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LETTERS

# 1-Ethyl-3-methylimidazolium halogenoaluminate ionic liquids as reaction media for the acylative cleavage of ethers

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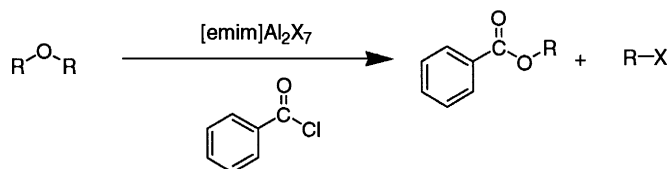
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## Abstract

Ionic liquids derived from 1-ethyl-3-methylimidazolium iodide (emimI), and aluminium chloride have been shown to be suitable solvents for the acylative cleavage of a series of cyclic and acyclic ethers. Difunctionalised  $\omega$ -iodobenzoate adducts have been isolated from the cleavage of cyclic ethers performed in Lewis acidic ionic liquids (i.e.  $\text{AlCl}_3$ :emimI ratio is greater than 1:1) in the presence of benzoyl chloride. © 2000 Elsevier Science Ltd. All rights reserved.


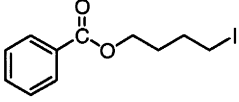
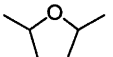
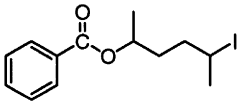

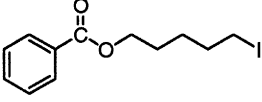
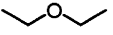
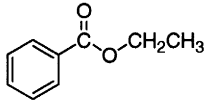
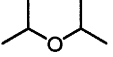
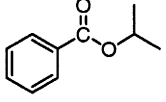

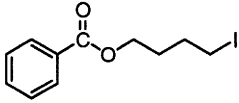
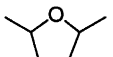
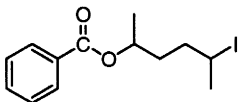

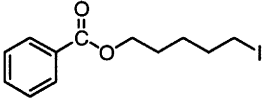
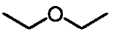
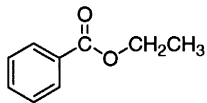
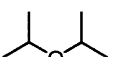
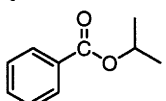
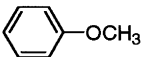
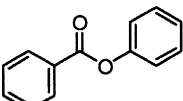
There has been ample recent interest in the use of ionic liquids as solvents for a variety of organic and organometallic reactions. Ionic liquids derived from 1,3-dialkylimidazolium cations and anions such as tetrafluoroborate, hexafluorophosphate, and heptachlorodialuminate(III) have been shown to possess several advantages over more conventional molecular solvents.<sup>1</sup> For example, these ionic liquids possess a wide liquidous range (i.e.  $\sim -96^\circ\text{C}$  to  $200^\circ\text{C}$  for 1-ethyl-3-methylimidazolium heptachlorodialuminate(III),  $[\text{emim}]\text{Al}_2\text{Cl}_7$ ), making them suitable for studying kinetics of reactions at a variety of temperatures. These solvents also have a negligible vapour pressure even at elevated temperatures and, in the case of the halogenoaluminate ionic liquids, can possess variable Lewis acidity. The ionic liquids with  $\text{BF}_4^-$  and  $\text{PF}_6^-$  anions are water stable whereas the halogenoaluminate ionic liquids decompose in the presence of water. It has been demonstrated that an array of organic and organometallic compounds such as aromatics, metallocenes, rhodium, nickel(II), and ruthenium(IV) complexes, titanium (IV) chloride,



Scheme 1. Acylative ether cleavage in 1-ethyl-3-methylimidazolium halogenoaluminate ionic liquids<sup>2</sup>

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Table 1  
Acylation cleavage of ethers in [emimI]·AlCl<sub>3</sub> derived ionic liquids

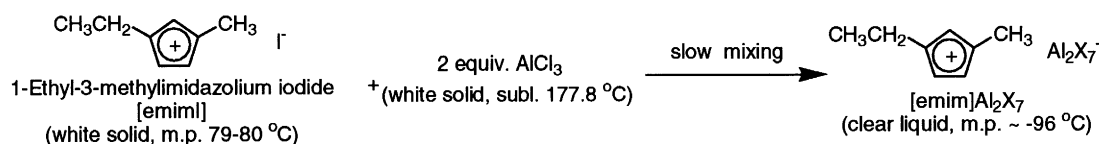
Entry	Ether	Product	Time (hrs)	Mole Fraction X(AlCl <sub>3</sub> )	Yield(%) <sup>a</sup>
1			2	0.67	95
2			2	0.67	25
3			2	0.67	13
4			2	0.67	16 <sup>b</sup>
5			2	0.67	51 <sup>b</sup>
6			24	0.52	61
7			24	0.52	46
8			2	0.52	65
9			24	0.52	22 <sup>b</sup>
10			24	0.52	58 <sup>b</sup>
11			2	0.67	25

<sup>a</sup>. Isolated products characterised by <sup>1</sup>H and <sup>13</sup>C NMR, EI-MS, and IR and are in agreement with those reported in the literature; <sup>b</sup>. Only product sufficiently involatile to be isolated.

zinc(II) chloride, dialkylethers, and others can be dissolved readily in 1,3-dialkylimidazolium based ionic liquids. Thus, it is likely that many chemical reactions can be conducted in these novel solvent systems with potential enhancement in both yield and selectivity.

Despite the availability of several methods with which to cleave ethers,<sup>3</sup> the literature lacks a general, reliable method to selectively cleave ether linkages in complex and otherwise fragile molecules. Since

it had been previously demonstrated by us and others that 1-ethyl-3-methylimidazolium halogenoaluminates possess ‘tunable’ Lewis acidity<sup>4</sup> we proceeded to show that these ionic liquids could be used for the acylative cleavage of cyclic and acyclic ethers (Scheme 1, Table 1). We report herein the acylative cleavage of dialkylethers conducted in Lewis acidic 1-ethyl-3-methylimidazolium halogenoaluminate ionic liquids (Scheme 2) and that these cleavages are sensitive to the ‘bulk’ Lewis acidity of the ionic solvent system.

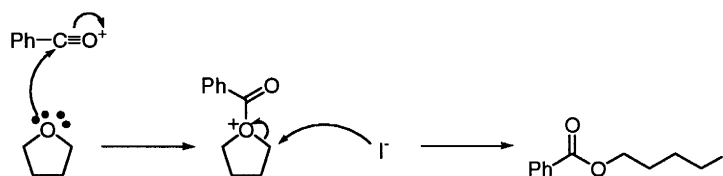


Scheme 2. Formation of ‘strictly acidic’ 1-ethyl-3-methylimidazolium heptahalodialuminate(III) ionic liquid

The cyclic ether tetrahydrofuran undergoes acylative cleavage to afford an excellent yield of 4-iodobutylbenzoate when the strictly acidic ionic liquid [emim]Al<sub>2</sub>X<sub>7</sub> is used (entry 1), but suffers a decrease in yield of difunctionalised product when the mildly acidic halogenoaluminate is used as solvent (entry 6). Interestingly, the other cyclic ethers investigated in this study, 1,5-dimethyltetrahydrofuran and tetrahydropyran display inverse behaviour in that they afford good yield of cleavage products only when the mildly acidic halogenoaluminate is used as solvent (entries 7 and 8). Diethyl ether, a primary ether, gave relatively poor yields of ethylbenzoate under all conditions attempted in this study. However, diisopropyl ether, a secondary ether, gave good yields of isopropylbenzoate in the mildly Lewis acidic solvent system (entry 10). Anisole underwent acylative cleavage to afford phenylbenzoate, but afforded the Friedel–Crafts adduct,<sup>1d,5</sup> methoxybenzophenone, as the major product (entry 11). 1,4-Dioxane nor 2,3-dihydro-2*H*-pyran afforded any isolable cleavage products under any of the conditions utilized in this study.

That these cleavage reactions were not the result of HCl presence during aqueous work-up was shown by performing the aqueous work-up using distilled water and adding it to the reaction mixtures at 0°C. The cleavage due to HCl could therefore not occur at this lowered temperature. Furthermore, if HCl induced the cleavage reactions, chlorine would be expected to be present in the products; spectroscopic data indicates that only iodine has been incorporated into the isolated products.

These results support a mechanism in which there is initial formation of a polarized complex between Lewis acidic halogenoaluminate or aluminium chloride species present in solution and benzoyl chloride or the formation of benzoyl cation upon addition of benzoyl chloride to the system. *O*-Acylation of the ether then occurs to give an oxonium ion species that cleaves to give the most stable carbonium ion or which undergoes nucleophilic attack by iodine present in these systems (Scheme 3). The lack of chlorine in any of the products isolated in this study indicates the latter of these two mechanistic possibilities is more likely. The differential results observed using ionic solvents of variable Lewis acidity suggest that this mechanism may be hindered by occupation of the etherial oxygen by some Lewis acidic species (i.e. Al<sub>2</sub>X<sub>7</sub><sup>-</sup>) other than acylium ion when the strictly acidic solvent system is used. We are currently conducting studies utilizing more complex ethers and a wider range of Lewis acidities to elucidate the full scope, selectivity, and limitations of the ether cleavage reactions conducted in these ionic solvents.



Scheme 3. *O*-Acylation of tetrahydrofuran by acylium ion followed by nucleophilic attack by iodide

## Acknowledgements

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## References

- (a) Guterman, L. *Chemistry, A. C. S.*; 12, Summer **1999**; (b) Earle, M. J.; McCormac, P. B.; Seddon, K. R. *Green Chemistry*; 23, **1999**; (c) Earle, M. J.; McCormac, P. B.; Seddon, K. R. *J. Chem. Soc., Chem. Commun.* **1998**, 2245; (d) Boon, J. A.; Levitsky, J. L.; Pflug, J. L.; Wilkes, J. S. *J. Org. Chem.* **1986**, 51, 480; (e) Surette, J. K. D.; Green, L.; Singer, R. D. *J. Chem. Soc., Chem. Commun.* **1996**, 2753; (f) Stark, A.; MacLean, B. L.; Singer, R. D. *J. Chem. Soc., Dalton Trans.* **1999**, 63; (g) Dyson, P. J.; Gossel, M. J.; Srinivasan, N.; Vine, T.; Welton, T.; Williams, D. J.; White, A. J. P.; Zigras, T. *J. Chem. Soc., Dalton Trans.* **1997**, 3465; (h) Monteiro, A. L.; Zinn, F. K.; de Souza, R. F.; Dupont, J. *Tetrahedron: Asymmetry* **1997**, 8, 177; (i) Chen, W.; Xu, L.; Chatterton, C.; Xiao, J. *J. Chem. Soc., Chem. Commun.* **1999**, 1247; (j) Einloft, S.; Dietrich, F. K.; de Souza, R. F.; Dupont, J. *Polyhedron* **1996**, 15, 3257; (k) Suarez, P. A. Z.; Dullius, J. E. L.; Einloft, S.; de Souza, R. F.; Dupont, J. *Polyhedron* **1996**, 15, 1217.
- Typical procedure: (Ionic liquid preparation): Aluminium chloride (3.08 g, 23.1 mmol for a  $X(\text{AlCl}_3)=0.52$ , mildly acidic ionic liquid, or 5.6 g, 42 mmol for a  $X(\text{AlCl}_3)=0.67$ , strictly acidic ionic liquid) was added slowly over 30 min to anhydrous 1-ethyl-3-methylimidazolium iodide (5.0 g, 21 mmol) in a dry box to afford a clear liquid upon stirring. The r.b. flask was sealed with a septum and removed from the dry box. (Acylation of tetrahydrofuran): Tetrahydrofuran (0.20 mL, 2.5 mmol) freshly distilled from potassium/benzophenone ketyl was added via syringe to the ionic liquid, as prepared above, and allowed to stir for 15 min. Freshly distilled benzoyl chloride (0.58 mL, 5 mmol) is then added via syringe to the solution and stirred under argon atmosphere for 2 h at room temperature. Aqueous work-up involved the careful addition of 20 mL of 0.1 M HCl or distilled water followed by extraction with chloroform (3×30 mL). The combined organic extracts were then washed with 50 mL of saturated sodium bicarbonate followed by drying with anhydrous  $\text{MgSO}_4$ , filtration through fluted filter paper, and concentration in vacuo. The crude reaction mixture was then purified using flash column chromatography on silica gel and using 10:1 hexanes/ethyl acetate eluent to afford 0.72 g, 95% yield of 4-iodobutyl benzoate: IR  $\nu$  1719  $\text{cm}^{-1}$  (carbonyl);  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  8.06–8.02, 7.60–7.41 (m, 5H,  $\text{C}_6\text{H}_5$ ), 4.35 (t,  $J=6$  Hz, 2H,  $\text{CH}_2\text{-COPh}$ ), 3.26 (t,  $J=6$  Hz, 2H,  $\text{CH}_2\text{-I}$ ), 2.03–1.87 (m, 4H,  $\text{CH}_2\text{CH}_2$ );  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ )  $\delta$  166.56 (carbonyl), 133.01, 130.20, 129.58, 128.41 ( $\text{C}_6\text{H}_5$ ), 63.78 ( $\text{CH}_2\text{-I}$ ), 30.12 ( $\text{CH}_2\text{-OAc}$ ), 29.69 ( $\text{CH}_2$ ), 6.03 ( $\text{CH}_2$ ).
- (a) Suzuki, Y.; Matsushima, M.; Kodomari, M. *Chem. Soc. Jap., Chem. Letters* **1998**, 319; (b) Guindon, Y.; Therien, M.; Girard, Y.; Yoakim, C. *J. Org. Chem.* **1987**, 52, 1680; (c) Cloke, J. B.; Pilgrim, F. J. *J. Am. Chem. Soc.* **1939**, 61, 2667; (d) Ganem, B.; Small Jr., V. R. *J. Org. Chem.* **1974**, 39, 3728; (e) Alper, H.; Huang, C.-C.; *J. Org. Chem.* **1973**, 38, 64; (f) Pri-Bar, I.; Stille, J. K. *J. Org. Chem.* **1982**, 47, 1215; (g) Iqbal, J.; Srivastava, R. R. *Tetrahedron* **1991**, 47, 3155; (h) Oriyama, T.; Kimura, M.; Oda, M.; Koga, G. *Synlett* **1993**, 437.
- The 'bulk' Lewis acidity of  $[\text{emimI}]\cdot\text{AlCl}_3$  ionic liquids is best described by the mole fraction of aluminium chloride,  $[\text{X}(\text{AlCl}_3)]$ , present. When  $\text{X}(\text{AlCl}_3) < 0.5$ , halide ion ( $\text{I}^-$  or  $\text{Cl}^-$ ) is in excess over  $\text{Al}_2\text{X}_7^-$  and the ionic solvent is 'basic'; when  $\text{X}(\text{AlCl}_3)=0.5$ , the ionic solvent is 'neutral'; when  $\text{X}(\text{AlCl}_3) > 0.5$ ,  $\text{Al}_2\text{X}_7^-$  ion is in excess over halide ion and the ionic solvent is 'acidic'.
- Adams, C. J.; Earle, M. J.; Roberts, G.; Seddon, K. R. *J. Chem. Soc., Chem. Commun.* **1998**, 2097.