Efficient Synthesis of 1-Alkyl(aralkyl)-3-methyl(ethyl)imidazolium Halides: Precursors for Room-Temperature Ionic Liquids

Sergei V. Dzyuba and Richard A. Bartsch*

Department of Chemistry and Biochemistry, Texas Tech University, Lubbock, Texas 79409

Received July 31, 2000

Facile preparation of 1-alkyl(aralkyl)-3-methyl(ethyl)imidazolium bromides and chlorides is reported. With short reaction times, the desired salts are obtained without purification in high yields from equimolar amounts of reactants.

J. Heterocyclic Chem., **38**, 265 (2001).

Introduction.

Room Temperature-Ionic Liquids (RTILs), salts that are liquids at ambient temperatures, continue to receive ever-increasing attention [1,2]. RTILs have been utilized in many areas of synthetic organic chemistry as solvents and catalysts [2]. Some examples of their use in separation chemistry have also been reported [3-5]. Although RTILs are superior to conventional solvents in many cases, only a very limited number of structures have been utilized. Most of the recent investigations have employed 1-butyl-3-methylimidazolium or 1-ethyl-3-methylimidazolium hexafluorophosphates or tetrafluoroborates [3-13].

Due to their hygroscopic nature, halide-containing RTILs are utilized less frequently [6]. However, these salts are usually employed as the synthetic precursors for corresponding hexafluorophosphates and tetrafluoroborates. Reported preparations of 1-alkyl-3-methylimidazolium halides from 1-methylimidazole and an alkyl halide involve long reaction times (from hours to days) and/or a large excess of one of the reactants [3,14,15]. We now report an efficient method in which 1-alkyl-3-methylimidazolium halides and analogues are prepared in high yields without purification using short reaction times and neat reactants.

Results and Discussion.

Structures of the 1-alkyl-3-methyl(ethyl)limidazolium bromides **1**-**17**, 1-aralkyl-3-methylimidazolium bromide **19** and 1-aralkyl-3-methylimidazolium chlorides **18** and **20**-**23** synthesized in this work are shown in Tables 1 and 2. Some of these salts have been mentioned in the literature, but usually without spectral characterization or elemental analysis results.

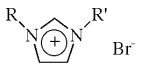
The preparation of 1-butyl-3-methylimidazolium chloride (as the precursor to the hexafluorophosphate salt) by reaction of neat 1-methylimidazole and 1-chlorobutane at 70 °C for 48 hours was reported recently [3]. When we substituted 1-bromobutane as the alkylating agent, a quantitative yield of 1-butyl-3-methylimidazolium bromide (**3**) was formed in 2 hours. ^{1}H nmr spectrum of the product contained only the absorptions expected for **3**. Increasing the reaction temperature to 110 and 140 °C gave quantitative yields of **3** in 1 hour and in 30 minutes, respectively. Due to the shorter reaction time, the latter conditions were chosen for development of a general method.

Synthesis of 1-Alkyl-3-methylimidazolium Bromides.

We have found that reactions of neat 1-methylimidazole and a variety of primary alkyl bromides for a short reaction time provide high yields of the desired salts without purification. An oil bath with a stirred flask containing equimolar amounts of commercially available 1-methylimidazole and the primary alkyl bromide was heated to 140 °C during a period of 10 minutes. During the latter stages of the heating, an exothermic reaction took place forming an emulsion that disappeared in a few minutes to produce a transparent, golden, slightly viscous liquid. At this point, the oil bath was removed and the solution was allowed to stir and cool for 10 minutes. The stirred solution was then heated in the 140 °C oil bath for an additional 10-15 minutes followed by drying under vacuum at 100-120 °C to afford the 1-alkyl-3-methylimidazolium bromide in essentially quantitative yield

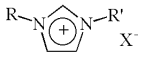
Table 1

Structures and Yields for 1-R-3-R'-imidazolium Bromides



Compound	R	R'	Yield, %
1	CH_3	C_2H_5	99
2	CH_3	*n*-C_3H_7	99
3	CH_3	*n*-C_4H_9	99
4	CH_3	*n*-C_5H_{11}	99
5	CH_3	*n*-C_6H_{13}	99
6	CH_3	*n*-C_7H_{15}	99
7	CH_3	*n*-C_8H_{17}	99
8	CH_3	*n*-C_9H_{19}	99
9	CH_3	iso-C_4H_9	98
10	C_2H_5	iso-C_4H_9	97
11	CH_3	*sec*-C_4H_9	67
12	C_2H_5	*sec*-C_4H_9	65
13	CH_3	iso-C_5H_{11}	98
14	CH_3	$CH_2CH(CH_3)C_3H_7$	95
15	CH_3	$CH_2CH_2CH(CH_3)C_2H_5$	96
16	CH_3	iso-C_6H_{13}	95
17	CH_3	$CH_2CH(C_2H_5)C_3H_7$	94

Table 2
Structures and Yields for 1-R-3-R'-imidazolium Halides



Compound	R	R'	X	Yield,%
18	CH_3	$CH_2C_6H_5$	Cl	95
19	CH_3	$CH_2CH_2C_6H_5$	Br	99
20	CH_3	$CH_2CH_2CH_2C_6H_5$	Cl	98
21	C_2H_5	$CH_2CH_2C_6H_5$	Cl	95
22	CH_3	$CH(C_6H_5)_2$	Cl	85
23	C_2H_5	$CH(C_6H_5)_2$	Cl	89

(Table 1). Yields of 94-99% were obtained when the primary alkyl group was ethyl, propyl, butyl, pentyl, hexyl, heptyl, nonyl, isobutyl, isopentyl, 2-methyl-1-pentyl, 3-methyl-1-pentyl, isohexyl, and 2-ethyl-1-pentyl.

When the reaction of 1-methylimidazole with 2-bromobutane, a secondary alkyl bromide, was conducted under the same conditions, only a 45% yield of 1-(*sec*-butyl)-3-methylimidazolium bromide (**11**) was isolated from the reaction mixture. Presumably, this lower yield resulted from a competing elimination reaction. When the oil bath temperature was reduced to 70 °C and the reaction time was increased to 2 hours, the yield of substitution product **11** increased to 67%.

Synthesis of 1-Alkyl-3-ethylimidazolium Bromides.

To probe the generality of this new synthetic procedure, 1-ethylimidazole was prepared by a literature method [16]. Reaction of 1-ethylimidazole with isobutyl bromide in a 140 °C oil bath afforded a 97% yield of 1-ethyl-3-isobutylimidazolium bromide (**10**). Under the same conditions, only a 50% yield of 1-ethyl-3-(*sec*-butyl)imidizolium bromide (**12**) was obtained when 2-bromobutane was the alkylating agent. However, the use of a 70 °C oil bath increased the yield of **12** to 65% in a 2-hour reaction. Thus, it is established that 1-ethylimidazole and 1-methylimidazole behave the same in these alkylation reactions.

Synthesis of 1-Aralkyl-3-methylimidazolium Halides.

Attempted extension of this method to aralkyl halide alkylating agents revealed that some purification of the product salt was necessary. To avoid this purification step, a modified synthetic method was developed. In this alternative procedure, equimolar amounts of 1-methylimidazole and the aralkyl halide were refluxed in benzene for 5-10 hours. The benzene was decanted and the residual viscous liquid or solid was washed with fresh benzene. Drying under vacuum at 100-110 °C removed traces of benzene to afford the pure desired product in very high yield (Table 2). Product yields of 85-99% were obtained from reactions of 1-methylimidazole with benzyl chloride, 2-phenylethyl bromide, 1-chloro-3-phenylpropane, and benzylhydryl chloride.

Reaction of 1-ethylimidazole with 2-phenylethyl bromide gave a 95% yield of 1-ethyl-3-(2-phenylethyl)imidazolium bromide (**21**). Alkylation of 1-ethylimidazole with benzhydryl chloride provided an 89% yield of 1-benzhydryl-3-ethylimidazolium chloride (**23**).

Table 3
Melting Points and Elemental Analysis Data for the Unsymetrically Disubstituted Imidazolium Halides

		Elemental analysis Analysis found Found (Calculated), (%)		
Compound	Mp, °C	C	H	N
4	oil	46.27 (46.36)	7.49 (7.35)	11.98 (12.02)
5	oil	46.86 (48.59)	7.86 (7.79)	11.41 (11.33)
6[a]	oil	49. 59 (49.98)	8.42 (8.15)	10.84 (10.58)
7[b]	oil	51.58 (51.69)	8.52 (8.46)	10.21 (10.05)
8	oil	54.16 (53.98)	8.86 (8.71)	9.75 (9.68)
9[c]	oil	42.85 (43.14)	7.12 (6.97)	12.80 (12.58)
10	oil	44. 67 (44.36)	7.31 (7.35)	12.05 (12.02)
11[d]	47-50	42.53 (42.80)	7.19 (7.00)	12.52 (12.48)
12	oil	45.97 (46.36)	7.50 (7.35)	11.87 (12.02)
13	oil	46.27 (46.36)	7.40 (7.35)	12.06 (12.02)
14[e]	oil	47.88 (47.89)	7.83 (7.80)	11.51 (11.17)
15	oil	48.20 (48.59)	7.67 (7.75)	11.21 (11.33)
16	oil	48.46 (48.59)	8.03 (7.75)	11.27 (11.33)
17	oil	51.97 (52.37)	8.36 (8.42)	10.55 (10.18)
18[f]	oil	61. 73 (61.71)	6.81 (6.40)	13.11 (13.09)
19[g]	72-73	52.35 (52.19)	5.88 (5.84)	10.29 (10.15)
20	oil	65.77 (65.95)	7.26 (7.24)	11.87 (11.83)
21	42-44	65.65 (65.95)	7.21 (7.24)	11.75 (11.83)
22	173-175	71.90 (71.70)	6.01 (6.02)	9.80 (9.84)
23	135-138	72.23 (72.35)	6.23 (6.41)	9.43 (9.38)

[a] Calculated for $C_{11}H_{21}BrN_2 \cdot 0.2H_2O$. [b] Calculated for $C_{12}H_{23}BrN_2 \cdot 0.2H_2O$. [c] Calculated for $C_8H_{15}BrN_2 \cdot 0.2H_2O$. [d] Calculated for $C_8H_{15}BrN_2 \cdot 0.3H_2O$. [e] Calculated for $C_{10}H_{19}BrN_2 \cdot 0.2H_2O$. [f] Calculated for $C_{11}H_{13}ClN_2 \cdot 0.3H_2O$. [g] Calculated for $C_{12}H_{15}BrN_2 \cdot 0.5H_2O$.

Table 4
Proton Chemical Shifts for Compounds **4**-**8** (number of protons, where needed, and multiplicity and coupling constants in Hz)

Compound	CH_3N	NCHN	NC*H*CHN	NCHC*H*N	NCH_2	NCH_2CH_2	alkyl	Term. CH_3
4	4.15 (s)	10.30 (s)	7.80 (t, 1.7)	7.65 (t, 1.7)	4.36 (t, 7.3)	1.97 (m)	1.34 (4H, m)	0.89 (t, 6.7)
5	4.15 (s)	10.29 (s)	7.82 (t, 1.8)	7.66 (t, 1.8)	4.36 (t, 7.3)	1.94 (m)	1.36 (6H, m)	0.87 (m)
6	4.15 (s)	10.29 (s)	7.80 (t, 1.7)	7.62 (t, 1.7)	4.35 (t, 7.3)	1.93 (m)	1.28 (8H, m)	0.87 (m)
7	4.16 (s)	10.28 (s)	7.84 (t, 1.8)	7.65 (t, 1.8)	4.36 (t, 7.3)	1.94 (m)	1.30 (10H, m)	0.87 (m)
8	4.16 (s)	10.29 (s)	7.83 (m)	7.65 (m)	4.36 (t, 7.1)	1.94 (m)	1.31 (12H, m)	0.87 (m)

Table 5

Proton Chemical Shifts for Compounds **9-17** (number of protons, where needed, and multiplicity and coupling constants in Hz)

Compound	CH_3N	CH_3CH_2N	CH_3CH_2N	NCHN	NC*H*CHN	NCHC*H*N	NCH_2	NCH_nCH_2	CH	CH_3CH	Alkyl	term CH_3
9	4.16 (s)	-	-	10.25 (s)	7.80 (t, 1.6)	7.63 (t, 1.7)	4.19 (d, 7.7)	-	2.26 (m)	-	-	1.01(d, 6.4)
10	-	1.63 (td, 7.3, 1.3)	4.49 (q, 7.4)	10.39 (s)	7.85 (t, 1.8)	7.76 (t, 1.8)	4.21 (d, 7.4)	-	2.28 (m)	-	-	0.99 (dd, 5.6, 1.2)
11	4.16 (s)	-	-	10.42 (s)	7.78 (m)	7.63 (m)	-	1.91 (p, 7.6)	4.64 (sept, 6.9)	1.62 (d, 6.8)	-	0.91 (t, 7.4)
12	-	1.63 (m)	4.49 (q, 7.4)	10.51 (s)	7.77 (t, 1.8)	7.62 (t, 1.8)	-	-	4.68 (q, 7.0)	1.62 (m)	1.94 (2H, m)	0.91 (t, 7.3)
13	4.15 (s)	-	-	10.30 (s)	7.83 (t, 1.7)	7.66 (t, 1.8)	4.38 (t, 7.5)	1.85 (q, 7.0)	1.64 (m)	-	-	1.03 (d, 6.4)
14	4.17 (s)	-	-	10.26 (s)	7.80 (t, 1.7)	7.53 (t, 1.7)	4.22 (m)	-	2.11 (m)	0.94 (d, 6.7)	1.30 (4H, m)	0.89 (t, 6.8)
15	4.14 (s)	-	-	10.36 (s)	8.19 (t, 1.5)	8.06 (t, 1.6)	4.52 (m)	1.90 (m)	1.22 (m)	0.97 (d, 6.5)	1.44 (2H, m)	0.87 (t, 7.1)
16	4.14 (s)	-	-	10.32 (s)	8.11 (t, 1.7)	8.02 (t, 1.7)	4.48 (t, 7.3)	1.94 (m)	1.61 (m)	-	1.29 (2H, m)	0.89 (d, 6.6)
17	4.17 (s)	-	-	10.31 (s)	7.88 (t, 1.7)	7.51 (t, 1.7)	4.23 (d, 7.9)	-	1.92 (m)	0.94 (d, 6.6)	1.30 (8H, m)	0.89 (t, 7.0)

Table 6

Proton Chemical Shifts for Compounds **18-23** (number of protons, where needed, and multiplicity and coupling constants in Hz)

Compound	CH_3N	CH_3CH_2N	CH_3CH_2N	NCHN	NC*H*CHN	NCHC*H*N	NCH_n	NCH_2CH_2	$NCH_2CH_2CH_2$	Ar (*o*-)	Ar (*m*-, *p*-)
18	4.06 (s)	-	-	10.71 (s)	7.63 (t, 1.8)	7.45 (m)	5.58 (2H, s)	-	-	7.45 (2H, m)	7.49 (3H, m)
19	4.02 (s)	-	-	10.16 (s)	7.56 (t,1.6)	7.42 (t, 1.6)	4.63 (2H, t, 7.2)	3.26 (t, 7.2)	-	7.25 (m)	7. 25 (m)
20	4.06 (s)	-	-	10.52 (s)	7.65 (m)	7.53 (m)	4.36 (2H, t, 7.3)	2.70 (m)	2.27 (m)	7.27 (m)	7.27 (m)
21	-	1.52 (t, 7.4)	4.33 (q, 7.3)	10.40 (s)	7.66 (s)	7.53 (s)	4.64 (2H, t, 7.3)	3.26 (t, 7.2)	-	7.26 (m)	7.26 (m)
22	4.09 (s)	-	-	10.49 (s)	7.99 (m)	7.16 (m)	7.50 (1H, s)	-	-	7.21 (4H, m)	7.34 (6H, m)
23	-	1.56 (t, 7.3)	4.43 (q, 7.4)	10.69 (s)	8.07 (s)	7.19 (t, 1.8)	7.59 (1H, s)	-	-	7.22 (4H, m)	7.34 (6H, m)

The unsymmetrically disubstituted imidazolium halides **4**-**23** were characterized by elemental analysis (Table 3) and ^{1}H nmr spectroscopy (Tables 4-6). Such data has been reported previously for **1**-**3**. Even with careful drying, absorption of water during transfer is evident from the elemental analysis results for several of these extremely hygroscopic disubstituted imidazolium halides. The ^{1}H nmr chemical shifts for disubstituted imidazolium salts are known to be dependent on both the concentration of the solution and the identity of the anion [16]. Resonances, corresponding to acidic imidazolium protons (NCHN) in **1**-**23**, are observed in the range of 10.20-11.10 ppm.

In conclusion, convenient and efficient synthetic methods have been developed for the preparation of a number of unsymmetrically disubstituted imidazolium halides. The availability of such precursors will provide easier access to RTILs with widely varying structures.

EXPERIMENTAL

The 1-methyimidazole and most of the alkyl and aralkyl halides were purchased from Acros or Aldrich and used as received. Alkyl bromides for the synthesis of salts **14**-**17** were prepared from the corresponding commercially available alcohols (Aldrich) by reaction with phosphorus tribromide [17]. The 1-ethylimidazole was prepared according to a literature procedure [16]. Proton nuclear magnetic resonance (^{1}H nmr) spectra were recorded on Bruker AF-200 or AF-300 spectrometers in deuteriochloroform with chemical shifts (δ) reported downfield from tetramethylsilane. Elemental analyses were performed by Desert Analytics Laboratory of Tuscon, Arizona. Melting points were obtained with a Mel-Temp melting point apparatus.

General Procedure for the Synthesis of 1-Alkyl-3-methyl-(ethyl)imidazolium Bromides.

Into a flask equipped with a condenser and magnetic stirrer were placed 60 mmoles of 1-methyl(ethyl)imidazole and 60 mmoles of the primary alkyl bromide. The flask was placed in a silicone oil bath and the bath was heated to 140 °C during a 10-minute period. During the latter stages of heating, an exothermic reaction took place forming an emulsion that disappeared after a few minutes to afford a transparent, golden, slightly viscous solution. When the emulsion disappeared, the flask was removed from the oil bath and the contents were allowed to stir and cool for 10 minutes. The flask was placed into the oil bath at 140 °C for another 10-15 minutes. The contents were dried under vacuum at 100-120 °C to produce the 1-alkyl-3-methyl(ethyl)-imidazolium bromide in very high yield.

For reactions of 1-methyl(ethyl)imidazole with 2-bromobutane, a lower oil bath temperature of 70 °C was utilized to reduce competing elimination. The crude product was purified by distillation to remove the contaminating 1-methyl(ethyl)-imidazole under a vacuum of 1 Torr.

General Procedure for the Preparation of 1-Aralkyl-3-methyl(ethyl)imidazolium Halides.

A solution of 60 mmoles of 1-methyl(ethyl)imidazole and 60 mmoles of the aralkyl halide in 10 ml of benzene was refluxed for 5-10 hours. The benzene was decanted and the residual viscous liquid or solid was washed with benzene (2 X 15 ml) followed by drying under vacuum at 100-110 °C to remove traces of benzene and provide the 1-aralkyl-3-methyl(ethyl)imidazolium halide in high yield.

Acknowledgment.

This research was supported by grants from the Texas Tech University Center for Energy Research and by the Texas Higher Education Coordinating Board Advanced Research Program.

REFERENCES AND NOTES

[1] K. R. Seddon, *J. Chem. Tech. Biotech.*, **68**, 351, (1997).

[2] T. Welton, *Chem. Rev.*, **99**, 2071 (1999).

[3] J. G. Huddleston, H. D. Willaner, R. P. Swatloski, A. E. Visser and R. D. Rogers, *J. Chem. Soc., Chem. Comm.*, 1765 (1998).

[4] S. Dai, Y. H. Ju and C. E. Barnes, *J. Chem. Soc., Dalton Trans*, 1201 (1999).

[5] D. W. Armstrong, L. He and Y.-S. Liu, *Anal. Chem.*, **71**, 3873 (1999).

[6] A. J. Carmichael, M. J. Earle, J. D. Holbrey, P. B. McCormac and K. R. Seddon, *Org. Lett.*, **1**, 997 (1999).

[7] C. J. Adams, M. J. Earle and K. R. Seddon, *J. Chem. Soc., Chem. Commun.*, 1043 (1999).

[8] W. Chen, L. Xu, C. Chatterton and J. Xiao, *J. Chem. Soc., Chem. Commun.*, 1247 (1999).

[9] G. M. Gordon and A. McClusky, *J. Chem. Soc., Chem. Commun.*, 1431 (1999).

[10] C. E. Song and E. J. Roh, *J. Chem. Soc., Chem. Commun.*, 837 (2000).

[11] G. S. Owens and M. M. Abu-Omar, *J. Chem. Soc., Chem. Commun.*, 1165 (2000).

[12] A. J. Carmichael, D. M. Haddleton, S. A. F. Bon and K. R. Seddon, *J. Chem. Soc., Chem. Commun.*, 1237 (2000).

[13] C. J. Mathews, P. J. Smith and T. Welton, *J. Chem. Soc., Chem. Commun.*, 1249 (2000).

[14] J. S. Wilkes, J. A. Levisky, R. A. Wilson and C. L. Hussey, *Inorg. Chem.*, **21**, 1263 (1982).

[15] B. K. M. Chan, N.-H. Chang and M. R. Grimmett, *Aust. J. Chem.*, **30**, 2005 (1977).

[16] P. Bonhote, A.-P. Dias, N. Papageorgion, K. Kalyanasundaram and M. Gratzel, *Inorg. Chem.*, **35**, 9168 (1996).

[17] C.-H. Lin, P. A. Aristoff, P. D. Johnson, J. P. McGrath, J. M. Timko and A. Robert, *J. Org. Chem.*, **52**, 5594 (1987).