Temperature and Concentration Dependence of Conductivities of Some New Semichelatoborates in Acetonitrile and Comparison with Other Borates

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Data on the temperature and concentration dependence of conductivities of some new ionic liquids based on the reduced symmetry of the semichelato-borate anion are presented and compared to data for the corresponding symmetrical chelato-borate and tetrafluoroborate salts. The compounds under investigation are the semichelato-borates tetraethylammonium difluoromono[1,2-oxalato(2-)-O,O′]borate ([TEA][BF_2OX]) and the new 1-ethyl-3-methylimidazolium difluoromono[1,2-oxalato(2-)-O,O′]borate ([EMIM][BF_2OX]), the chelato-borates tetraethylammonium bis[1,2-oxalato(2-)-O,O′]borate ([TEA][$B(OX)_2$]) and the new 1-ethyl-3-methylimidazolium bis[1,2-oxalato(2-)-O,O′]borate ([EMIM][$B(OX)_2$]), and the well-known tetrafluoroborates tetraethylammonium tetrafluoroborate ([TEA][BF_4]) and 1-ethyl-3-methylimidazolium tetrafluoroborate ([EMIM][BF_4]). The concentration dependence of conductivities of [TEA][BF_2OX], [EMIM][BF_2OX], [TEA][$B(OX)_2$], [EMIM][$B(OX)_2$], [TEA][BF_4], and [EMIM][BF_4] in pure acetonitrile was measured at 25 °C, 5 °C, –15 °C, and –35 °C and fitted to the Casteel−Amis equation. Data presented in this work should clarify the influence of reduced symmetry caused by the substitution of two fluorine atoms by the oxalate moiety in the borate anion on its conductivity behavior, especially at low temperatures.

Introduction

Double-layer capacitors (DLCs) are electrochemical devices for electrical energy storage.[1,2] Their main advantages in comparison to the most important electrical energy storage devices, rechargeable batteries, are a far superior power density (more than 10^4 W·kg^{-1} vs about 10^2 W·kg^{-1} for lithium-ion batteries) and a better cycleability (more than ca. 10^5 vs ca. 10^3 cycles) without appreciable loss in performance.[1–4] Two major types of DLCs can be distinguished, with aqueous electrolytes and nonaqueous electrolytes, respectively. DLCs with aqueous electrolytes exhibit superior power density at lower energy density, whereas DLCs with nonaqueous electrolytes exhibit superior energy density but inferior power density due to the larger voltage window but lower conductivity of nonaqueous electrolytes. A search for better electrolytes or electrolytes with special features has been performed by several groups.[5–10] This work includes synthesis of new salts, electrochemical characterization of electrolytes, DLC performance investigations, and studies of electrolyte conductivities, a key parameter for the power density of DLCs, which is closely related to ESR values as obtained from impedance spectroscopy.

In ref 11, we reported that for the tetraethylammonium salt [TEA][BF_2OX] the lower symmetry of the borate anion leads to a low melting point of 33 °C compared to the high melting point of 382 °C for [TEA][BF_4].[12] Salts with low melting points are known to have typically a very high solubility in many solvents, a feature that is important for double-layer capacitors at low temperatures.

In this work, the influence of structural modifications of the tetrafluoroborate anion on the specific conductivity, especially at low temperatures, is investigated. It should be primarily clarified what effect the substitution of fluorine atoms by the oxalate moiety has on the specific conductivity and the solubility at various temperatures. Therefore, the bisoxalatoborates [TEA][$B(OX)_2$] and [EMIM][$B(OX)_2$], with melting points of (118 and 56) °C,[11,10] and the new ionic liquids based on the lower symmetric difluoromono[1,2-oxalato(2-)-O,O′]borate anion, [TEA][BF_2OX] and [EMIM][BF_2OX], with melting points of (33 and 18) °C[11] were synthesized.

Table 1. Specific Conductivities of [TEA][BF_2OX] in AN at Several Temperatures

m / mol·kg^{-1}	κ_T / mS·cm^{-1} (25 °C)	κ_T / mS·cm^{-1} (5 °C)	κ_T / mS·cm^{-1} (−15 °C)	κ_T / mS·cm^{-1} (−35 °C)
3.6	55.26	41.83	29.15	17.83
3.0	56.62	43.76	31.41	20.07
2.4	56.43	43.30	32.54	21.53
1.8	53.03	42.63	32.35	22.51
1.2	44.78	36.64	28.49	20.57
0.6	30.98	25.74	20.46	15.23

Experimental Section

All procedures related to electrolyte preparation, conductivity measurement, and cell filling were carried out in a nitrogen-filled glovebox (O_2 and H_2O < 10 ppm) (Mecaplex).

For electrolytic conductivity measurements, solutions of [TEA][BF_2OX], [EMIM][BF_2OX], [TEA][$B(OX)_2$], [EMIM][$B(OX)_2$], [TEA][BF_4], and [EMIM][BF_4] were prepared using highly pure acetonitrile (AN) (Merck, selectipur) with a very low water content [(10 to 30) ppm], as checked by coulometric Karl Fischer titration using a Mitsubishi Moisturemeter, model CA-20.

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Table 2. Fit Parameters (Casteel−Amis Equation) of [TEA][BF_2OX] in AN

	25 °C	5 °C	−15 °C	−35 °C
κ_{max}/mS·cm^{-1}	56.98 ± 0.18	44.43 ± 0.15	32.73 ± 0.13	22.29 ± 0.13
μ/mol·kg^{-1}	2.811 ± 0.023	2.555 ± 0.024	2.247 ± 0.032	1.889 ± 0.045
a	0.7157 ± 0.0516	0.7340 ± 0.0520	0.7592 ± 0.0645	0.8081 ± 0.0942
b	−0.0141 ± 0.0079	−0.0120 ± 0.0081	−0.0096 ± 0.0103	−0.0046 ± 0.0156
R^2	0.99993	0.99992	0.99987	0.99969

Table 3. Specific Conductivities of [TEA][B(OX)$_2$] in AN at Several Temperatures

m / mol·kg^{-1}	κ_T / mS·cm^{-1} (25 °C)	κ_T / mS·cm^{-1} (5 °C)	κ_T / mS·cm^{-1} (−15 °C)	κ_T / mS·cm^{-1} (−35 °C)
2.4	38.44	27.68	17.84	10.11
2.0	38.92	29.07	19.61	11.88
1.6	37.96	29.07	20.65	12.90
1.2	34.76	27.23	19.98	13.30
0.8	27.43	22.33	16.71	11.30
0.4	17.36	14.18	11.04	7.03

Table 4. Fit Parameters (Casteel−Amis Equation) of [TEA][B(OX)$_2$] in AN

	25 °C	5 °C	−15 °C	−35 °C
κ_{max}/mS·cm^{-1}	39.13 ± 0.22	29.33 ± 0.07	20.63 ± 0.11	13.27 ± 0.09
μ/mol·kg^{-1}	2.018 ± 0.046	1.792 ± 0.010	1.568 ± 0.019	1.365 ± 0.025
a	0.8525 ± 0.1070	0.8872 ± 0.0389	0.8088 ± 0.0865	1.143 ± 0.124
b	−0.0466 ± 0.0354	−0.0450 ± 0.0132	−0.0926 ± 0.0303	−0.0473 ± 0.0442
R^2	0.99976	0.99996	0.99980	0.99958

Table 5. Specific Conductivities of [TEA][BF_4] in AN at Several Temperatures[a]

m / mol·kg^{-1}	κ_T / mS·cm^{-1} (25 °C)	κ_T / mS·cm^{-1} (5 °C)	κ_T / mS·cm^{-1} (−15 °C)	κ_T / mS·cm^{-1} (−35 °C)
3.6	63.99	–	–	–
3.0	63.98	–	–	–
2.4	61.70	49.57	37.58	–
1.8	55.81	45.74	35.59	–
1.2	45.73	37.99	30.11	22.30
0.6	32.52	26.75	21.16	18.03

[a] Due to the limited solubility of [TEA][BF_4] at lower temperatures, conductivity measurements were not possible at lower temperatures for the more concentrated systems.

Table 6. Fit Parameters (Casteel−Amis Equation) of [TEA][BF_4] in AN[a]

	25 °C	5 °C	−15 °C	−35 °C
κ_{max}/mS·cm^{-1}	64.48 ± 0.21	49.95 ± –	37.59 ± –	–
μ/mol·kg^{-1}	3.211 ± 0.056	2.655 ± –	2.445 ± –	–
a	0.4546 ± 0.0611	0.3539 ± –	0.4263 ± –	–
b	−0.0431 ± 0.0092	−0.0881 ± –	−0.0873 ± –	–
R^2	0.99991	1	1	–

[a] Because of the limited solubility of [TEA][BF_4] at low temperatures, there were not enough data points to fit at –35 °C. For the same reason, at (−15 and 5) °C, no reasonable errors for the fit parameters can be given, as the number of data points is the same as the number of free fit parameters.

Table 7. Specific Conductivities of [EMIM][BF_2OX] in AN at Several Temperatures

m / mol·kg^{-1}	κ_T / mS·cm^{-1} (25 °C)	κ_T / mS·cm^{-1} (5 °C)	κ_T / mS·cm^{-1} (−15 °C)	κ_T / mS·cm^{-1} (−35 °C)
3.6	59.63	45.30	31.71	19.51
3.0	59.31	45.10	33.34	21.57
2.4	56.38	44.70	33.27	22.48
1.8	50.80	41.00	31.28	21.92
1.2	42.01	33.45	26.07	18.87
0.6	29.05	22.56	17.25	12.31

Synthesis, analysis, and physical and electrochemical properties of [EMIM][B(OX)$_2$], [TEA][BF_2OX], and [EMIM][BF_2OX] are given elsewhere.[10,11] [TEA][B(OX)$_2$] was synthesized according to the synthesis of [EMIM][B(OX)$_2$].[10,13] [EMIM][BF_4] was synthesized via an established method,[14] and [TEA][BF_4] was used as received from Merck (selectipur grade).

Conductivity measurements have been carried out with an in-house built Wheatstone bridge, with Wagner earth, and a set of U-type cells with platinum electrodes as described elsewhere.[15] Cell constants covering the range from (27 to 89) cm^{-1} were calibrated precisely with standard methods (aqueous KCl solutions).

Resistances of the semichelato-borates [TEA][BF_2OX] and [EMIM][BF_2OX], the chelato-borates [TEA][B(OX)$_2$] and [EMIM][B(OX)$_2$], and the tetrafluoroborates [TEA][BF_4] and [EMIM][BF_4] were measured at frequencies of 3.5 kHz, 5.0 kHz, 6.5 kHz, and 8.0 kHz, respectively, and extrapolated to infinite frequency to get exact values (0.01 % range).

Table 8. Fit Parameters (Casteel−Amis Equation) of [EMIM][BF_2OX] in AN

	25 °C	5 °C	−15 °C	−35 °C
κ_{max}/mS·cm^{-1}	59.77 ± 0.03	46.15 ± 0.12	33.57 ± 0.06	22.56 ± 0.03
μ/mol·kg^{-1}	3.395 ± 0.011	3.044 ± 0.034	2.688 ± 0.012	2.288 ± 0.008
a	0.5483 ± 0.0078	0.6457 ± 0.0496	0.7733 ± 0.0307	0.9109 ± 0.0219
b	−0.0285 ± 0.0012	−0.0314 ± 0.0075	−0.0247 ± 0.0047	−0.0204 ± 0.0034
R^2	1	0.99994	0.99998	0.99999

Table 9. Specific Conductivities of [EMIM][$B(OX)_2$] in AN at Several Temperatures[10]

m / mol·kg^{-1}	κ_T / mS·cm^{-1} (25 °C)	κ_T / mS·cm^{-1} (5 °C)	κ_T / mS·cm^{-1} (−15 °C)	κ_T / mS·cm^{-1} (−35 °C)
2.42	41.35	29.92	19.53	10.84
2.00	41.52	30.71	20.72	12.14
1.40	40.07	30.55	21.55	13.53
1.03	36.27	28.33	20.69	13.70
0.58	27.92	22.37	16.93	11.82
0.30	18.70	15.23	11.80	8.52

Table 10. Fit Parameters (Casteel−Amis Equation) of [EMIM][$B(OX)_2$] in AN[10]

	25 °C	5 °C	−15 °C	−35 °C
κ_{max}/mS·cm^{-1}	41.69 ± 0.12	30.97 ± 0.08	21.53 ± 0.02	13.74 ± 0.02
μ/mol·kg^{-1}	2.050 ± 0.046	1.766 ± 0.014	1.463 ± 0.006	1.163 ± 0.007
a	0.7940 ± 0.0376	0.7993 ± 0.0264	0.8058 ± 0.0126	0.8181 ± 0.0161
b	0.0148 ± 0.0147	0.0200 ± 0.0106	0.0252 ± 0.0052	0.0305 ± 0.0069
R^2	0.99994	0.99997	0.99999	0.99998

Table 11. Specific Conductivities of [EMIM][BF_4] in AN at Several Temperatures

m / mol·kg^{-1}	κ_T / mS·cm^{-1} (25 °C)	κ_T / mS·cm^{-1} (5 °C)	κ_T / mS·cm^{-1} (−15 °C)	κ_T / mS·cm^{-1} (−35 °C)
5.00	66.79	51.67	37.25	24.10
4.00	65.32	51.86	38.71	26.33
3.00	60.75	49.18	37.71	26.64
2.00	51.41	42.48	33.44	24.51
1.00	34.58	29.08	23.42	17.74

Table 12. Fit Parameters (Casteel−Amis Equation) of [EMIM][BF_4] in AN

	25 °C	5 °C	−15 °C	−35 °C
κ_{max}/mS·cm^{-1}	66.80 ± 0.01	52.04 ± 0.03	38.69 ± 0.06	26.82 ± 0.07
μ/mol·kg^{-1}	5.125 ± 0.014	4.417 ± 0.020	3.817 ± 0.017	3.270 ± 0.029
a	0.8026 ± 0.0032	0.7873 ± 0.0137	0.7705 ± 0.0300	0.7409 ± 0.0521
b	0.0004 ± 0.0002	−0.0018 ± 0.0010	−0.0048 ± 0.0022	−0.0096 ± 0.0039
R^2	1	1	0.99999	0.99997

Table 13. Specific Conductivity Maxima, κ_{max}, of [TEA][BF_2OX], [TEA][$B(OX)_2$], [TEA][BF_4], [EMIM][BF_2OX], [EMIM][$B(OX)_2$], and [EMIM][BF_4] in AN (Casteel−Amis)

κ_{max}/mS·cm^{-1}	25 °C	5 °C	−15 °C	−35 °C
([TEA][BF_2OX])	56.98 ± 0.18	44.43 ± 0.15	32.73 ± 0.13	22.29 ± 0.13
([TEA][$B(OX)_2$])	39.13 ± 0.22	29.33 ± 0.07	20.63 ± 0.11	13.27 ± 0.09
([TEA][BF_4])	64.48 ± 0.21	49.95 ± −	37.59 ± −	−
([EMIM][BF_2OX])	59.77 ± 0.03	46.15 ± 0.12	33.57 ± 0.06	22.56 ± 0.03
([EMIM][$B(OX)_2$])	41.69 ± 0.12	30.97 ± 0.08	21.53 ± 0.02	13.74 ± 0.02
([EMIM][BF_4])	66.80 ± 0.01	52.04 ± 0.03	38.69 ± 0.06	26.82 ± 0.07

Temperature was controlled to ± 0.005 K with the help of a thermostat coupled to a cryostat (for details see refs 15 and 16).

The conductivity cells containing ~3 mL of electrolyte solution (with AN as solvent) were filled in the glovebox, closed gastight with glass stopcocks, and then transferred to the thermostatting bath.[15,16]

The thermostat was checked with an F-250 MkII thermometer from Automatic Systems Laboratories (Milton Keynes, UK). The appertaining platinum thermometer was calibrated by WYCO (ROMSAY) according to UKAS with an accuracy of ± 10 mK. The temperature and concentration dependence of conductivity was then measured at (25, 5, −15, and −35) °C. The resistances were converted to specific conductivities κ as a function of molal concentration m and temperature T.

Results and Discussion

Conductivity data were fitted with the help of the empirical Casteel−Amis (CA) equation (eq 1).[17]

$$\kappa = \kappa_{max}\left(\frac{m}{\mu}\right)^{a}\exp\left[b(m-\mu)^2 - \frac{a}{\mu}(m-\mu)\right] \qquad (1)$$

In eq 1, κ_{max} is the conductivity maximum attained at a given temperature and the corresponding molal concentration μ. a and b are empirical fit parameters without physical meaning (for details of the fitting procedure and its limitations, see ref 18). The nonlinear fits were carried out with Microcal Origin.

Experimental specific conductivity data, $\kappa_T = f(m)$, of [TEA][BF_2OX], [TEA][$B(OX)_2$], [TEA][BF_4], [EMIM][BF_2OX], [EMIM][$B(OX)_2$], and [EMIM][BF_4] in AN at several

Table 14. Molality Maxima, μ, of [TEA][BF$_2$OX], [TEA][B(OX)$_2$], [TEA][BF$_4$], [EMIM][BF$_2$OX], [EMIM][B(OX)$_2$], and [EMIM][BF$_4$] in AN (Casteel−Amis)

	μ / mol·kg^{-1} (25 °C)	μ / mol·kg^{-1} (5 °C)	μ / mol·kg^{-1} (−15 °C)	μ / mol·kg^{-1} (−35 °C)
([TEA][BF$_2$OX])	2.811 ± 0.030	2.555 ± 0.024	2.247 ± 0.032	1.889 ± 0.045
([TEA][B(OX)$_2$])	2.018 ± 0.046	1.792 ± 0.010	1.568 ± 0.019	1.365 ± 0.025
([TEA][BF$_4$])	3.211 ± 0.056	2.655 ± −	2.445 ± −	−
([EMIM][BF$_2$OX])	3.395 ± 0.011	3.044 ± 0.034	2.688 ± 0.012	2.288 ± 0.008
([EMIM][B(OX)$_2$])	2.050 ± 0.046	1.766 ± 0.014	1.463 ± 0.006	1.163 ± 0.007
([EMIM][BF$_4$])	5.125 ± 0.014	4.417 ± 0.020	3.817 ± 0.017	3.270 ± 0.029

Table 15. Values for the Walden Analogous Expression, $B = 10^3\eta_0(\kappa_{max}/\mu)$, for [TEA][BF$_2$OX], [TEA][B(OX)$_2$], [TEA][BF$_4$], [EMIM][BF$_2$OX], [EMIM][B(OX)$_2$], and [EMIM][BF$_4$] in AN

θ/°C	B (25 °C)	B (5 °C)	B (−15 °C)	B (−35 °C)
[TEA][BF$_2$OX]	7.040	7.321	7.701	7.154
[TEA][B(OX)$_2$]	6.734	6.891	6.956	5.894
[TEA][BF$_4$]	6.974	7.921	8.128	–
[EMIM][BF$_2$OX]	6.114	6.383	6.603	5.978
[EMIM][B(OX)$_2$]	7.063	7.383	7.781	7.163
[EMIM][BF$_4$]	4.527	4.960	5.359	4.973

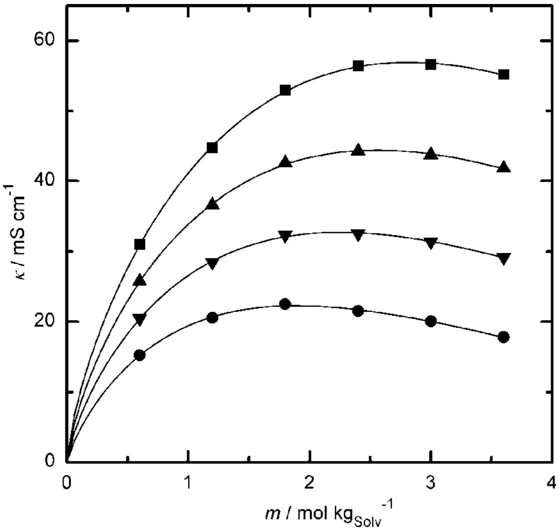

Figure 1. Specific conductivity κ_T vs molality m of [TEA][BF$_2$OX] in AN, $\kappa = f(m)$: ■, 25 °C; ▲, 5 °C; ▼, −15 °C; ●, −35 °C.

molalities, m, and temperatures, T, are listed in Tables 1, 3, 5, 7, 9, and 11. Corresponding fit parameters, the specific conductivity maximum κ_{max}, the molal concentration μ of the electrolyte at κ_{max}, and empirical fit parameters a and b are listed in Tables 2, 4, 6, 8, 10, and 12 together with appertaining standard deviations and R^2. The number of figures given for the parameters κ_{max}, μ, a, and b is needed to obtain a sufficient accordance of measured and calculated values. A fitted plot of κ_T vs molality m is given in Figure 1 as an example to show the quality of the Casteel−Amis fits. A summary of specific conductivity maxima κ_{max} and the according molality maxima of all investigated salts is listed in Tables 13 and 14.

From Tables 13 and 14, it can be seen that in AN the maxima of specific conductivities, κ_{max}, and the corresponding molalities, μ, of the tetraethylammonium salts decrease in the order of [TEA][BF$_4$] > [TEA][BF$_2$OX] > [TEA][B(OX)$_2$]. Thereby, κ_{max} values of [TEA][BF$_2$OX] are more similar to those of [TEA][BF$_4$] than to those of [TEA][B(OX)$_2$]. At −35 °C, due to the limited solubility of [TEA][BF$_4$] at low temperatures, there were not enough data points to fit. [TEA][BF$_2$OX] did not precipitate in any investigated system, in contrast to [TEA][BF$_4$], which already precipitates at 5 °C at a concentration of 3.0 mol·kg^{-1}. The reason for the higher solubility of [TEA][BF$_2$OX] is the low interaction in the crystal lattice between cations and anions resulting in the low melting point of 33 °C, which is mainly caused by the reduced anion symmetry of [BF$_2$OX]$^-$ vs the highly symmetrical [BF$_4$]$^-$ anion. [TEA][B(OX)$_2$] did not precipitate at any investigated temperature and concentration as well, but κ_{max} values of [TEA][B(OX)$_2$] cannot compete with those of [TEA][BF$_4$] and [TEA][BF$_2$OX] (cf. Table 13). The possible reason for this is the larger anion size of [TEA][B(OX)$_2$], which is a limiting factor for the ion mobility in the solution and thereby for its conductivity.[19,20]

It can be summarized that the standard electrolyte, [TEA][BF$_4$], shows the best results for specific conductivities, κ_{max}, at temperatures down to −15 °C. However, for low temperature applications (−35 °C), the specific conductivity maxima of [TEA][BF$_2$OX] are superior to those of [TEA][BF$_4$] due to the better solubility of [TEA][BF$_2$OX].

The maxima of specific conductivities in AN, κ_{max}, and the corresponding molalities, μ, of the 1-ethyl-3-methylimidazolium salts decrease in the order of [EMIM][BF$_4$] > [EMIM][BF$_2$OX] > [EMIM][B(OX)$_2$] at any temperatures. Again, the κ_{max} values of the low symmetric [BF$_2$OX] salt are more similar to those of [EMIM][BF$_4$] than to the [EMIM][B(OX)$_2$] values (cf. Table 13, and [TEA][BF$_2$OX] vs [TEA][BF$_4$] and [TEA][B(OX)$_2$]).

Although, compared to the tetraethylammonium salts the 1-ethyl-3-methylimidazolium salts exhibit slightly higher specific conductivities at any temperatures, the main advantage of the tetraethylammonium salts is their easy availability with a much higher purity grade. Thereby, the tetraethylammonium salts ([TEA][BF$_4$], [TEA][BF$_2$OX], and [TEA][B(OX)$_2$]) can be synthesized by direct synthesis methods, which can exclude any halide impurities,[10,11,13] whereas [EMIM][BF$_4$] and [EMIM][BF$_2$OX] are mostly prepared by metathesis reactions, making halide removal difficult.[21]

The importance of viscosity as a factor of a nonspecific hindrance of transport is illustrated in Table 15. A Walden analogous expression (eq 2), the product of the solvent viscosity η_0 and the mobility function at $m = \mu(\kappa_{max}/\mu)$, is used to show the effect of the solvent viscosity η_0 and its temperature dependence.[19] For η_0 of AN at various temperatures, see ref 22.

$$B = \eta_0(\kappa_{max}/\mu) \qquad (2)$$

B-values of [TEA][BF$_2$OX], [TEA][B(OX)$_2$], [EMIM][BF$_2$OX], [EMIM][B(OX)$_2$], and [EMIM][BF$_4$] electrolyte solutions in AN calculated by eq 2 show roughly constant values approximately in the range 6 to 7. Only [EMIM][BF$_4$] shows a larger deviation; this deviation may be tentatively explained by a stronger ion–ion interaction. In contrast to [TEA] in [TEA][BF$_4$], the charge of the cation [EMIM] is not shielded by alkyl chains. Substitution of fluorine ligands by oxalate as in [EMIM][B(OX)$_2$] reduces this effect completely, whereas partial substitution as in [EMIM][BF$_2$OX] shows an intermediate behavior. The tentative explanation given here will be substantiated by conductivity measurements at low concentrations to determine association constants.

Finally, the ratios $\kappa_{\max}$([EMIM][BF_2OX])/$\kappa_{\max}$([TEA][BF_2OX]) (1.03 ± 0.02) and $\kappa_{\max}$([EMIM][$B(OX)_2$])/$\kappa_{\max}$([TEA][$B(OX)_2$]) (1.04 ± 0.02) are found to be constant, independent from temperature, and are equal. The ratio $\kappa_{\max}$([EMIM][BF_4])/$\kappa_{\max}$([TEA][BF_4]) is also approximately constant at temperatures between (25 and −15) °C (1.04 ± 0.01).

Conclusion

To summarize, conductivities of some new ionic liquids with a semichelato-borate anion, tetraethylammonium difluoromono[1,2-oxalato(2-)-O,O′]borate, and 1-ethyl-3-methylimidazolium difluoromono[1,2-oxalato(2-)-O,O′]borate were measured in the temperature range (–35 to +25) °C in steps of 20 °C. The obtained specific conductivity maxima are compared with those of the according chelato-borates, the tetraethylammonium bis[1,2-oxalato(2-)-O,O′]borate, and the new 1-ethyl-3-methylimidazolium bis[1,2-oxalato(2-)-O,O′]borate and the well-known tetrafluoroborates, tetraethylammonium tetrafluoroborate and 1-ethyl-3-methylimidazolium tetrafluoroborate. The maxima of specific conductivities, $\kappa_{\max}$, and the according molalities, μ, of the 1-ethyl-3-methylimidazolium salts decrease in the order [EMIM][BF_4] > [EMIM][BF_2OX] > [EMIM][$B(OX)_2$] at any temperatures in AN as expected. A comparison of specific conductivity maxima of the pure tetraethylammonium borates, [TEA][BF_2OX], [TEA][$B(OX)_2$], and [TEA][BF_4], in AN shows that the specific conductivities of up to 64.48 $mS \cdot cm^{-1}$ at 25 °C decrease in the sequence: [TEA][BF_4] > [TEA][BF_2OX] > [TEA][$B(OX)_2$] at temperatures down to −15 °C.

Due to its better solubility, [TEA][BF_2OX] may be useful as an alternative electrolyte for low temperature applications in electrochemical energy storage devices such as in double-layer capacitors.

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