Viscosities of Solutions of K_2SO_4, Na_2SO_4, KCl, NaCl, KNO_3, and $NaNO_3$ in (K_2CO_3 + $KHCO_3$) and (Na_2CO_3 + $NaHCO_3$) Buffers

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We report the kinematic viscosities and densities (at 298.1 K) of solutions of K_2SO_4, Na_2SO_4, KCl, NaCl, KNO_3, or $NaNO_3$ in (0.5 + 0.5) mol·dm^{-3} (K_2CO_3 + $KHCO_3$) and (0.5 + 0.5) mol·dm^{-3} (Na_2CO_3 + $NaHCO_3$) buffer at temperatures ranging from 293.1 to 323.1 K at 5 K intervals. Total ionic strength ranged from 2.0 to 5.0 mol·dm^{-3}. The experimental viscosity data were satisfactorily correlated with the temperature and/or solute concentration by means of empirical equations.

Introduction

The design of industrial absorption columns requires knowledge of the mass transfer coefficients of the corresponding physical absorption processes and the kinetic constants of any relevant chemical absorption processes. These data are commonly obtained from laboratory gas−liquid mass transfer experiments. In order to calculate the required parameters from the experimental mass transfer data, certain physical properties of the gas−liquid system must be known, among them the viscosity and the density of the liquid phase, which to maintain constant pH and so simplify mathematical modeling of the absorption system (Danckwerts, 1970) is frequently a sodium or potasssium carbonate + bicarbonate buffer containing a neutral salt (see, for example: Sharma and Danckwerts, 1963; Joosten and Danckwerts, 1973; Alper, 1981; Camacho *et al*., 1983; Pohorecki, 1968; Pohorecki and Moniuk, 1988). The ionic strength of this buffer (Pohorecki and Moniuk, 1988) and the cation used (Na^+ or K^+) (Peiper and Pitzer, 1982; Roy *et al*., 1984) influence the kinetics of its chemical reaction with the gas to be absorbed (often CO_2), but the extent to which this influence is due to the viscosity of the buffer is not known because very few viscosity data have been reported for these solutions.

As a preliminary to further studies on mass transfer, in this work we determined the kinematic viscosities of aqueous solutions of K_2SO_4, Na_2SO_4, KCl, NaCl, KNO_3, or $NaNO_3$ in (K_2CO_3 + $KHCO_3$) and (Na_2CO_3 + $NaHCO_3$) buffers. The viscosities of these systems can either increase or, as in the case of KCl solutions (Afzal *et al*., 1989), decrease with increasing neutral salt concentration, so allowing a flexible combination of liquid-phase viscosity and ionic strength, and hence of gas diffusivity and solubility in the liquid phase. These viscosity data complement data reported previously for sodium carbonate + bicarbonate buffers containing sugars (Vázquez *et al*., 1994a), potassium carbonate + bicarbonate buffers (Vázquez *et al*., 1994b), and mixtures of mono-, di-, and tripotassium and sodium orthophosphates (Chenlo *et al*., 1996), which are also of interest for studies of absorption processes.

Experimental Section

Potassium and sodium carbonate and bicarbonate (>99.9% pure), KCl, NaCl, and $NaNO_3$ (>99.5% pure), and KNO_3, K_2SO_4, and Na_2SO_4 (>99.0% pure) were Merck products and were dried to constant mass before use (A&D instruments AD 4712 IR humidity balance). Water was distilled and degassed. Solutions of K_2SO_4, Na_2SO_4, KCl, NaCl, KNO_3, or $NaNO_3$ in (0.5 + 0.5) mol·dm^{-3} sodium or potassium carbonate + bicarbonate buffer were made up at concentrations ranging from 0 to about 2.0 mol·dm^{-3} (or the solubility limit of the solute) at approximately constant molar concentration intervals. The corresponding total ionic strengths ranged from 2.0 mol·dm^{-3} (buffer alone) to 5.0 mol·dm^{-3}. All concentrations refer to solution volumes at 298.1 K. The solutions were made up by weighing on a Mettler AJ 150 balance precise to within ±0.0001 g. In what follows, component concentrations are expressed as mass fractions; the maximum deviations from the desired values were <0.1%. All solutions were filtered before use.

Table 1. Kinematic Viscosities ν of Potassium Carbonate + Potassium Bicarbonate and Sodium Carbonate + Sodium Bicarbonate Buffer at Various Temperatures

	$10^6\nu$/m^2·s^{-1}	
	K_2CO_3 (A) + $KHCO_3$ (B) + H_2O (C)	Na_2CO_3 (A) + $NaHCO_3$ (B) + H_2O (C)
T/K	w_A = 0.063 63, w_B = 0.046 09	w_A = 0.049 15, w_B = 0.038 96
293.1	1.131	1.363
298.1	1.014	1.209
303.1	0.918	1.080
308.1	0.836	0.978
313.1	0.767	0.888
318.1	0.704	0.812
323.1	0.652	0.740

The kinematic viscosities of the solutions at temperatures ranging from 293.1 to 323.1 K in 5 K intervals were calculated from the transit times of the liquid meniscus through a capillary, which were measured with a precision ±0.01 s in a Schott-Geräte AVS 350 automatic Ubbelohde viscometer. Each measurement was repeated at least five times with a maximum deviation of less than 0.4%. Tridistilled water was employed to calibrate the apparatus. The measured kinematic viscosities of water at the working temperatures all were within 0.2% of published values (Sengers and Watson, 1986). The densities of the solutions were determined at 298.1 K in a Bosch S2000/30 density balance precise to within ±0.0001 g·cm^{-3} (the maximum deviation in the values quoted is <0.03%). For both viscosity and density measurements, the temperature was controlled with a thermostated water bath. The precision of the temperature control in these measurements was ±0.05 K.

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Table 2. Kinematic Viscosities ν of Potassium and Sodium Carbonate + Bicarbonate Buffers Containing a Salt at Various Mass Fractions w and Temperatures T

K_2CO_3 (A) + $KHCO_3$ (B) + Na_2SO_4 (C) + H_2O (D)

T/K	$10^6\nu/m^2\cdot s^{-1}$			
	w_A = 0.062 38 w_B = 0.045 19 w_C = 0.032 06	w_A = 0.060 75 w_B = 0.044 01 w_C = 0.062 44	w_A = 0.059 19 w_B = 0.042 88 w_C = 0.091 25	w_A = 0.057 85 w_B = 0.041 91 w_C = 0.118 90
293.1	1.242	1.380	1.527	1.686
298.1	1.110	1.233	1.350	1.485
303.1	1.004	1.106	1.216	1.334
308.1	0.910	1.001	1.101	1.202
313.1	0.833	0.910	1.002	1.092
318.1	0.765	0.838	0.912	0.995
323.1	0.704	0.768	0.838	0.912

Na_2CO_3 (A) + $NaHCO_3$ (B) + Na_2SO_4 (C) + H_2O (D)

T/K	$10^6\nu/m^2\cdot s^{-1}$			
	w_A = 0.048 07 w_B = 0.038 10 w_C = 0.032 21	w_A = 0.046 81 w_B = 0.037 10 w_C = 0.062 73	w_A = 0.045 60 w_B = 0.036 16 w_C = 0.091 70	w_A = 0.044 66 w_B = 0.035 40 w_C = 0.119 69
293.1	1.507	1.672	1.845	2.051
298.1	1.334	1.476	1.622	1.806
303.1	1.188	1.305	1.439	1.599
308.1	1.070	1.175	1.293	1.429
313.1	0.970	1.065	1.163	1.287
318.1	0.886	0.971	1.055	1.161
323.1	0.807	0.882	0.961	1.051

K_2CO_3 (A) + $KHCO_3$ (B) + NaCl (C) + H_2O (D)

T/K	$10^6\nu/m^2\cdot s^{-1}$			
	w_A = 0.062 70 w_B = 0.045 43 w_C = 0.026 52	w_A = 0.061 80 w_B = 0.044 80 w_C = 0.052 30	w_A = 0.060 70 w_B = 0.043 90 w_C = 0.076 90	w_A = 0.059 80 w_B = 0.043 30 w_C = 0.101 11
293.1	1.185	1.235	1.307	1.363
298.1	1.060	1.107	1.164	1.221
303.1	0.961	1.009	1.049	1.104
308.1	0.876	0.919	0.954	1.005
313.1	0.798	0.835	0.876	0.916
318.1	0.735	0.772	0.803	0.844
323.1	0.679	0.716	0.743	0.777

Na_2CO_3 (A) + $NaHCO_3$ (B) + NaCl (C) + H_2O (D)

T/K	$10^6\nu/m^2\cdot s^{-1}$			
	w_A = 0.048 40 w_B = 0.038 40 w_C = 0.026 70	w_A = 0.047 70 w_B = 0.037 80 w_C = 0.052 60	w_A = 0.046 90 w_B = 0.037 20 w_C = 0.077 65	w_A = 0.046 20 w_B = 0.036 60 w_C = 0.101 97
293.1	1.411	1.471	1.543	1.625
298.1	1.255	1.306	1.369	1.436
303.1	1.127	1.173	1.228	1.287
308.1	1.013	1.059	1.109	1.157
313.1	0.920	0.962	1.007	1.048
318.1	0.841	0.876	0.920	0.957
323.1	0.771	0.805	0.843	0.875

K_2CO_3 (A) + $KHCO_3$ (B) + KCl (C) + H_2O(D)

T/K	$10^6\nu/m^2\cdot s^{-1}$			
	w_A = 0.062 33 w_B = 0.045 16 w_C = 0.033 63	w_A = 0.061 20 w_B = 0.044 35 w_C = 0.066 06	w_A = 0.060 32 w_B = 0.043 70 w_C = 0.097 60	w_A = 0.059 25 w_B = 0.042 92 w_C = 0.127 85
293.1	1.116	1.101	1.085	1.081
298.1	1.005	0.995	0.990	0.985
303.1	0.913	0.905	0.902	0.900
308.1	0.831	0.826	0.826	0.828
313.1	0.761	0.762	0.762	0.764
318.1	0.703	0.703	0.707	0.710
323.1	0.650	0.650	0.658	0.661

Na_2CO_3 (A) + $NaHCO_3$ (B) + KCl (C) + H_2O (D)

T/K	$10^6\nu/m^2\cdot s^{-1}$			
	w_A = 0.048 40 w_B = 0.038 35 w_C = 0.034 00	w_A = 0.047 40 w_B = 0.037 50 w_C = 0.066 60	w_A = 0.046 60 w_B = 0.036 95 w_C = 0.097 80	w_A = 0.045 70 w_B = 0.032 01 w_C = 0.128 63
293.1	1.330	1.306	1.296	1.286
298.1	1.187	1.169	1.165	1.159
303.1	1.068	1.052	1.050	1.052
308.1	0.964	0.958	0.958	0.956
313.1	0.880	0.874	0.873	0.879
318.1	0.806	0.802	0.811	0.810
323.1	0.741	0.738	0.750	0.748

K_2CO_3 (A) + $KHCO_3$ (B) + K_2SO_4 (C) + H_2O (D)

T/K	$10^6\nu/m^2\cdot s^{-1}$		
	w_A = 0.062 99 w_B = 0.045 60 w_C = 0.015 89	w_A = 0.062 00 w_B = 0.044 99 w_C = 0.031 30	w_A = 0.061 66 w_B = 0.044 67 w_C = 0.046 65
293.1	1.151	1.168	1.178
298.1	1.036	1.048	1.060
303.1	0.933	0.949	0.962
308.1	0.852	0.866	0.877
313.1	0.780	0.791	0.802
318.1	0.717	0.728	0.740
323.1	0.659	0.670	0.682

Table 2. (Continued)

Na_2CO_3 (A) + $NaHCO_3$ (B) + K_2SO_4 (C) + H_2O (D)

	$10^6\nu/\mathrm{m^2{\cdot}s^{-1}}$				$10^6\nu/\mathrm{m^2{\cdot}s^{-1}}$		
	w_A = 0.048 10	w_A = 0.046 95	w_A = 0.046 17		w_A = 0.048 10	w_A = 0.046 95	w_A = 0.046 17
	w_B = 0.038 10	w_B = 0.037 20	w_B = 0.036 60		w_B = 0.038 10	w_B = 0.037 20	w_B = 0.036 60
T/K	w_C = 0.031 60	w_C = 0.061 76	w_C = 0.091 10	T/K	w_C = 0.031 60	w_C = 0.061 76	w_C = 0.091 10
293.1	1.397	1.437	1.474	313.1	0.915	0.938	0.970
298.1	1.243	1.277	1.322	318.1	0.835	0.882	0.893
303.1	1.113	1.152	1.182	323.1	0.764	0.793	0.820
308.1	1.005	1.039	1.070				

K_2CO_3 (A) + $KHCO_3$ (B) + KNO_3 (C) + H_2O (D)

	$10^6\nu/\mathrm{m^2{\cdot}s^{-1}}$					$10^6\nu/\mathrm{m^2{\cdot}s^{-1}}$			
	w_A = 0.062 14	w_A = 0.060 38	w_A = 0.058 95	w_A = 0.057 80		w_A = 0.062 14	w_A = 0.060 38	w_A = 0.058 95	w_A = 0.057 80
	w_B = 0.045 17	w_B = 0.043 75	w_B = 0.042 70	w_B = 0.041 88		w_B = 0.045 17	w_B = 0.043 75	w_B = 0.042 70	w_B = 0.041 88
T/K	w_C = 0.045 46	w_C = 0.088 36	w_C = 0.129 40	w_C = 0.169 20	T/K	w_C = 0.045 46	w_C = 0.088 36	w_C = 0.129 40	w_C = 0.169 20
293.1	1.105	1.084	1.081	1.080	313.1	0.755	0.750	0.751	0.758
298.1	0.995	0.980	0.977	0.978	318.1	0.695	0.691	0.696	0.703
303.1	0.901	0.893	0.888	0.895	323.1	0.643	0.638	0.645	0.655
308.1	0.823	0.815	0.815	0.821					

Na_2CO_3 (A) + $NaHCO_3$ (B) + KNO_3 (C) + H_2O (D)

	$10^6\nu/\mathrm{m^2{\cdot}s^{-1}}$					$10^6\nu/\mathrm{m^2{\cdot}s^{-1}}$			
	w_A = 0.048 08	w_A = 0.046 80	w_A = 0.045 70	w_A = 0.044 50		w_A = 0.048 08	w_A = 0.046 80	w_A = 0.045 70	w_A = 0.044 50
	w_B = 0.038 11	w_B = 0.037 10	w_B = 0.036 20	w_B = 0.035 30		w_B = 0.038 11	w_B = 0.037 10	w_B = 0.036 20	w_B = 0.035 30
T/K	w_C = 0.045 87	w_C = 0.089 30	w_C = 0.130 70	w_C = 0.169 70	T/K	w_C = 0.045 87	w_C = 0.089 30	w_C = 0.130 70	w_C = 0.169 70
293.1	1.315	1.282	1.268	1.260	313.1	0.867	0.857	0.848	0.854
298.1	1.176	1.143	1.135	1.140	318.1	0.798	0.790	0.786	0.788
303.1	1.060	1.033	1.026	1.024	323.1	0.730	0.724	0.724	0.729
308.1	0.956	0.939	0.934	0.934					

K_2CO_3 (A) + $KHCO_3$ (B) + $NaNO_3$ (C) + H_2O (D)

	$10^6\nu/\mathrm{m^2{\cdot}s^{-1}}$					$10^6\nu/\mathrm{m^2{\cdot}s^{-1}}$			
	w_A = 0.062 10	w_A = 0.060 80	w_A = 0.059 50	w_A = 0.058 10		w_A = 0.062 10	w_A = 0.060 80	w_A = 0.059 50	w_A = 0.058 10
	w_B = 0.044 96	w_B = 0.044 10	w_B = 0.043 10	w_B = 0.042 10		w_B = 0.044 96	w_B = 0.044 10	w_B = 0.043 10	w_B = 0.042 10
T/K	w_C = 0.038 20	w_C = 0.074 80	w_C = 0.109 70	w_C = 0.142 97	T/K	w_C = 0.038 20	w_C = 0.074 80	w_C = 0.109 70	w_C = 0.142 97
293.1	1.170	1.211	1.265	1.337	313.1	0.789	0.815	0.852	0.897
298.1	1.053	1.087	1.133	1.198	318.1	0.729	0.753	0.784	0.824
303.1	0.952	0.982	1.026	1.081	323.1	0.673	0.697	0.722	0.760
308.1	0.865	0.892	0.931	0.981					

Na_2CO_3 (A) + $NaHCO_3$ (B) + $NaNO_3$ (C) + H_2O (D)

	$10^6\nu/\mathrm{m^2{\cdot}s^{-1}}$					$10^6\nu/\mathrm{m^2{\cdot}s^{-1}}$			
	w_A = 0.048 09	w_A = 0.047 10	w_A = 0.046 10	w_A = 0.044 90		w_A = 0.048 09	w_A = 0.047 10	w_A = 0.046 10	w_A = 0.044 90
	w_B = 0.038 11	w_B = 0.037 30	w_B = 0.036 55	w_B = 0.035 60		w_B = 0.038 11	w_B = 0.037 30	w_B = 0.036 55	w_B = 0.035 60
T/K	w_C = 0.038 56	w_C = 0.075 56	w_C = 0.110 90	w_C = 0.143 98	T/K	w_C = 0.038 56	w_C = 0.075 56	w_C = 0.110 90	w_C = 0.143 98
293.1	1.389	1.435	1.491	1.548	313.1	0.909	0.934	0.974	1.010
298.1	1.236	1.273	1.323	1.373	318.1	0.830	0.857	0.888	0.923
303.1	1.110	1.145	1.188	1.229	323.1	0.760	0.782	0.816	0.847
308.1	1.001	1.034	1.070	1.109					

Results

Table 1 lists the kinematic viscosities of the (0.5 + 0.5) $\mathrm{mol{\cdot}dm^{-3}}$ sodium and potassium carbonate + bicarbonate buffers in the working temperature range. These values deviate from those reported by Moniuk and Pohorecki (1991) by <0.8%. Fitting them with the Cornelissen and Waterman (1955) equation for the dependence of kinematic viscosity, ν, on absolute temperature, T, afforded the expresions

$$\nu_o = \nu_{K,buffer}/\mathrm{m^2{\cdot}s^{-1}} = 1.2881 \times 10^{-7} e^{5.4631\times10^7/(T/K)^3} \quad (1)$$

and

$$\nu_o = \nu_{Na,buffer}/\mathrm{m^2{\cdot}s^{-1}} = 1.2466 \times 10^{-7} e^{6.01482\times10^7/(T/K)^3} \quad (2)$$

where the second subscript of the ν's indicates the buffer cation. The deviations between the experimental data and the predictions of eqs 1 and 2 were <0.3%.

Table 2 lists the kinematic viscosities of the (0.5 + 0.5) $\mathrm{mol{\cdot}dm^{-3}}$ sodium and potassium carbonate + bicarbonate buffers containing added salts. When the solute was Na_2SO_4, NaCl, $NaNO_3$, and K_2SO_4, the kinematic viscosity increased with increasing solute concentration. For these systems, the dependence of ν on solute concentration (mass fraction, w) and absolute temperature was expressed by an empirical equation of the form

$$\nu = \nu_o + A e^{B/T^m} w^n \quad (3)$$

where ν_o was obtained from eqs 1 or 2 above, m = 3, and the parameters n, A, and B were optimized (Table 3). The maximum deviation between the experimental data and eq 3 was <0.9%. For the remaining solutes (KCl and KNO_3), the kinematic viscosity decreased or passed through

Table 3. Parameters (*A, B,* and *n*) of Eq 3 for the Dependence of the Kinematic Viscosity of the Listed (Carbonate + Bicarbonate Buffer + Solute) Systems on Solute Concentration and Temperature

$10^7 A$/m^2·s^{-1}	$10^{-7} B$/K^3	n
K_2CO_3 (A) + $KHCO_3$ (B) + Na_2SO_4 (C) + H_2O (D)		
3.8206	7.3879	1.21
Na_2CO_3 (A) + $NaHCO_3$ (B) + Na_2SO_4 (C) + H_2O (D)		
3.6770	7.8450	1.18
K_2CO_3 (A) + $KHCO_3$ (B) + NaCl (C) + H_2O (D)		
2.6864	5.9413	1.10
Na_2CO_3 (A) + $NaHCO_3$ (B) + NaCl (C) + H_2O (D)		
3.1813	6.2088	1.18
K_2CO_3 (A) + $KHCO_3$ (B) + K_2SO_4 (C) + H_2O (D)		
1.0552	5.2606	0.91
Na_2CO_3 (A) + $NaHCO_3$ (B) + K_2SO_4 (C) + H_2O (D)		
3.3491	4.0062	1.11
K_2CO_3 (A) + $KHCO_3$ (B) + $NaNO_3$ (C) + H_2O (D)		
1.7640	6.1523	1.20
Na_2CO_3 (A) + $NaHCO_3$ (B) + $NaNO_3$ (C) + H_2O (D)		
2.6687	5.5629	1.34

Table 4. Parameters (*C* and *D*) of Eq 4 for the Dependence of the Kinematic Viscosity of the Listed (Carbonate + Bicarbonate Buffer + Solute) Systems on Solute Concentration at Various Temperatures

T/K	C/g of solution·g of solute^{-1})	D/g of solution·g of solute^{-1})^2
K_2CO_3 (A) + $KHCO_3$ (B) + KCl (C) + H_2O (D)		
293.1	−0.4685	0.7705
298.1	−0.3013	0.5579
303.1	−0.2278	0.5640
308.1	−0.2501	1.3602
313.1	−0.1957	1.3463
318.1	−0.0706	1.0839
323.1	−0.1315	1.9702
Na_2CO_3 (A) + $NaHCO_3$ (B) + KCl (C) + H_2O (D)		
293.1	−0.8046	2.7536
298.1	−0.6406	2.4703
303.1	−0.5244	2.4319
308.1	−0.4601	2.3044
313.1	−0.3890	2.3414
318.1	−0.2707	2.0481
323.1	−0.0277	1.0463
K_2CO_3 (A) + $KHCO_3$ (B) + KNO_3 (C) + H_2O (D)		
293.1	−0.6648	2.3366
298.1	−0.5362	1.9163
303.1	−0.5088	2.1101
308.1	−0.4672	2.1106
313.1	−0.4501	2.2533
318.1	−0.3921	2.2805
323.1	−0.4741	3.0046
Na_2CO_3 (A) + $NaHCO_3$ (B) + KNO_3 (C) + H_2O (D)		
293.1	−0.9199	2.6977
298.1	−0.8664	3.0130
303.1	−0.6239	1.7896
308.1	−0.6396	2.1693
313.1	−0.6384	2.3685
318.1	−0.4633	1.6961
323.1	−0.4163	1.9467

a minimum value as the solute concentration increased, and its dependence on this concentration at each temperature was expressed by the empirical equation proposed by Azfal *et al.* (1989):

$$\nu = \nu_o e^{Cw+Dw^2} \tag{4}$$

The values of the optimized parameters C and D are listed in Table 4. The maximum deviation between the experimental data and eq 4 was <0.6%.

Table 5. Densities of the Potassium and Sodium Buffers Carbonate + Bicarbonate and Buffers Containing an Additional Solute at Various Mass Fractions *w* at 298.1 K

w_A	w_B	w_C	ρ/kg·m^{-3}
K_2CO_3 (A) + $KHCO_3$ (B) + H_2O (C)			
0.063 63	0.046 09		1083.0
Na_2CO_3 (A) + $NaHCO_3$ (B) + H_2O (C)			
0.049 15	0.038 96		1078.5
K_2CO_3 (A) + $KHCO_3$ (B) + Na_2SO_4 (C) + H_2O (D)			
0.062 38	0.045 19	0.032 06	1109.8
0.060 75	0.044 01	0.062 44	1137.5
0.059 19	0.042 88	0.091 25	1167.5
0.057 85	0.041 91	0.118 90	1194.6
Na_2CO_3 (A) + $NaHCO_3$ (B) + Na_2SO_4 (C) + H_2O (D)			
0.048 07	0.038 10	0.032 21	1103.5
0.046 81	0.037 10	0.062 73	1132.2
0.045 60	0.036 16	0.091 70	1160.2
0.044 66	0.035 40	0.119 69	1186.8
K_2CO_3 (A) + $KHCO_3$ (B) + NaCl (C) + H_2O (D)			
0.062 70	0.045 43	0.026 52	1102.1
0.061 80	0.044 80	0.052 30	1118.6
0.060 70	0.043 90	0.076 90	1138.7
0.059 80	0.043 30	0.101 11	1156.0
Na_2CO_3 (A) + $NaHCO_3$ (B) + NaCl (C) + H_2O (D)			
0.048 40	0.038 40	0.026 70	1094.2
0.047 70	0.037 80	0.052 60	1111.0
0.046 90	0.037 20	0.077 65	1129.0
0.046 20	0.036 60	0.101 97	1146.3
K_2CO_3 (A) + $KHCO_3$ (B) + KCl (C) + H_2O (D)			
0.062 33	0.045 16	0.063 60	1104.1
0.061 20	0.044 35	0.066 06	1124.2
0.060 32	0.043 70	0.097 60	1145.7
0.059 25	0.042 92	0.127 85	1166.4
Na_2CO_3 (A) + $NaHCO_3$ (B) + KCl (C) + H_2O (D)			
0.048 40	0.038 35	0.034 00	1098.9
0.047 40	0.037 50	0.066 60	1119.0
0.046 60	0.036 95	0.097 80	1137.5
0.045 70	0.032 01	0.128 63	1159.3
K_2CO_3 (A) + $KHCO_3$ (B) + K_2SO_4 (C) + H_2O (D)			
0.062 99	0.045 60	0.015 89	1097.1
0.062 00	0.044 99	0.031 30	1112.6
0.061 66	0.044 67	0.046 65	1124.7
Na_2CO_3 (A) + $NaHCO_3$ (B) + K_2SO_4 (C) + H_2O (D)			
0.048 10	0.038 10	0.031 60	1102.2
0.046 95	0.037 20	0.061 76	1126.9
0.046 17	0.036 60	0.091 10	1147.7
K_2CO_3 (A) + $KHCO_3$ (B) + KNO_3 (C) + H_2O (D)			
0.062 14	0.045 17	0.045 46	1112.2
0.060 38	0.043 75	0.088 36	1144.4
0.058 95	0.042 70	0.129 40	1172.3
0.057 80	0.041 88	0.169 20	1199.3
Na_2CO_3 (A) + $NaHCO_3$ (B) + KNO_3 (C) + H_2O (D)			
0.048 08	0.038 11	0.045 87	1103.2
0.046 80	0.037 10	0.089 30	1131.7
0.045 70	0.036 20	0.130 70	1160.3
0.044 50	0.035 30	0.169 70	1190.2
K_2CO_3 (A) + $KHCO_3$ (B) + $NaNO_3$ (C) + H_2O (D)			
0.062 10	0.044 96	0.038 20	1110.5
0.060 80	0.044 10	0.074 80	1136.1
0.059 50	0.043 10	0.109 70	1162.2
0.058 10	0.042 10	0.142 97	1189.0
Na_2CO_3 (A) + $NaHCO_3$ (B) + $NaNO_3$ (C) + H_2O (D)			
0.048 09	0.038 11	0.038 56	1102.2
0.047 10	0.037 30	0.075 56	1124.8
0.046 10	0.036 55	0.110 90	1149.4
0.044 90	0.035 60	0.143 98	1177.0

The densities of the solutions at 298.1 K are listed in Table 5.

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