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Fries rearrangement in ionic melts

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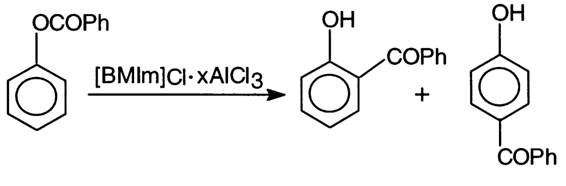
Abstract—1-Butyl-3-methylimidazolium chloroaluminate, $[\text{BMIm}]^+\text{Al}_2\text{Cl}_7^-$, was used as a solvent as well as a Lewis acid catalyst in Fries rearrangement reactions of phenyl benzoates. The rate of consumption of phenyl benzoate obeyed first-order kinetics. Good yields and high selectivity are the features observed in this unconventional but interesting aprotic solvent.

Ionic melts were first prepared by US scientists Frank Hurley and Tom Weir in the late 1940s. Initial phases of research on room temperature ionic melts centred on their potential applications in the field of electrochemistry.[1] However, recently scientists have started looking upon them as ideal solvents blessed with the ability to solvate a wide variety of organic substrates, defying the rule of thumb, 'like dissolves like'. Apart from the fact that they can solvate organic, organometallic and inorganic compounds, their negligible vapour pressure, ease of handling and potential for recycling, circumvent many of the problems associated with volatile, molecular organic solvents. Their properties can be altered by the fine-tuning of other parameters, such as the choice of organic cation, inorganic anion and alkyl chain attached to the organic cation. These properties have been exploited in reactions such as hydrogenation,[2] alkylation,[3] Diels–Alder reactions,[4] and many other reactions that have been reviewed.[5]

Halogeno and alkylhalogenoaluminate(III) ionic melts fascinated us the most owing to their remarkable Lewis acidity, which prompted us to try Fries rearrangements in such a system. Lewis acidity of such ionic melts is a function of the mole fraction of AlCl_3 present. We herein report for the first time Fries rearrangement reactions in 1-butyl-3-methylimidazolium chloroaluminate, $[\text{BMIm}]^+\text{Al}_2\text{Cl}_7^-$. Substantial rate enhancement, good yields and high selectivity by control of temperature are the features observed in this system. One of the interesting properties possessed by this system is the wide range of Lewis acidity attainable, variation of which can be brought about by changing the molar ratio of the two components,[6] viz. the organic halide and AlCl_3. In chloroaluminate ionic melts, the Lewis acid species present in AlCl_3-rich compositions is well established and known to be Al_2Cl_7^-. Composition of the ionic liquids is expressed as the apparent AlCl_3 mole fraction, N. Accordingly, they are classified as basic, neutral and acidic melts where N is 0–0.5, 0.5 and 0.5–0.67, respectively. The Fries rearrangement reaction of phenyl benzoate was carried out in $N=0.33$, 0.5 and 0.67 melts. Positive results were obtained only in the case of an acidic ionic melt as expected. This rearrangement reaction is known to be catalysed by Lewis acids; thus, in our attempt to envisage its effect on the extent of conversion, we carried out a series of experiments on phenyl benzoate (Scheme 1) at 120°C for 2 h by varying the melt composition in terms of AlCl_3, i.e. N over the range 0.56–0.67.



x	N	o (%)	p (%)
1.27	0.56	-	-
1.53	0.60	37	24
1.80	0.64	24	55
2.00	0.67	17	80

Scheme 1. Fries rearrangement of phenyl benzoate in $[\text{BMIm}]\text{Cl}\cdot x\text{AlCl}_3$.

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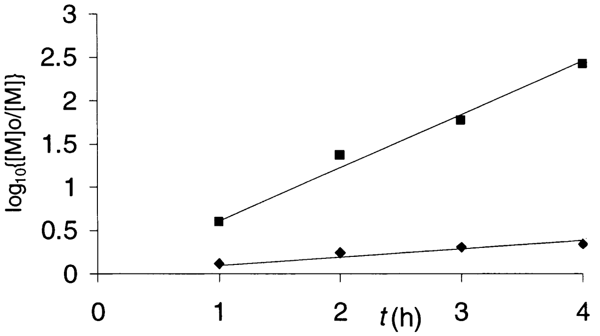


Figure 1. First-order plots of the Fries rearrangement of phenyl benzoate in $[BMIm]^+Al_2Cl_7^-$; (◆) reaction at 80°C; (■) reaction at 100°C. Conversion was monitored by GC.

Our studies revealed that the extent of conversion is a function of Lewis acidity of the ionic melt. This demonstrated the increase in catalytic activity of the melt due to the consequent increase in the concentration of the catalytic species $Al_2Cl_7^-$ as calculated.[7] On carefully monitoring the *o*/*p* ratio while the Lewis acidity was varied, it was observed that, at low Lewis acidity, more of the *o*-hydroxy benzophenone was formed but in melts of high Lewis acidity the proportion of *p*-hydroxy benzophenone increased as shown in Scheme 1.

The melt corresponding to $N=0.67$ gave maximum conversion (97%) and hence was utilised for further studies. The molar ratio of the phenyl benzoate to $[BMIm]^+Al_2Cl_7^-$ was optimised and was found to be 1:1.2, beyond which the increase in molar ratio resulted in no significant rise in the percentage conversion.

In order to investigate the rate of reaction in $[BMIm]^+Al_2Cl_7^-$, we carried out a series of experiments with constant amounts of phenyl benzoate and $[BMIm]^+Al_2Cl_7^-$, as described in the experimental procedure (see References), at different temperatures. Results revealed that the rate of consumption of phenyl benzoate obeyed first-order kinetics (Fig. 1).

Surprising results were observed when the effect of temperature on the *o*/*p* ratio of the rearranged product of phenyl benzoate at 80°C was studied. After 1 h of the reaction, 66% of the total product (26%) formed was found to be *ortho*, i.e. the thermodynamically-favoured product at low temperature. Higher regioselectivities were observed in this system at different temperatures. At 120°C, 81% *p*-product was obtained after 2 h whereas at 180°C, 85% *o*-product was obtained after 4 h. Apart from this, the variation of the *o*/*p* ratio with temperature and time is illustrated in Fig. 2.

In an attempt to contemplate the mechanistic details of the Fries rearrangement reaction in $[BMIm]^+Al_2Cl_7^-$, several experiments were carried out. Crossover experiments of phenyl benzoate and *p*-methylphenyl acetate were carried out at 120°C for 2 h, which resulted in typical products as expected from an intermolecular rearrangement reaction. However, the above experiment did not decisively prove intermolecularity since the possibility of transesterification or acyl/aroyl interchange could not be ruled out. Thus, phenyl benzoate was subjected to the rearrangement reaction in the presence of anisole at 120°C for 2 h, which gave *p*-methoxybenzophenone as the major product. This provided evidence for intermolecularity of the rearrangement reaction. Earlier endeavours to elucidate the mechanism of the Fries reaction led to three different mechanisms,[8] one of which emphasised the dissociation of the phenyl ester to furnish phenolate ions and an acid chloride which subsequently, via acylation, gave products. We carried out experiments on phenyl pivalate at 120°C; the reaction mixture gave off copious amounts of carbon monoxide. This indicated dissociation of the substrate to the oxocarbonium ion, $Me_3C\text{-}CO^+$, and phenolate ion, out of which the former underwent subsequent decomposition to the more stable *tert*-carbocation, $^+CMe_3$. However, in this case, trace amounts of a ketonic material were formed; therefore, to increase its yield by suppressing the decomposition of the acyl cation, the reaction was carried out at low temperature. The reaction at low temperature gave marginal yields; the other products obtained were phenol and the unreacted ester. The ketone that was obtained was characterised as the *o*-hydroxyketone, which suggested a probable intramolecular rearrangement via a polarised co-ordination complex of the ester and chloroaluminate species of the ionic melt.

The reaction was studied on various substrates in $[BMIm]^+Al_2Cl_7^-$ melt[9] at 120°C for 2 h. Good yields of the rearranged products were seen in the case of substrates bearing electron-donating groups, whereas in substrates bearing electron-withdrawing groups considerable debenzoylation was observed. The results are summarised in Table 1.

In conclusion, $[BMIm]^+Al_2Cl_7^-$ proved to be a useful medium for Fries rearrangements, eliminating the use of solvent by playing a dual role of solvent as well as Lewis acid catalyst. The substrates show significant increase in reactivity, minimising the reaction times and improving the yields substantially. The experimental procedure[10] is quite simple, avoiding tedious procedures

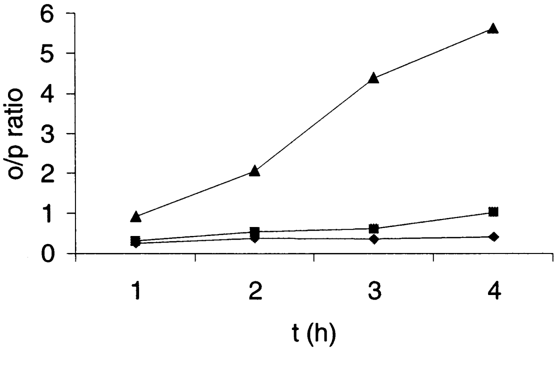
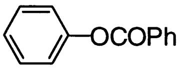
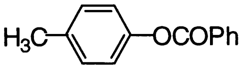
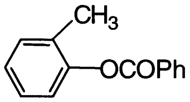
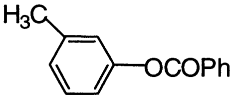
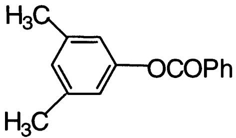
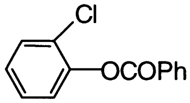
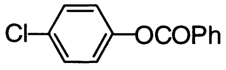
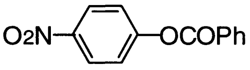


Figure 2. Fries rearrangement of phenyl benzoate in $[BMIm]^+Al_2Cl_7^-$: variation of *o*/*p* ratio with temperature and time; (◆) reaction at 140°C; (■) reaction at 160°C; (▲) reaction at 180°C.

Table 1. Fries rearrangement of phenyl benzoates in $[BMIm]^+Al_2Cl_7^-$

Entry	Substrate	Fries Product[a]		Debenzoylation (%)	Unreacted ester (%)
		o %	*p* %		
1		17	80	3	-
2		96	-	4	-
3		4	91	5	-
4		16	80	4	-
5		94	-	6	-
6		4	76	20	-
7		17	-	55	28
8		1	-	99	-

[a] % of *o*-, *p*-hydroxybenzophenones, unreacted ester and debenzoylation were determined by GC/MS.

and cumbersome work-up[11] involving the removal of solvents like nitrobenzene. Further investigations concerning the mechanism of this reaction in the melt are currently in progress.

References

1. Wilkes, J. S.; Levisky, J. A.; Wilson, R. A.; Hussey, C. L. *Inorg. Chem.* **1982**, *21*, 1263.
2. Dyson, P. J.; Ellis, D. J.; Parker, D. G.; Welton, T. *Chem. Commun.* **1999**, 25.
3. Earle, M. J.; McCormac, P. B.; Seddon, K. R. *Chem. Commun.* **1998**, 2245.
4. Fisher, T.; Sethi, A.; Welton, T.; Woolf, J. *Tetrahedron Lett.* **1999**, *40*, 793.
5. Review: Welton, T. *Chem. Rev.* **1999**, *99*, 2071.
6. Hussey, C. L. *Pure Appl. Chem.* **1988**, *60*, 1763.
7. Boon, J. A.; Levisky, J. A.; Pflug, J. L.; Wilkes, J. S. *J. Org. Chem.* **1986**, *51*, 480.
8. *Friedel–Crafts and Related Reactions*; Olah, G. A., Ed. Acylation and related reactions; Interscience: New York, 1964; Vol. III, p. 502.
9. The melt was prepared as previously described: (a) Wilkes, J. S.; Levisky, J. A.; Wilson, R. A.; Hussey, C. L. *Inorg. Chem.* **1982**, *21*, 1263; (b) Abdul-Sada, A. K.; Greenway, A. M.; Seddon, K. R.; Welton, T. *Org. Mass Spectrom.* **1993**, *28*, 759.
10. Experimental procedure: To the weighed quantity of $[BMIm]^+Al_2Cl_7^-$ melt (6 mmol), the aryl benzoate (5 mmol) was added and the mixture was stirred at different temperatures. The same quantities were used in the kinetic experiments. All additions were carried out in an inert atmosphere glove box. The reactions were quenched by adding 6 M HCl. The neutralised reaction mixture was then extracted with diethyl ether (3×5 mL). The combined organic layers were dried using sodium sulphate and evaporated under reduced pressure. The products, obtained after extraction, were then analysed by GC/MS, chromatographed using a silica gel column and further characterised by IR, NMR and physical constants.
11. Baltzly, R.; Ide, W. S.; Phillips, A. P. *J. Am. Chem. Soc.* **1955**, *77*, 2522.