.15 K, $w_{3,23}$ = 5.00 wt %									
0.020	−136.7	0.120	−208.0	0.200	−99.6	0.280	19.9	0.360	133.4
0.040	−216.6	0.140	−183.1	0.220	−70.5	0.300	49.2	0.380	161.9
0.060	−246.9	0.160	−155.7	0.240	−40.0	0.320	77.0	0.400	189.4
0.080	−245.5	0.180	−127.8	0.260	−9.4	0.340	105.7	0.420	216.1
0.100	−229.9								
T = 323.15 K, $w_{3,23}$ = 7.50 wt %									
0.020	−122.9	0.080	−209.1	0.140	−145.2	0.200	−67.1	0.260	17.3
0.040	−193.3	0.100	−190.5	0.160	−119.2	0.220	−39.3	0.280	42.0
0.060	−215.0	0.120	−168.5	0.180	−92.4	0.240	−10.3		
T = 338.15 K, $w_{3,23}$ = 2.50 wt %									
0.015	−75.3	0.090	−138.8	0.240	90.3	0.360	271.7	0.480	413.6
0.030	−128.1	0.105	−118.8	0.270	138.6	0.390	312.6	0.510	439.6
0.045	−156.8	0.150	−53.6	0.300	185.2	0.420	350.0	0.540	462.8
0.060	−162.0	0.180	−4.1	0.330	229.0	0.450	383.5	0.570	479.8
0.075	−154.0	0.210	42.4						
T = 338.15 K, $w_{3,23}$ = 5.00 wt %									
0.020	−96.3	0.120	−66.6	0.200	47.5	0.280	169.5	0.360	280.4
0.040	−129.3	0.140	−39.1	0.220	79.4	0.300	196.7	0.380	303.0
0.060	−135.4	0.160	−11.2	0.240	109.5	0.320	222.8	0.400	328.4
0.080	−119.7	0.180	19.2	0.260	137.9	0.340	250.2	0.420	351.8
0.100	−95.0								
T = 338.15 K, $w_{3,23}$ = 7.50 wt %									
0.020	−73.9	0.080	−91.4	0.140	−17.4	0.200	69.8	0.260	154.4
0.040	−105.8	0.100	−70.3	0.160	12.0	0.220	98.1	0.280	184.4
0.060	−106.1	0.120	−44.2	0.180	39.3	0.240	130.8		

Table 9. Excess Enthalpies of 2-Propanol (1) + (Water (2) + KCl (3))

$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}	$x_{1,123}$	h^E_{1+23}/J·mol^{-1}
T = 285.65 K, $w_{3,23}$ = 2.50 wt %									
0.020	−290.9	0.100	−817.1	0.180	−709.7	0.275	−523.2	0.375	−332.0
0.040	−536.2	0.120	−805.0	0.200	−671.6	0.300	−474.9	0.400	−284.9
0.060	−711.0	0.140	−778.3	0.225	−622.6	0.325	−427.1	0.425	−244.6
0.080	−798.3	0.160	−747.1	0.250	−571.0	0.350	−377.1		
T = 285.65 K, $w_{3,23}$ = 5.00 wt %									
0.020	−280.2	0.060	−673.0	0.100	−766.7	0.140	−723.0	0.180	−659.4
0.040	−509.9	0.080	−747.2	0.120	−749.4	0.160	−694.1	0.200	−623.4
T = 285.65 K, $w_{3,23}$ = 7.50 wt %									
0.015	−202.3	0.060	−629.2	0.105	−699.8	0.150	−655.8	0.195	−590.6
0.030	−382.4	0.075	−679.8	0.120	−687.9	0.165	−635.1	0.210	−566.4
0.045	−530.9	0.090	−699.0	0.135	−672.8	0.180	−614.1	0.225	−547.5
T = 298.15 K, $w_{3,23}$ = 2.50 wt %									
0.030	−342.7	0.151	−564.2	0.271	−363.7	0.391	−149.3	0.481	5.7
0.060	−557.2	0.181	−515.9	0.301	−313.1	0.421	−100.1	0.511	50.5
0.090	−614.6	0.211	−467.1	0.331	−257.9	0.451	−53.9	0.542	109.5
0.121	−603.1	0.241	−417.1	0.361	−199.5				
T = 298.15 K, $w_{3,23}$ = 5.00 wt %									
0.020	−222.6	0.100	−566.5	0.181	−480.2	0.261	−352.7	0.341	−225.2
0.040	−411.3	0.121	−553.0	0.201	−450.8	0.281	−322.1	0.361	−191.8
0.060	−515.7	0.141	−532.8	0.221	−419.3	0.301	−290.2	0.381	−162.8
0.080	−561.4	0.161	−506.8	0.241	−385.1	0.321	−252.6		
T = 298.15 K, $w_{3,23}$ = 7.50 wt %									
0.020	−216.8	0.080	−516.6	0.141	−487.1	0.201	−410.7	0.261	−321.6
0.040	−385.9	0.100	−518.3	0.160	−463.8	0.221	−382.2	0.281	−283.4
0.060	−482.2	0.121	−504.4	0.181	−433.9	0.241	−352.7		
T = 308.15 K, $w_{3,23}$ = 2.50 wt %									
0.030	−285.3	0.150	−421.3	0.270	−225.9	0.390	−23.5	0.510	146.0
0.060	−442.9	0.180	−376.6	0.300	−177.5	0.420	22.8	0.540	182.7
0.090	−477.2	0.210	−327.2	0.330	−127.3	0.450	64.4	0.570	212.5
0.120	−458.3	0.240	−278.0	0.360	−76.4	0.480	105.5		
T = 308.15 K, $w_{3,23}$ = 5.00 wt %									
0.020	−191.3	0.100	−431.2	0.180	−339.8	0.260	−220.4	0.340	−97.2
0.040	−333.8	0.120	−414.9	0.200	−310.8	0.280	−188.0	0.360	−61.0
0.060	−409.9	0.140	−392.9	0.220	−282.2	0.300	−157.3	0.380	−31.1
0.080	−434.3	0.160	−369.1	0.240	−252.1	0.320	−125.8		
T = 308.1.5 K, $w_{3,23}$ = 7.50 wt %									
0.020	−182.4	0.080	−400.7	0.140	−359.8	0.200	−282.3	0.260	−200.5
0.040	−315.9	0.100	−395.5	0.160	−334.4	0.220	−255.0	0.280	−169.3
0.060	−384.0	0.120	−380.2	0.180	−309.2	0.240	−224.7		
T = 323.15 K, $w_{3,23}$ = 2.50 wt %									
0.030	−204.2	0.150	−221.9	0.270	−31.3	0.390	152.8	0.510	305.6
0.060	−290.2	0.180	−175.9	0.300	15.9	0.420	196.3	0.540	335.0
0.090	−291.8	0.210	−129.1	0.330	63.3	0.450	236.5	0.570	359.2
0.120	−262.1	0.240	−80.3	0.360	109.6	0.480	272.5		
T = 323.15 K, $w_{3,23}$ = 5.00 wt %									
0.020	−140.5	0.100	−254.4	0.180	−151.9	0.260	−31.9	0.340	87.0
0.040	−229.4	0.120	−232.6	0.200	−122.7	0.280	−3.1	0.360	116.8
0.060	−267.2	0.140	−207.9	0.220	−91.6	0.300	27.8	0.380	143.8
0.080	−268.6	0.160	−181.4	0.240	−63.3	0.320	58.9		
T = 323.15 K, $w_{3,23}$ = 7.50 wt %									
0.020	−132.2	0.080	−242.1	0.140	−183.5	0.200	−102.2	0.260	−16.3
0.040	−213.6	0.100	−227.1	0.160	−157.9	0.220	−74.7	0.280	15.2
0.060	−244.0	0.120	−207.6	0.180	−130.3	0.240	−47.2		
T = 338.15 K, $w_{3,23}$ = 2.50 wt %									
0.015	−80.8	0.090	−146.8	0.240	83.3	0.360	267.9	0.480	412.3
0.030	−132.2	0.105	−126.7	0.270	130.7	0.390	306.2	0.510	440.4
0.045	−162.8	0.150	−62.7	0.300	178.5	0.419	344.2	0.540	464.8
0.060	−169.8	0.180	−12.7	0.330	222.9	0.449	381.3	0.570	483.6
0.075	−162.7	0.210	33.8						
T = 338.15 K, $w_{3,23}$ = 5.00 wt %									
0.020	−92.0	0.100	−115.0	0.180	3.5	0.260	124.5	0.340	240.1
0.040	−142.7	0.120	−87.5	0.200	33.6	0.280	153.8	0.360	269.8
0.060	−153.6	0.140	−58.5	0.220	63.0	0.300	184.0	0.380	294.5
0.080	−138.5	0.160	−27.5	0.240	93.6	0.320	211.0		
T = 338.15 K, $w_{3,23}$ = 7.50 wt %									
0.020	−87.7	0.080	−122.5	0.140	−44.4	0.200	42.6	0.260	128.5
0.040	−132.1	0.100	−98.7	0.160	−17.9	0.220	72.3	0.280	157.3
0.060	−137.7	0.120	−72.1	0.180	14.0	0.240	102.3		

Table 10. Excess Enthalpies of Methanol (1) + Water (2)

$x_{1,12}$	h^E_{1+2}/J·mol^{-1}	$x_{1,12}$	h^E_{1+2}/J·mol^{-1}	$x_{1,12}$	h^E_{1+2}/J·mol^{-1}	$x_{1,12}$	h^E_{1+2}/J·mol^{-1}	$x_{1,12}$	h^E_{1+2}/J·mol^{-1}
				T = 285.65 K					
0.050	−363.1	0.250	−947.9	0.450	−898.7	0.650	−706.3	0.850	−386.0
0.100	−644.1	0.300	−962.6	0.500	−857.3	0.700	−643.8	0.900	−275.4
0.150	−795.6	0.350	−954.0	0.550	−813.1	0.750	−567.8	0.950	−145.0
0.200	−901.5	0.400	−928.1	0.600	−761.7	0.800	−485.0		
				T = 298.15 K					
0.050	−330.3	0.250	−879.8	0.450	−850.8	0.650	−680.2	0.850	−385.3
0.100	−570.9	0.300	−895.2	0.500	−815.0	0.700	−619.6	0.900	−270.1
0.150	−739.4	0.350	−888.4	0.550	−779.3	0.750	−555.3	0.950	−136.4
0.200	−832.9	0.400	−873.4	0.600	−737.8	0.800	−476.3		
				T = 308.15 K					
0.050	−281.8	0.251	−802.2	0.451	−785.1	0.651	−632.1	0.851	−356.8
0.100	−509.0	0.301	−820.4	0.501	−756.3	0.701	−580.6	0.900	−256.6
0.150	−663.2	0.351	−817.6	0.551	−722.1	0.751	−515.2	0.950	−134.3
0.201	−753.9	0.401	−806.0	0.600	−680.2	0.800	−444.5		
				T = 323.15 K					
0.050	−289.1	0.250	−677.2	0.450	−683.3	0.650	−558.0	0.850	−314.0
0.100	−492.7	0.300	−696.4	0.500	−658.5	0.700	−509.0	0.900	−225.5
0.150	−575.1	0.350	−706.7	0.550	−623.1	0.750	−457.1	0.950	−112.5
0.200	−635.8	0.400	−703.0	0.600	−595.6	0.800	−393.7		

Table 11. Excess Enthalpies of Ethanol (1) + Water (2)

$x_{1,12}$	h^E_{1+2}/J·mol^{-1}	$x_{1,12}$	h^E_{1+2}/J·mol^{-1}	$x_{1,12}$	h^E_{1+2}/J·mol^{-1}	$x_{1,12}$	h^E_{1+2}/J·mol^{-1}	$x_{1,12}$	h^E_{1+2}/J·mol^{-1}
				T = 285.65 K					
0.025	−288.5	0.150	−958.5	0.275	−845.2	0.540	−490.5	0.780	−291.6
0.050	−534.3	0.175	−958.2	0.300	−806.8	0.600	−430.2	0.840	−242.7
0.075	−723.9	0.200	−938.5	0.360	−717.2	0.660	−381.3	0.901	−178.2
0.100	−854.9	0.225	−910.7	0.420	−635.7	0.720	−335.4	0.959	−86.0
0.125	−929.4	0.250	−879.3	0.480	−559.8				
				T = 308.15 K					
0.050	−378.8	0.251	−569.2	0.451	−344.3	0.651	−201.2	0.801	−150.8
0.100	−585.6	0.301	−512.8	0.502	−298.6	0.701	−182.0	0.851	−137.0
0.151	−639.8	0.352	−453.4	0.551	−257.8	0.752	−159.9	0.901	−103.9
0.201	−618.2	0.401	−396.8	0.602	−227.2				
				T = 323.15 K					
0.050	−280.1	0.250	−354.4	0.450	−157.6	0.650	−52.6	0.850	−50.6
0.100	−413.0	0.300	−301.8	0.500	−119.7	0.700	−47.3	0.901	−46.7
0.150	−434.3	0.350	−250.5	0.550	−89.6	0.751	−46.2	0.950	−25.4
0.200	−403.6	0.400	−200.6	0.600	−67.5	0.800	−48.0		
				T = 338.15 K					
0.025	−108.8	0.150	−253.3	0.350	−49.0	0.550	87.7	0.750	83.1
0.050	−188.6	0.175	−232.5	0.400	−2.8	0.600	99.5	0.849	42.3
0.075	−238.5	0.200	−208.9	0.450	36.2	0.650	102.1	0.901	30.7
0.100	−261.9	0.250	−156.9	0.500	66.7	0.700	96.8	0.950	23.7
0.125	−263.9	0.300	−100.6						

LP1200S balance (accuracy, ±2 mg; precision, ±1 mg) for degassed water, and a Sartorius MC210P balance (accuracy, ±10 μg; precision, ±20 μg) for the salt. Both components, the salt water as well as the alkanol, are delivered by syringe pumps through thermostated PTFE tubing to the measuring cell where they are mixed. The total flow rate of the mixture is kept constant at 0.08 mL·min^{-1}. Starting with salt water, an excess enthalpy isotherm is measured by stepwise increase of the alkanol fraction. The maximum alkanol fraction is given by the maximum solubility of the salt in the solvent mixture (Wagner et al., 1998) or, for mixtures with propanols, by avoiding the occurrence of two liquid phases (Gomis et al., 1994, 1997); that is, the resulting mixture is always a homogeneous liquid phase. The mole fraction can be adjusted with a standard deviation <0.008. The standard deviation of the excess enthalpy is estimated to be <2%.

Results and Discussion

The results of the excess enthalpy measurements influenced by salt are given in Tables 2−9. Additionally, the excess enthalpies of the solvents without salt were measured after changes of alkanol or temperature in order to verify the reliability of the measurements periodically. The results of those measurements are shown in Tables 10−13. The excess enthalpies of the salt-free system ethanol + water at 298.15 K as well as the excess enthalpies of methanol + (water + NaCl) at 298.15 and 323.15 K for salt water concentrations of 5 and 10 wt %, respectively, are given in a previous work (Friese et al., 1998). In Figure 1, the good correspondence with literature regarding the excess enthalpies of salt-free systems is shown exemplarily for ethanol + water isotherms.

By means of Figures 2−5, the influence of salt on the excess enthalpy related to a variation in salt concentration, temperature, alkanol, or salt is illustrated.

In both the figures and tables, the following nomenclature is used to specify mole fractions or mass fractions, respectively: In the system alkanol (1) + water (2) + salt (3), for example, $w_{3,23}$ is the mass fraction of salt in the salt water solution or $x_{1,123}$ is the mole fraction of alkanol in the entire mixture.

An influence of salt on the excess enthalpy of alkanol + water mixtures can be observed already at low salt

Table 12. Excess Enthalpies of 1-Propanol (1) + Water (2)

$x_{1,12}$	h^E_{1+2}/J·mol^{-1}	$x_{1,12}$	h^E_{1+2}/J·mol^{-1}	$x_{1,12}$	h^E_{1+2}/J·mol^{-1}	$x_{1,12}$	h^E_{1+2}/J·mol^{-1}	$x_{1,12}$	h^E_{1+2}/J·mol^{-1}
				T = 285.65 K					
0.060	−536.3	0.140	−484.3	0.260	−299.3	0.500	−1.6	0.740	81.2
0.080	−557.7	0.160	−451.8	0.320	−214.7	0.559	44.6	0.860	31.4
0.100	−539.9	0.180	−421.8	0.380	−136.8	0.620	76.7	0.920	0.7
0.120	−513.5	0.200	−391.3	0.439	−65.6	0.680	82.9		
				T = 298.15 K					
0.030	−261.2	0.240	−157.4	0.450	97.2	0.630	200.0	0.810	148.6
0.060	−376.8	0.270	−116.3	0.480	123.1	0.660	202.8	0.841	113.2
0.090	−366.7	0.300	−76.5	0.510	147.0	0.690	199.9	0.870	92.5
0.120	−328.8	0.330	−36.9	0.540	165.7	0.719	191.7	0.900	65.8
0.150	−286.1	0.360	1.0	0.571	182.6	0.749	179.3	0.930	43.2
0.180	−242.1	0.390	34.5	0.600	194.3	0.781	162.1	0.960	29.0
0.210	−200.2	0.420	68.1						
				T = 308.15 K					
0.030	−201.8	0.241	−18.7	0.451	232.7	0.631	315.3	0.810	229.6
0.060	−263.4	0.271	23.4	0.481	258.2	0.661	312.8	0.841	184.6
0.090	−237.5	0.301	64.8	0.511	277.5	0.691	304.0	0.870	149.5
0.120	−195.2	0.331	103.0	0.541	294.8	0.720	289.8	0.901	110.5
0.150	−150.2	0.361	140.8	0.571	306.8	0.750	270.7	0.931	74.8
0.181	−105.6	0.391	173.8	0.601	313.6	0.782	242.1	0.960	50.5
0.211	−61.6	0.421	204.3						
				T = 323.15 K					
0.030	−114.2	0.240	181.9	0.450	434.1	0.630	486.1	0.809	328.0
0.060	−115.8	0.270	226.4	0.480	455.3	0.660	476.2	0.840	286.8
0.090	−69.5	0.300	267.9	0.510	472.3	0.689	457.9	0.870	234.9
0.120	−16.2	0.330	307.7	0.540	484.8	0.720	434.3	0.901	182.8
0.150	34.7	0.360	344.5	0.569	490.3	0.750	406.1	0.931	133.1
0.180	85.2	0.390	379.2	0.600	491.5	0.780	369.7	0.960	78.2
0.210	134.7	0.420	408.6						
				T = 338.15 K					
0.015	−32.1	0.090	70.6	0.299	461.8	0.549	671.1	0.800	475.5
0.030	−39.6	0.105	104.4	0.349	530.1	0.599	658.3	0.851	359.1
0.045	−25.9	0.150	199.2	0.400	586.1	0.649	647.0	0.901	252.4
0.060	3.7	0.200	296.0	0.450	627.9	0.699	585.9	0.951	121.5
0.075	37.3	0.250	383.6	0.499	654.1	0.750	542.1		
				T = 353.15 K					
0.050	74.6	0.250	560.2	0.450	820.7	0.650	800.6	0.851	433.2
0.100	219.9	0.300	645.7	0.500	835.5	0.700	740.8	0.901	301.9
0.150	347.5	0.350	716.4	0.550	845.7	0.750	646.9	0.951	150.8
0.200	461.6	0.400	784.1	0.600	837.6	0.800	556.1		

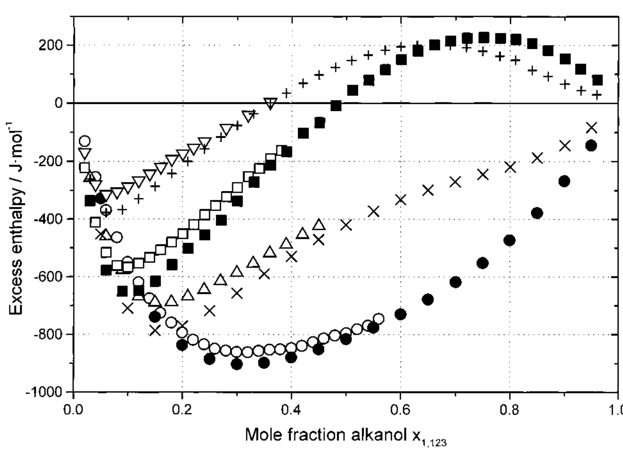

Figure 4. Effect of KCl on the excess enthalpy of different alkanols (1) + (water (2) + KCl (3)) at 298.15 K and $w_{3,23}$(KCl) = 5.00 wt %. Methanol: (●) salt-free; (○) with salt. Ethanol: (×) salt-free; (△) with salt. 1-Propanol: (+) salt-free; (▽) with salt. 2-Propanol: (■) salt-free; (□) with salt.

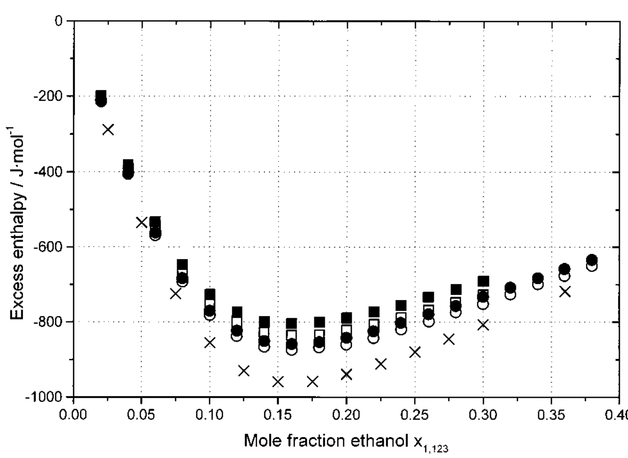

Figure 5. Effect of salt (3) (NaCl or KCl) on the excess enthalpy of ethanol (1) + water (2) at 285.65 K for 1.2558 mol % salt in water [(○) 5.00 wt % $w_{3,23}$(KCl); (●) 3.96 wt % $w_{3,23}$(NaCl)] and 1.9216 mol % salt in water [(□) 7.50 wt % $w_{3,23}$(KCl); (■) 5.98 wt % $w_{3,23}$(NaCl)]; (×) salt-free system.

concentrations ($w_{3,23}$ = 1.00 wt %). In Figure 2 it is shown that the difference with regard to the salt-free system becomes more significant if the salt concentration is increased. For the example given in Figure 2, this means that the excess enthalpy of a mixture of an aqueous solution containing 7.50 wt % sodium chloride with 2-propanol at 308.15 K is finally reduced by about one third compared to that for the salt-free system.

The shift to less exothermic excess enthalpies due to salt as observed in Figure 2 cannot be generalized. The excess enthalpy isotherms of the salt-free system 1-propanol + water turn from predominantly exothermic values at

Table 13. Excess Enthalpies of 2-Propanol (1) + Water (2)

$x_{1,12}$	h^E_{1+2}/J·mol^{-1}	$x_{1,12}$	h^E_{1+2}/J·mol^{-1}	$x_{1,12}$	h^E_{1+2}/J·mol^{-1}	$x_{1,12}$	h^E_{1+2}/J·mol^{-1}	$x_{1,12}$	h^E_{1+2}/J·mol^{-1}
				T = 285.65 K					
0.020	−303.0	0.120	−859.7	0.260	−581.7	0.500	−115.9	0.740	128.5
0.040	−557.6	0.140	−829.5	0.320	−456.4	0.560	−25.5	0.800	121.3
0.060	−744.5	0.160	−793.8	0.380	−333.2	0.620	46.3	0.860	99.3
0.080	−845.0	0.180	−753.5	0.440	−219.0	0.679	107.5	0.920	50.6
0.100	−871.2	0.200	−711.5						
				T = 298.15 K					
0.030	−336.5	0.241	−455.2	0.451	−67.4	0.631	180.2	0.811	220.7
0.060	−577.6	0.271	−403.6	0.481	−8.0	0.661	200.5	0.840	206.5
0.091	−650.9	0.301	−337.3	0.511	43.7	0.691	214.3	0.870	182.5
0.121	−647.7	0.331	−271.6	0.541	78.4	0.721	224.4	0.901	152.6
0.151	−615.9	0.362	−213.8	0.571	115.4	0.751	226.5	0.929	117.5
0.181	−558.3	0.391	−167.9	0.601	150.8	0.782	224.2	0.961	80.1
0.211	−500.8	0.421	−103.2						
				T = 308.15 K					
0.030	−298.8	0.210	−359.0	0.390	−34.9	0.570	213.7	0.749	296.1
0.060	−465.5	0.240	−304.9	0.420	13.9	0.600	245.0	0.780	285.9
0.090	−516.9	0.270	−250.2	0.450	61.5	0.629	270.2	0.870	215.2
0.120	−498.5	0.300	−194.8	0.480	104.7	0.660	283.8	0.901	175.2
0.150	−460.1	0.330	−141.7	0.510	146.2	0.690	294.7	0.929	136.3
0.180	−411.5	0.360	−87.4	0.540	183.6	0.721	296.7	0.959	99.7
				T = 323.15 K					
0.060	−298.3	0.270	−41.2	0.450	240.7	0.629	402.2	0.810	361.5
0.090	−301.2	0.300	10.5	0.480	279.7	0.660	411.0	0.840	316.0
0.120	−286.6	0.330	59.6	0.509	313.4	0.690	412.8	0.870	275.6
0.150	−244.2	0.360	108.5	0.540	342.6	0.721	407.3	0.901	225.6
0.180	−196.6	0.390	156.1	0.570	368.4	0.749	396.4	0.929	178.2
0.210	−146.0	0.420	201.1	0.600	388.5	0.780	376.7	0.959	116.6
0.240	−93.8								
				T = 338.15 K					
0.015	−81.1	0.090	−162.8	0.300	180.6	0.549	481.0	0.800	417.5
0.030	−138.9	0.105	−143.5	0.350	261.8	0.600	501.4	0.850	357.5
0.045	−174.0	0.150	−72.5	0.399	330.5	0.650	510.7	0.901	271.7
0.060	−183.1	0.200	11.7	0.449	392.7	0.699	498.0	0.950	153.4
0.075	−177.4	0.250	97.5	0.499	443.4	0.749	464.8		

285.65 K to endothermic values over the whole mole fraction range at 353.15 K (see Figure 3; for better distinctness, the measured values are connected by lines). Along with this change in sign of the excess enthalpy with increasing temperature, the shift to less exothermic excess enthalpies under the influence of salt decreases and, for temperatures greater than 323.15 K, salt-free and salt-influenced isotherms intersect; that is, a shift to less endothermic excess enthalpies can be observed in relation to the salt-free isotherm if the alkanol mole fraction exceeds that at the point of intersection. With increasing temperature, this point is moved to lower alkanol mole fractions, although the total salt concentration $w_{3,123}$ rises with decreasing alkanol mole fractions. Regarding the 353.15 K isotherms, the behavior of the excess enthalpy in the alkanol mole fraction range from about 0.06 to 0.2 is hardly affected by the addition of salt even though the salt concentration in the mixture is relatively high.

In Figure 4, the influence of salt at the constant salt-water concentration $w_{3,23}$(KCl) = 5.00 wt % and constant temperature is displayed for different alkanols. The difference with regard to the salt-free excess enthalpy isotherm due to the addition of salt is significantly smaller for mixtures with methanol, both relatively and absolutely, than for the other alkanols. The greatest effect can be observed at the minimum of the salt-free isotherm of each system. While in mixtures of ethanol, 1-propanol, or 2-propanol with water the addition of KCl causes a reduction of the exothermic effect of 13−16% at the isotherm's minimum, in mixtures with methanol only a reduction of about 5% can be achieved; that is, the interaction between methanol and water is much less affected by the addition of salt. Compared to the other alkanols, methanol is smaller and more polar. Therefore, it is easier for a methanol molecule to interact with water molecules in the solvation shell of an ion or to replace it.

The influence of different kinds of salt on the excess enthalpy of alkanol + water mixtures can be shown by means of Figure 5. In this work sodium chloride and potassium chloride were investigated. Both are 1,1-electrolytes with chloride as the anion. Therefore, the differences in the salt influence on the excess enthalpy of the solvent mixture are likely to result from the type of cation. Generally speaking, for alkali halides, cations not anions are responsible for the observed shift in phase equilibria and in excess enthalpies because they are smaller and consequently carry a higher surface charge. Provided that the salt is completely dissociated, the influence of sodium and potassium ions can be compared if the same number of chloride moles is dissolved in the solvent mixture. The assumption of complete dissociation is at least valid at low mole fractions of alkanol. In Figure 5, two concentrations (1.2558 and 1.9216 mol % salt in water) were investigated for both sodium and potassium chloride. The excess enthalpy isotherm of ethanol + water at 285.65 K is slightly more affected by sodium chloride than by potassium chloride. This observation can also be attributed to the size of the cation because sodium ion is the smaller one with a higher surface charge.

The excess enthalpies h^E_{1+23} are measured by mixing alkanol with a salt water solution of constant mass fraction $w_{3,23}$, that is alkanol (1) + (water (2) + salt (3)). The total excess enthalpy h^E_{123} refers to a mixture of pure alkanol (1) + pure water (2) + salt at infinite dilution (3). It can be calculated according to

$$\frac{H^E_{123}}{n_1 + n_2 + n_3} = \frac{H^E_{1+23}}{n_1 + n_2 + n_3} + \frac{n_2 + n_3}{n_1 + n_2 + n_3} \cdot \frac{H^E_{23}}{n_2 + n_3} \quad (1)$$

$$h^E_{123} = h^E_{1+23} + (1 - x_{1,123}) \cdot h^E_{23} \quad (2)$$

In eq 2, the excess enthalpy h^E_{23} of a mixture of pure water with salt at infinite dilution cannot be measured directly, but it is part of the solution process of solid salt in water. In this experiment, the integral enthalpy of solution $H^{sol,int}_{23}$ is experimentally accessible as a function of temperature and final salt concentration for each salt. The quantity consists of an enthalpy $H^{sol,\infty}_{23}$ describing the transformation of the salt from the solid state to infinite dilution and of the unknown excess enthalpy H^E_{23} for mixing water with infinitely diluted salt.

$$H^{sol,int}_{23} = H^E_{23} + H^{sol,\infty}_{23} \quad (3)$$

After introducing specific variables, eq 3 yields the results

$$\frac{H^E_{23}}{n_2 + n_3} = \frac{n_3}{n_2 + n_3}\left(\frac{H^{sol,int}_{23}}{n_3} - \frac{H^{sol,\infty}_{23}}{n_3}\right) \quad (4)$$

$$h^E_{23} = x_{3,23}(h^{sol,int}_{23} - h^{sol,\infty}_{23}) \quad (5)$$

$$\text{with } h^{sol,\infty}_{23} = \lim_{x_{3,23}\to 0} h^{sol,int}_{23} \quad (6)$$

If enthalpies of solution for salt in water are available as a function of temperature and salt concentration, excess enthalpies h^E_{123} can be calculated by means of eq 2 using the results for h^E_{1+23} given in this article.

Conclusion

The influence of salt on the excess enthalpies of alkanol + water mixtures was investigated by flow-calorimetric measurements. Results of h^E_{1+23}, that is the excess enthalpies of a mixture of alkanol (1) + salt water (23), are given for 117 isotherms along with 19 excess enthalpy isotherms for the salt-free binaries. Methanol, ethanol, 1-propanol, and 2-propanol were mixed with aqueous solutions of both sodium chloride and potassium chloride at different salt water mass fractions $w_{3,23}$. On the basis of the experimental results for h^E_{1+23} and considering different reference states, an equation is proposed for the calculation of excess enthalpies of pure alkanol + pure water + salt at infinite dilution, h^E_{123}. The data presented in this work contain excess enthalpies for up to six temperatures over a broad temperature range from 285.65 to 353.15 K. Using the Gibbs−Helmholtz equation, parameters for g^E models can be fitted not only to VLE data but also to excess enthalpy data under the influence of salt in order to yield better thermodynamic consistency.

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