

Statistical refinement and fitting of experimental viscosity-to-temperature data in ionic liquids

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Supporting Information

References of Table 1

1. Kuang, Q.; Zhang, J.; Wang, Z., Revealing long-range density fluctuations in dialkylimidazolium chloride ionic liquids by dynamic light scattering. *The journal of physical chemistry. B* 2007, 111, (33), 9858-9863.
2. Zhang, H.; Wu, J.; Zhang, J.; He, J. S., 1-Allyl-3-methylimidazolium chloride room temperature ionic liquid: A new and powerful nonderivatizing solvent for cellulose. *Macromolecules* 2005, 38, (20), 8272-8277.
3. Whitehead, J. A.; Lawrance, G. A.; McCluskey, A., Analysis of gold in solutions containing ionic liquids by inductively coupled plasma atomic emission spectrometry. *Australian Journal of Chemistry* 2004, 57, (2), 151-155.
4. Gomez, E.; Gonzalez, B.; Dominguez, A.; Tojo, E.; Tojo, J., Dynamic viscosities of a series of 1-alkyl-3-methylimidazolium chloride ionic liquids and their binary mixtures with water at several temperatures. *Journal of Chemical and Engineering Data* 2006, 51, (2), 696-701.
5. Huddleston, J. G.; Visser, A. E.; Reichert, W. M.; Willauer, H. D.; Broker, G. A.; Rogers, R. D., Characterization and comparison of hydrophilic and hydrophobic

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room temperature ionic liquids incorporating the imidazolium cation. *Green Chemistry* 2001, 3, (4), 156-164.

6. Arzhantsev, S.; Jin, H.; Baker, G. A.; Maroncelli, M., Measurements of the complete solvation response in ionic liquids. *Journal of Physical Chemistry B* 2007, 111, (18), 4978-4989.
7. Deive, F. J.; Rivas, M. A.; Rodríguez, A., Thermophysical properties of two ionic liquids based on benzyl imidazolium cation. *Journal of Chemical Thermodynamics* 2011, 43, (3), 487-491.
8. Branco, L. C.; Rosa, J. N.; Ramos, J. J. M.; Afonso, C. A. M., Preparation and characterization of new room temperature ionic liquids. *Chemistry-a European Journal* 2002, 8, (16), 3671-3677.
9. Deive, F. J.; Rivas, M. A.; Rodríguez, A., Study of thermodynamic and transport properties of phosphonium-based ionic liquids. *The Journal of Chemical Thermodynamics* 2013, 62, (0), 98-103.
10. Ferguson, L.; Scovazzo, P., Solubility, diffusivity, and permeability of gases in phosphonium-based room temperature ionic liquids: Data and correlations. *Industrial & Engineering Chemistry Research* 2007, 46, (4), 1369-1374.
11. Fraser, K. J.; Izgorodina, E. I.; Forsyth, M.; Scott, J. L.; MacFarlane, D. R., Liquids intermediate between "molecular" and "ionic" liquids: Liquid Ion Pairs? *Chemical Communications* 2007, (37), 3817-3819.
12. Bradaric, C. J.; Downard, A.; Kennedy, C.; Robertson, A. J.; Zhou, Y. H., Industrial preparation of phosphonium ionic liquids. *Green Chemistry* 2003, 5, (2), 143-152.
13. Gorlov, M.; Kloo, L., Ionic liquid electrolytes for dye-sensitized solar cells. *Dalton Transactions* 2008, (20), 2655-2666.
14. Wachter, P.; Zistler, M.; Schreiner, C.; Fleischmann, M.; Gerhard, D.; Wasserscheid, P.; Barthel, J.; Gores, H. J., Temperature Dependence of the Non-Stokesian Charge Transport in Binary Blends of Ionic Liquids. *Journal of Chemical and Engineering Data* 2009, 54, (2), 491-497.
15. Mikoshiba, S.; Murai, S.; Sumino, H.; Kado, T.; Kosugi, D.; Hayase, S., Ionic liquid type dye-sensitized solar cells: increases in photovoltaic performances by adding a small amount of water. *Current Applied Physics* 2005, 5, (2), 152-158.
16. Zafer, C.; Ocakoglu, K.; Ozsoy, C.; Icli, S., Dicationic bis-imidazolium molten salts for efficient dye sensitized solar cells: Synthesis and photovoltaic properties. *Electrochimica Acta* 2009, 54, (24), 5709-5714.
17. Abbott, A. P.; McKenzie, K. J., Application of ionic liquids to the electrodeposition of metals. *Physical Chemistry Chemical Physics* 2006, 8, (37), 4265-4279.

18. Fletcher, S. I.; Sillars, F. B.; Hudson, N. E.; Hall, P. J., Physical Properties of Selected Ionic Liquids for Use as Electrolytes and Other Industrial Applications. *Journal of Chemical and Engineering Data* 2010, 55, (2), 778-782.
19. McEwen, A. B.; Ngo, H. L.; LeCompte, K.; Goldman, J. L., Electrochemical properties of imidazolium salt electrolytes for electrochemical capacitor applications. *Journal of the Electrochemical Society* 1999, 146, (5), 1687-1695.
20. Nishida, T.; Tashiro, Y.; Yamamoto, M., Physical and electrochemical properties of 1-alkyl-3-methylimidazolium tetrafluoroborate for electrolyte. *Journal of Fluorine Chemistry* 2003, 120, (2), 135-141.
21. Sanmamed, Y. A.; Gonzalez-Salgado, D.; Troncoso, J.; Romani, L.; Baylaucq, A.; Boned, C., Experimental methodology for precise determination of density of RTILs as a function of temperature and pressure using vibrating tube densimeters. *Journal of Chemical Thermodynamics* 2010, 42, (4), 553-563.
22. Seddon, K. R.; Stark, A.; Torres, M. J., Influence of chloride, water, and organic solvents on the physical properties of ionic liquids. *Pure and Applied Chemistry* 2000, 72, (12), 2275-2287.
23. Stepniak, I.; Andrzejewska, E., Highly conductive ionic liquid based ternary polymer electrolytes obtained by in situ photopolymerisation. *Electrochimica Acta* 2009, 54, (24), 5660-5665.
24. Van Valkenburg, M. E.; Vaughn, R. L.; Williams, M.; Wilkes, J. S., Thermochemistry of ionic liquid heat-transfer fluids. *Thermochimica Acta* 2005, 425, (1-2), 181-188.
25. Zhou, Z. B.; Matsumoto, H.; Tatsumi, K., Structure and properties of new ionic liquids based on alkyl- and alkenyltrifluoroborates. *Chemphyschem* 2005, 6, (7), 1324-1332.
26. Sato, T.; Masuda, G.; Takagi, K., Electrochemical properties of novel ionic liquids for electric double layer capacitor applications (vol 49, pg 3603, 2004). *Electrochimica Acta* 2008, 53, (14), 4934-4935.
27. Zafarani-Moattar, M. T.; Majdan-Cegincara, R., Viscosity, density, speed of sound, and refractive index of binary mixtures of organic solvent plus ionic liquid, 1-butyl-3-methylimidazolium hexafluorophosphate at 298.15 K. *Journal of Chemical and Engineering Data* 2007, 52, (6), 2359-2364.
28. Fukuda, M.; Kajimoto, O.; Terazima, M.; Kimura, Y., Application of the transient grating method to the investigation of the photo-thermalization process of malachite green in room temperature ionic liquids. *Journal of Molecular Liquids* 2007, 134, (1-3), 49-54.
29. Harris, K. R.; Kanakubo, M.; Woolf, L. A., Temperature and pressure dependence of the viscosity of the ionic liquid 1-butyl-3-methylimidazolium tetrafluoroborate: Viscosity and density relationships in ionic liquids. *Journal of Chemical and Engineering Data* 2007, 52, (6), 2425-2430.

30. Jin, H.; O'Hare, B.; Dong, J.; Arzhantsev, S.; Baker, G. A.; Wishart, J. F.; Benesi, A. J.; Maroncelli, M., Physical properties of ionic liquids consisting of the 1-butyl-3-methylimidazolium cation with various anions and the bis(trifluoromethylsulfonyl)imide anion with various cations. *Journal of Physical Chemistry B* 2008, 112, (1), 81-92.
31. Liu, W. W.; Zhao, T. Y.; Zhang, Y. M.; Wang, H. P.; Yu, M. F., The physical properties of aqueous solutions of the ionic liquid BMIM BF₄. *Journal of Solution Chemistry* 2006, 35, (10), 1337-1346.
32. Meredith, M. B.; McMillen, C. H.; Goodman, J. T.; Hanusa, T. P., Ambient temperature imidazolium-based ionic liquids with tetrachloronickelate(II) anions. *Polyhedron* 2009, 28, (12), 2355-2358.
33. Okoturo, O. O.; VanderNoot, T. J., Temperature dependence of viscosity for room temperature ionic liquids. *Journal of Electroanalytical Chemistry* 2004, 568, (1-2), 167-181.
34. Ries, L. A. S.; do Amaral, F. A.; Matos, K.; Martini, E. M. A.; de Souza, M. O.; de Souza, R. F., Evidence of change in the molecular organization of 1-n-butyl-3-methylimidazolium tetrafluoroborate ionic liquid solutions with the addition of water. *Polyhedron* 2008, 27, (15), 3287-3293.
35. Sanmamed, Y. A.; Gonzalez-Salgado, D.; Troncoso, J.; Cerdeirina, C. A.; Romani, L., Viscosity-induced errors in the density determination of room temperature ionic liquids using vibrating tube densitometry. *Fluid Phase Equilibria* 2007, 252, (1-2), 96-102.
36. Suarez, P. A. Z.; Einloft, S.; Dullius, J. E. L.; de Souza, R. F.; Dupont, J., Synthesis and physical-chemical properties of ionic liquids based on 1-n-butyl-3-methylimidazolium cation. *Journal De Chimie Physique Et De Physico-Chimie Biologique* 1998, 95, (7), 1626-1639.
37. Tomida, D.; Kumagai, A.; Qiao, K.; Yokoyama, C., Viscosity of bmim PF₆ and bmim BF₄ at high pressure. *International Journal of Thermophysics* 2006, 27, (1), 39-47.
38. Wu, B. Q.; Reddy, R. G.; Rogers, R. D. In *Proceedings of Solar Forum, Solar Energy: The Power to Choose*, Washington, DC, 2001; Washington, DC, 2001.
39. Olivier-Bourbigou, H.; Magna, L., Ionic liquids: perspectives for organic and catalytic reactions. *Journal of Molecular Catalysis a-Chemical* 2002, 182, (1), 419-437.
40. Ue, M.; Takeda, M.; Toriumi, A.; Kominato, A.; Hagiwara, R.; Ito, Y., Application of low-viscosity ionic liquid to the electrolyte of double-layer capacitors. *Journal of the Electrochemical Society* 2003, 150, (4), A499-A502.
41. Silvester, D. S.; Ward, K. R.; Aldous, L.; Hardacre, C.; Compton, R. G., The electrochemical oxidation of hydrogen at activated platinum electrodes in room

temperature ionic liquids as solvents. *Journal of Electroanalytical Chemistry* 2008, 618, (1-2), 53-60.

42. Sanchez, L. G.; Espel, J. R.; Onink, F.; Meindersma, G. W.; de Haan, A. B., Density, Viscosity, and Surface Tension of Synthesis Grade Imidazolium, Pyridinium, and Pyrrolidinium Based Room Temperature Ionic Liquids. *Journal of Chemical and Engineering Data* 2009, 54, (10), 2803-2812.
43. Malham, I. B.; Turmine, M., Viscosities and refractive indices of binary mixtures of 1-butyl-3-methylimidazolium tetrafluoroborate and 1-butyl-2,3-dimethylimidazolium tetrafluoroborate with water at 298 K. *Journal of Chemical Thermodynamics* 2008, 40, (4), 718-723.
44. Hardacre, C.; Holbrey, J. D.; Katdare, S. P.; Seddon, K. R., Alternating copolymerisation of styrene and carbon monoxide in ionic liquids. *Green Chemistry* 2002, 4, (2), 143-146.
45. Ignat'ev, N. V.; Welz-Biermann, U.; Kucheryna, A.; Bissky, G.; Willner, H., New ionic liquids with tris(perfluoroalkyl)trifluorophosphate (FAP) anions. *Journal of Fluorine Chemistry* 2005, 126, (8), 1150-1159.
46. Muhammad, A.; Mutalib, M. I. A.; Wilfred, C. D.; Murugesan, T.; Shafeeq, A., Thermophysical properties of 1-hexyl-3-methyl imidazolium based ionic liquids with tetrafluoroborate, hexafluorophosphate and bis(trifluoromethylsulfonyl)imide anions. *Journal of Chemical Thermodynamics* 2008, 40, (9), 1433-1438.
47. Zhou, Z. B.; Matsumoto, H.; Tatsumi, K., Low-melting, low-viscous, hydrophobic ionic liquids: 1-alkyl(alkyl ether)-3-methylimidazolium perfluoroalkyl-trifluoroborate. *Chemistry-a European Journal* 2004, 10, (24), 6581-6591.
48. Harris, K. R.; Kanakubo, M.; Woolf, L. A., Temperature and pressure dependence of the viscosity of the ionic liquids 1-methyl-3-octylimidazolium hexafluorophosphate and 1-methyl-3-octylimidazolium tetrafluoroborate. *Journal of Chemical and Engineering Data* 2006, 51, (3), 1161-1167.
49. Ciocirlan, O.; Iulian, O., Properties of Pure 1-Butyl-2,3-dimethylimidazolium Tetrafluoroborate Ionic Liquid and Its Binary Mixtures with Dimethyl Sulfoxide and Acetonitrile. *Journal of Chemical & Engineering Data* 2012, 57, (11), 3142-3148.
50. Mokhtarani, B.; Sharifi, A.; Mortaheb, H. R.; Mirzaei, M.; Mafi, M.; Sadeghian, F., Density and viscosity of pyridinium-based ionic liquids and their binary mixtures with water at several temperatures. *Journal of Chemical Thermodynamics* 2009, 41, (3), 323-329.
51. Khupse, N. D.; Kumar, A., Dramatic Change in Viscosities of Pure Ionic Liquids upon Addition of Molecular Solvents. *Journal of Solution Chemistry* 2009, 38, (5), 589-600.

52. Bandrés, I.; Alcalde, R.; Lafuente, C.; Atilhan, M.; Aparicio, S., On the Viscosity of Pyridinium Based Ionic Liquids: An Experimental and Computational Study. *The Journal of Physical Chemistry B* 2011, 115, (43), 12499-12513.
53. Bandres, I.; Pera, G.; Martin, S.; Castro, M.; Lafuente, C., Thermophysical Study of 1-Butyl-2-Methylpyridinium Tetrafluoroborate Ionic Liquid. *Journal of Physical Chemistry B* 2009, 113, (35), 11936-11942.
54. Crosthwaite, J. M.; Muldoon, M. J.; Dixon, J. K.; Anderson, J. L.; Brennecke, J. F., Phase transition and decomposition temperatures, heat capacities and viscosities of pyridinium ionic liquids. *Journal of Chemical Thermodynamics* 2005, 37, (6), 559-568.
55. Gardas, R. L.; Coutinho, J. A. P., A group contribution method for viscosity estimation of ionic liquids. *Fluid Phase Equilibria* 2008, 266, (1-2), 195-201.
56. Gonzalez, B.; Calvar, N.; Gomez, E.; Macedo, E. A.; Dominguez, A., Synthesis and physical properties of 1-ethyl 3-methylpyridinium ethylsulfate and its binary mixtures with ethanol and water at several temperatures. *Journal of Chemical and Engineering Data* 2008, 53, (8), 1824-1828.
57. Bandres, I.; Giner, B.; Artigas, H.; Lafuente, C.; Royo, F. M., Thermophysical Properties of N-Octyl-3-methylpyridinium Tetrafluoroborate. *Journal of Chemical and Engineering Data* 2009, 54, (2), 236-240.
58. Domanska, U.; Laskowska, M., Temperature and Composition Dependence of the Density and Viscosity of Binary Mixtures of {1-Butyl-3-methylimidazolium Thiocyanate+1-Alcohols}. *Journal of Chemical and Engineering Data* 2009, 54, (7), 2113-2119.
59. Domanska, U.; Laskowska, M., Effect of Temperature and Composition on the Density and Viscosity of Binary Mixtures of Ionic Liquid with Alcohols. *Journal of Solution Chemistry* 2009, 38, (6), 779-799.
60. Deng, M. J.; Chen, P. Y.; Leong, T. I.; Sun, I. W.; Chang, J. K.; Tsai, W. T., Dicyanamide anion based ionic liquids for electrodeposition of metals. *Electrochemistry Communications* 2008, 10, (2), 213-216.
61. Froba, A. P.; Kremer, H.; Leipertz, A., Density, refractive index, interfacial tension, and viscosity of ionic liquids EMIM EtSO₄, EMIM NTf₂, EMIM N(CN)₂, and OMA NTf₂ in dependence on temperature at atmospheric pressure. *Journal of Physical Chemistry B* 2008, 112, (39), 12420-12430.
62. Leong, T. I.; Sun, I. W.; Deng, M. J.; Wu, C. M.; Chen, P. Y., Electrochemical study of copper in the 1-ethyl-3-methylimidazolium dicyanamide room temperature ionic liquid. *Journal of the Electrochemical Society* 2008, 155, (4), F55-F60.
63. Yoshida, Y.; Baba, O.; Saito, G., Ionic liquids based on dicyanamide anion: Influence of structural variations in cationic structures on ionic conductivity. *Journal of Physical Chemistry B* 2007, 111, (18), 4742-4749.

64. Yoshida, Y.; Fujii, J.; Muroi, K.; Otsuka, A.; Saito, G.; Takahashi, M.; Yoko, T., Highly conducting ionic liquids based on 1-ethyl-3-methylimidazolium cation. *Synthetic Metals* 2005, 153, (1-3), 421-424.
65. Yoshida, Y.; Muroi, K.; Otsuka, A.; Saito, G.; Takahashi, M.; Yoko, T., 1-ethyl-3-methylimidazolium based ionic liquids containing cyano groups: Synthesis, characterization, and crystal structure. *Inorganic Chemistry* 2004, 43, (4), 1458-1462.
66. McHale, G.; Hardacre, C.; Ge, R.; Doy, N.; Allen, R. W. K.; MacInnes, J. M.; Bown, M. R.; Newton, M. I., Density-viscosity product of small-volume ionic liquid samples using quartz crystal impedance analysis. *Analytical Chemistry* 2008, 80, (15), 5806-5811.
67. Yoshida, Y.; Baba, O.; Larriba, C.; Saito, G., Imidazolium-based ionic liquids formed with dicyanamide anion: Influence of cationic structure on ionic conductivity. *Journal of Physical Chemistry B* 2007, 111, (42), 12204-12210.
68. Bandres, I.; Giner, B.; Gascon, I.; Castro, M.; Lafuente, C., Physicochemical characterization of n-butyl-3-methylpyridinium dicyanamide ionic liquid. *Journal of Physical Chemistry B* 2008, 112, (39), 12461-12467.
69. MacFarlane, D. R.; Golding, J.; Forsyth, S.; Forsyth, M.; Deacon, G. B., Low viscosity ionic liquids based on organic salts of the dicyanamide anion. *Chemical Communications* 2001, (16), 1430-1431.
70. González, E. J.; González, B.; Macedo, E. A., Thermophysical Properties of the Pure Ionic Liquid 1-Butyl-1-methylpyrrolidinium Dicyanamide and Its Binary Mixtures with Alcohols. *Journal of Chemical & Engineering Data* 2013, 58, (6), 1440-1448.
71. Gerhard, D.; Alpaslan, S. C.; Gores, H. J.; Uerdingen, M.; Wasserscheid, P., Trialkylsulfonium dicyanamides - a new family of ionic liquids with very low viscosities. *Chemical Communications* 2005, (40), 5080-5082.
72. Matsumoto, H.; Matsuda, T.; Miyazaki, Y., Room temperature molten salts based on trialkylsulfonium cations and bis(trifluoromethylsulfonyl)imide. *Chemistry Letters* 2000, (12), 1430-1431.
73. Del Sesto, R. E.; Corley, C.; Robertson, A.; Wilkes, J. S., Tetraalkylphosphonium-based ionic liquids. *Journal of Organometallic Chemistry* 2005, 690, (10), 2536-2542.
74. Ito, N.; Arzhantsev, S.; Heitz, M.; Maroncelli, M., Solvation dynamics and rotation of coumarin 153 in alkylphosphonium ionic liquids. *Journal of Physical Chemistry B* 2004, 108, (18), 5771-5777.
75. Pereiro, A. B.; Veiga, H. I. M.; Esperanca, J.; Rodriguez, A., Effect of temperature on the physical properties of two ionic liquids. *Journal of Chemical Thermodynamics* 2009, 41, (12), 1419-1423.

76. Dai, Q.; Menzies, D. B.; MacFarlane, D. R.; Batten, S. R.; Forsyth, S.; Spiccia, L.; Cheng, Y. B.; Forsyth, M., Dye-sensitized nanocrystalline solar cells incorporating ethylmethylimidazolium-based ionic liquid electrolytes. *Comptes Rendus Chimie* 2006, 9, (5-6), 617-621.
77. Neves, C. M. S. S.; Kurnia, K. A.; Coutinho, J. A. P.; Marrucho, I. M.; Canongia Lopes, J. N.; Freire, M. G.; Rebelo, L. P. N., Systematic Study of the Thermophysical Properties of Imidazolium-Based Ionic Liquids with Cyano-Functionalized Anions. *Journal of Physical Chemistry B* 2013, 117, (35), 10271-10283.
78. Carvalho, P. J.; Regueira, T.; Santos, L.; Fernandez, J.; Coutinho, J. A. P., Effect of Water on the Viscosities and Densities of 1-Butyl-3-methylimidazolium Dicyanamide and 1-Butyl-3-methylimidazolium Tricyanomethane at Atmospheric Pressure. *Journal of Chemical and Engineering Data* 2010, 55, (2), 645-652.
79. Biso, M.; Mastragostino, M.; Montanino, M.; Passerini, S.; Soavia, F., Electropolymerization of poly(3-methylthiophene) in pyrrolidinium-based ionic liquids for hybrid supercapacitors. *Electrochimica Acta* 2008, 53, (27), 7967-7971.
80. Guerfi, A.; Duchesne, S.; Kobayashi, Y.; Vijh, A.; Zaghib, K., LiFePO₄ and graphite electrodes with ionic liquids based on bis(fluorosulfonyl)imide (FSI)(-) for Li-ion batteries. *Journal of Power Sources* 2008, 175, (2), 866-873.
81. Ishikawa, M.; Sugimoto, T.; Kikuta, M.; Ishiko, E.; Kono, M., Pure ionic liquid electrolytes compatible with a graphitized carbon negative electrode in rechargeable lithium-ion batteries. *Journal of Power Sources* 2006, 162, (1), 658-662.
82. Matsumoto, H.; Sakaebe, H.; Tatsumi, K.; Kikuta, M.; Ishiko, E.; Kono, M., Fast cycling of Li/LiCoO₂ cell with low-viscosity ionic liquids based on bis(fluorosulfonyl)imide FSI (-). *Journal of Power Sources* 2006, 160, (2), 1308-1313.
83. Zhou, Q.; Henderson, W. A.; Appetecchi, G. B.; Montanino, M.; Passerini, S., Physical and Electrochemical Properties of N-Alkyl-N-methylpyrrolidinium Bis(fluorosulfonyl)imide Ionic Liquids: PY13FSI and PY14FSI. *Journal of Physical Chemistry B* 2008, 112, (43), 13577-13580.
84. Bonhote, P.; Dias, A. P.; Papageorgiou, N.; Kalyanasundaram, K.; Gratzel, M., Hydrophobic, highly conductive ambient-temperature molten salts. *Inorganic Chemistry* 1996, 35, (5), 1168-1178.
85. Camper, D.; Becker, C.; Koval, C.; Noble, R., Diffusion and solubility measurements in room temperature ionic liquids. *Industrial & Engineering Chemistry Research* 2006, 45, (1), 445-450.
86. Evans, R. G.; Klymenko, O. V.; Hardacre, C.; Seddon, K. R.; Compton, R. G., Oxidation of N,N,N',N'-tetraalkyl-para-phenylenediamines in a series of room

temperature ionic liquids incorporating the bis(trifluoromethylsulfonyl)imide anion. *Journal of Electroanalytical Chemistry* 2003, 556, 179-188.

87. Francois, Y.; Zhang, K.; Varenne, A.; Gareil, P., New integrated measurement protocol using capillary electrophoresis instrumentation for the determination of viscosity, conductivity and absorbance of ionic liquid-molecular solvent mixtures. *Analytica Chimica Acta* 2006, 562, (2), 164-170.
88. Koeddermann, T.; Ludwig, R.; Paschek, D., On the validity of Stokes-Einstein and Stokes-Einstein-Debye relations in ionic liquids and ionic-liquid mixtures. *Chemphyschem* 2008, 9, (13), 1851-1858.
89. Pringle, J. M.; Golding, J.; Baranyai, K.; Forsyth, C. M.; Deacon, G. B.; Scott, J. L.; MacFarlane, D. R., The effect of anion fluorination in ionic liquids - physical properties of a range of bis(methanesulfonyl)amide salts. *New Journal of Chemistry* 2003, 27, (10), 1504-1510.
90. Torriero, A. A. J.; Siriwardana, A. I.; Bond, A. M.; Bugar, I. M.; Dunlop, N. F.; Deacon, G. B.; MacFarlane, D. R., Physical and Electrochemical Properties of Thioether-Functionalized Ionic Liquids. *Journal of Physical Chemistry B* 2009, 113, (32), 11222-11231.
91. Bini, R.; Malvaldi, M.; Pitner, W. R.; Chiappe, C., QSPR correlation for conductivities and viscosities of low-temperature melting ionic liquids. *Journal of Physical Organic Chemistry* 2008, 21, (7-8), 622-629.
92. Gan, Q.; Rooney, D.; Xue, M. L.; Thompson, G.; Zou, Y. R., An experimental study of gas transport and separation properties of ionic liquids supported on nanofiltration membranes. *Journal of Membrane Science* 2006, 280, (1-2), 948-956.
93. Osada, R.; Hoshino, T.; Okada, K.; Ohmasa, Y.; Yao, M., Surface tension of room temperature ionic liquids measured by dynamic light scattering. *Journal of Chemical Physics* 2009, 130, (18), 8.
94. Kandil, M. E.; Marsh, K. N.; Goodwin, A. R. H., Measurement of the viscosity, density, and electrical conductivity of 1-hexyl-3-methylimidazolium bis(trifluorosulfonyl)imide at temperatures between (288 and 433) K and pressures below 50 MPa. *Journal of Chemical and Engineering Data* 2007, 52, (6), 2382-2387.
95. Le, M. L. P.; Alloin, F.; Strobel, P.; Lepretre, J. C.; del Valle, C. P.; Judeinstein, P., Structure-Properties Relationships of Lithium Electrolytes Based on Ionic Liquid. *Journal of Physical Chemistry B* 2010, 114, (2), 894-903.
96. Marsh, K. N.; Brennecke, J. F.; Chirico, R. D.; Frenkel, M.; Heintz, A.; Magee, J. W.; Peters, C. J.; Rebelo, L. P. N.; Seddon, K. R., Thermodynamic and thermophysical properties of the reference ionic liquid: 1-hexyl-3-methylimidazolium bis(trifluoromethyl)sulfonyl amide (including mixtures) Part

1. Experimental Methods and Results (IUPAC Technical Report). Pure and Applied Chemistry 2009, 81, (5), 781-790.
97. Widegren, J. A.; Magee, J. W., Density, viscosity, speed of sound, and electrolytic conductivity for the ionic liquid 1-hexyl-3-methylimidazolium bis(trifluoromethylsulfonyl)imide and its mixtures with water. Journal of Chemical and Engineering Data 2007, 52, (6), 2331-2338.
98. Gan, Q.; Xue, M. L.; Rooney, D., A study of fluid properties and microfiltration characteristics of room temperature ionic liquids C-10-min NTf2 and N-8881 NTf2 and their polar solvent mixtures. Separation and Purification Technology 2006, 51, (2), 185-192.
99. Hardacre, C.; Holbrey, J. D.; Mullan, C. L.; Nieuwenhuyzen, M.; Reichert, W. M.; Seddon, K. R.; Teat, S. J., Ionic liquid characteristics of 1-alkyl-n-cyanopyridinium and 1-alkyl-n-(trifluoromethyl) pyridinium salts. New Journal of Chemistry 2008, 32, (11), 1953-1967.
100. Appetecchi, G. B.; Montanino, M.; Zane, D.; Carewska, M.; Alessandrini, F.; Passerini, S., Effect of the alkyl group on the synthesis and the electrochemical properties of N-alkyl-N-methyl-pyrrolidinium bis(trifluoromethanesulfonyl)imide ionic liquids. Electrochimica Acta 2009, 54, (4), 1325-1332.
101. Kondoh, T.; Asano, A.; Yang, J. F.; Norizawa, K.; Takahashi, K.; Taguchi, M.; Nagaishi, R.; Katoh, R.; Yoshida, Y., Pulse radiolysis study of ion-species effects on the solvated electron in alkylammonium ionic liquids. Radiation Physics and Chemistry 2009, 78, (12), 1157-1160.
102. Sun, J.; MacFarlane, D. R.; Forsyth, M., A new family of ionic liquids based on the 1-alkyl-2-methyl pyrrolinium cation. Electrochimica Acta 2003, 48, (12), 1707-1711.
103. Spohr, H. V.; Patey, G. N., Structural and dynamical properties of ionic liquids: The influence of charge location. Journal of Chemical Physics 2009, 130, (10), 11.
104. Deng, M. J.; Chen, P. Y.; Sun, I. W., Electrochemical study and electrodeposition of manganese in the hydrophobic butylmethylpyrrolidinium bis((trifluoromethyl)sulfonyl) imide room-temperature ionic liquid. Electrochimica Acta 2007, 53, (4), 1931-1938.
105. Shirota, H.; Funston, A. M.; Wishart, J. F.; Castner, E. W., Ultrafast dynamics of pyrrolidinium cation ionic liquids. Journal of Chemical Physics 2005, 122, (18), 12.
106. Funston, A. M.; Fadeeva, T. A.; Wishart, J. F.; Castner, E. W., Fluorescence probing of temperature-dependent dynamics and friction in ionic liquid local environments. Journal of Physical Chemistry B 2007, 111, (18), 4963-4977.

107. Sakaebe, H.; Matsumoto, H., N-Methyl-N-propylpiperidinium bis(trifluoromethanesulfonyl)imide (PP 13-TFSI) - novel electrolyte base for Li battery. *Electrochemistry Communications* 2003, 5, (7), 594-598.
108. Domańska, U.; Zawadzki, M.; Zwolińska, M., Thermophysical properties and phase equilibria study of the binary systems {N-hexylquinolinium bis(trifluoromethylsulfonyl)imide + aromatic hydrocarbons, or an alcohol}. *The Journal of Chemical Thermodynamics* 2011, 43, (5), 775-781.
109. Domańska, U.; Zawadzki, M., Thermodynamic properties of the N-butylisoquinolinium bis(trifluoromethylsulfonyl)imide. *The Journal of Chemical Thermodynamics* 2011, 43, (6), 989-995.
110. Domanska, U.; Zawadzki, M.; Tshibangu, M. M.; Ramjugernath, D.; Letcher, T. M., Phase Equilibria Study of {N-Hexylisoquinolinium bis{(trifluoromethyl)sulfonyl}imide plus Aromatic Hydrocarbons or an Alcohol} Binary Systems. *Journal of Physical Chemistry B* 2011, 115, (14), 4003-4010.
111. Matsumoto, H.; Sakaebe, H.; Tatsumi, K., Preparation of room temperature ionic liquids based on aliphatic onium cations and asymmetric amide anions and their electrochemical properties as a lithium battery electrolyte. *Journal of Power Sources* 2005, 146, (1-2), 45-50.
112. Pramanik, R.; Rao, V. G.; Sarkar, S.; Ghatak, C.; Setua, P.; Sarkar, N., To Probe the Interaction of Methanol and Acetonitrile with the Ionic Liquid N,N,N-Trimethyl-N-propyl Ammonium Bis(trifluoromethanesulfonyl) Imide at Different Temperatures by Solvation Dynamics Study. *Journal of Physical Chemistry B* 2009, 113, (25), 8626-8634.
113. Matsumoto, H.; Yanagida, M.; Tanimoto, K.; Nomura, M.; Kitagawa, Y.; Miyazaki, Y., Highly conductive room temperature molten salts based on small trimethylalkylammonium cations and bis(trifluoromethylsulfonyl)imide. *Chemistry Letters* 2000, (8), 922-923.
114. Kilaru, P. K.; Scovazzo, P., Correlations of low-pressure carbon dioxide and hydrocarbon solubilities in imidazolium-, phosphonium-, and ammonium-based room-temperature ionic liquids. Part 2. using activation energy of viscosity. *Industrial & Engineering Chemistry Research* 2008, 47, (3), 910-919.
115. Kanatani, T.; Matsumoto, K.; Hagiwara, R., Syntheses and Physicochemical Properties of Low-Melting Salts Based on VOF₄- and MoOF₅-, and the Molecular Geometries of the Dimeric (VOF₄)₂ and Mo₂O₄F₆²⁻ Anions. *European Journal of Inorganic Chemistry* 2010, (7), 1049-1055.
116. Taggougui, M.; Diaw, M.; Carre, B.; Willmann, P.; Lemordant, D., Solvents in salt electrolyte: Benefits and possible use as electrolyte for lithium-ion battery. *Electrochimica Acta* 2008, 53, (17), 5496-5502.

117. Chen, P. Y.; Hussey, C. L., Electrodeposition of cesium at mercury electrodes in the tri-1-butylmethylammonium bis((trifluoromethyl)sulfonyl)imide room-temperature ionic liquid. *Electrochimica Acta* 2004, 49, (28), 5125-5138.
118. Sun, J.; Forsyth, M.; MacFarlane, D. R., Room-temperature molten salts based on the quaternary ammonium ion. *Journal of Physical Chemistry B* 1998, 102, (44), 8858-8864.
119. Vega, J. A.; Zhou, J. F.; Kohl, P. A., Electrochemical Comparison and Deposition of Lithium and Potassium from Phosphonium- and Ammonium-TFSI Ionic Liquids. *Journal of the Electrochemical Society* 2009, 156, (4), A253-A259.
120. Kulkarni, P. S.; Branco, L. C.; Crespo, J. G.; Nunes, M. C.; Raymundo, A.; Afonso, C. A. M., Comparison of physicochemical properties of new ionic liquids based on imidazolium, quaternary ammonium, and guanidinium cations. *Chemistry-a European Journal* 2007, 13, (30), 8478-8488.
121. Liu, X. M.; Zhou, G. H.; Zhang, S. J.; Yu, G. R., Molecular simulations of phosphonium-based ionic liquid. *Molecular Simulation* 2010, 36, (1), 79-86.
122. Ohno, H.; Fukumoto, K., Amino Acid Ionic Liquids. *Accounts of Chemical Research* 2007, 40, (11), 1122-1129.
123. Mateus, N. M. M.; Branco, L. C.; Lourenco, N. M. T.; Afonso, C. A. M., Synthesis and properties of tetra-alkyl-dimethylguanidinium salts as a potential new generation of ionic liquids. *Green Chemistry* 2003, 5, (3), 347-352.
124. Pereiro, A. B.; Santamarta, F.; Tojo, E.; Rodriguez, A.; Tojo, J., Temperature dependence of physical properties of ionic liquid 1,3-dimethylimidazolium methyl sulfate. *Journal of Chemical and Engineering Data* 2006, 51, (3), 952-954.
125. Pereiro, A. B.; Verdia, P.; Tojo, E.; Rodriguez, A., Physical properties of 1-butyl-3-methylimidazolium methyl sulfate as a function of temperature. *Journal of Chemical and Engineering Data* 2007, 52, (2), 377-380.
126. Arce, A.; Rodil, E.; Soto, A., Volumetric and viscosity study for the mixtures of 2-ethoxy-2-methylpropane, ethanol, and 1-ethyl-3-methylimidazolium ethyl sulfate ionic liquid. *Journal of Chemical and Engineering Data* 2006, 51, (4), 1453-1457.
127. Altin, E.; Gradl, J.; Peukert, W., First studies on the rheological behavior of suspensions in ionic liquids. *Chemical Engineering & Technology* 2006, 29, (11), 1347-1354.
128. Gonzalez, B.; Calvar, N.; Gomez, E.; Dominguez, I.; Dominguez, A., Synthesis and Physical Properties of 1-Ethylpyridinium Ethylsulfate and its Binary Mixtures with Ethanol and 1-Propanol at Several Temperatures. *Journal of Chemical and Engineering Data* 2009, 54, (4), 1353-1358.
129. Bandres, I.; Royo, F. M.; Gascon, I.; Castro, M.; Lafuente, C., Anion Influence on Thermophysical Properties of Ionic Liquids: 1-Butylpyridinium Tetrafluoroborate

and 1-Butylpyridinium Triflate. *Journal of Physical Chemistry B* 2010, 114, (10), 3601-3607.

130. Wasserscheid, P.; van Hal, R.; Bosmann, A., 1-n-Butyl-3-methylimidazolium (bmim) octylsulfate - an even 'greener' ionic liquid. *Green Chemistry* 2002, 4, (4), 400-404.
131. Jacquemin, J.; Husson, P.; Majer, V.; Padua, A. A. H.; Gomes, M. F. C., Thermophysical properties, low pressure solubilities and thermodynamics of solvation of carbon dioxide and hydrogen in two ionic liquids based on the alkylsulfate anion. *Green Chemistry* 2008, 10, (9), 944-950.
132. Harris, K. R.; Kanakubo, M.; Woolf, L. A., Temperature and pressure dependence of the viscosity of the ionic liquids 1-hexyl-3-methylimidazolium hexafluorophosphate and 1-butyl-3-methylimidazolium bis(trifluoromethylsulfonyl)imide. *Journal of Chemical and Engineering Data* 2007, 52, (3), 1080-1085.
133. Fan, W.; Zhou, Q.; Sun, J.; Zhang, S. J., Density, Excess Molar Volume, and Viscosity for the Methyl Methacrylate+1-Butyl-3-methylimidazolium Hexafluorophosphate Ionic Liquid Binary System at Atmospheric Pressure. *Journal of Chemical and Engineering Data* 2009, 54, (8), 2307-2311.
134. Liu, J.; Jiang, G. B.; Chi, Y. G.; Cai, Y. Q.; Zhou, Q. X.; Hu, J. T., Use of ionic liquids for liquid-phase microextraction of polycyclic aromatic hydrocarbons. *Analytical Chemistry* 2003, 75, (21), 5870-5876.
135. Pereiro, A. B.; Legido, J. L.; Rodriguez, A., Physical properties of ionic liquids based on 1-alkyl-3-methylimidazolium cation and hexafluorophosphate as anion and temperature dependence. *Journal of Chemical Thermodynamics* 2007, 39, (8), 1168-1175.
136. Tomida, D.; Kumagai, A.; Kenmochi, S.; Qiao, K.; Yokoyama, C., Viscosity of 1-hexyl-3-methylimidazolium hexafluorophosphate and 1-octyl-3-methylimidazolium hexafluorophosphate at high pressure. *Journal of Chemical and Engineering Data* 2007, 52, (2), 577-579.
137. Bogolitsyn, K. G.; Skrebets, T. E.; Makhova, T. A., Physicochemical properties of 1-butyl-3-methylimidazolium acetate. *Russian Journal of General Chemistry* 2009, 79, (1), 125-128.
138. Greaves, T. L.; Weerawardena, A.; Fong, C.; Krodziewska, I.; Drummond, C. J., Protic ionic liquids: Solvents with tunable phase behavior and physicochemical properties. *Journal of Physical Chemistry B* 2006, 110, (45), 22479-22487.
139. Kurnia, K. A.; Wilfred, C. D.; Murugesan, T., Thermophysical properties of hydroxyl ammonium ionic liquids. *Journal of Chemical Thermodynamics* 2009, 41, (4), 517-521.

140. Burrell, G. L.; Burgar, I. M.; Separovic, F.; Dunlop, N. F., Preparation of protic ionic liquids with minimal water content and N-15 NMR study of proton transfer. *Physical Chemistry Chemical Physics* 2010, 12, (7), 1571-1577.
141. Zhang, Y. Q.; Zhang, S. J.; Lu, X. M.; Zhou, Q.; Fan, W.; Zhang, X. P., Dual Amino-Functionalised Phosphonium Ionic Liquids for CO₂ Capture. *Chemistry-a European Journal* 2009, 15, (12), 3003-3011.
142. Hagiwara, R.; Hirashige, T.; Tsuda, T.; Ito, Y., A highly conductive room temperature molten fluoride: EMIF center dot 2.3HF. *Journal of the Electrochemical Society* 2002, 149, (1), D1-D6.
143. Matsumoto, H.; Matsuda, T.; Tsuda, T.; Hagiwara, R.; Ito, Y.; Miyazaki, Y., The application of room temperature molten salt with low viscosity to the electrolyte for dye-sensitized solar cell. *Chemistry Letters* 2001, (1), 26-27.
144. Shirota, H.; Nishikawa, K.; Ishida, T., Atom Substitution Effects of XF₆ (-) in Ionic Liquids. 1. Experimental Study. *Journal of Physical Chemistry B* 2009, 113, (29), 9831-9839.
145. Maginn, E. J. *Design and Evaluation of Ionic Liquids as Novel CO₂ Absorbents*; 2005-2007; p Medium: ED.