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Synthesis of 1,3-dialkylimidazolium-2-carboxylates by direct carboxylation of 1,3-dialkylimidazolium chlorides with CO_2

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Abstract—1,3-Dialkylimidazolium-2-carboxylates **1a** and **1b** are obtained in good to excellent yield and selectivity by carboxylation of the corresponding 1,3-dialkylimidazolium chloride salts with a CO_2/Na_2CO_3 system at temperatures ranging from 80 to 135 °C. The effect of temperature and reaction time on the yield and the selectivity of the carboxylation products has been studied. Coupling the CO_2-based synthesis of 1,3-dialkylimidazolium-2-carboxylates with the transcarboxylation reaction described earlier [Tommasi, I.; Sorrentino, F.; *Tetrahedron Lett.*, **2005**, *46*, 2141] allows us to set up a new synthetic procedure for the synthesis of organic carboxylates and alkylcarbonate anions avoiding the use of strong bases.
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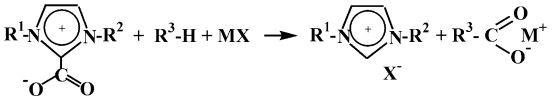
1. Introduction

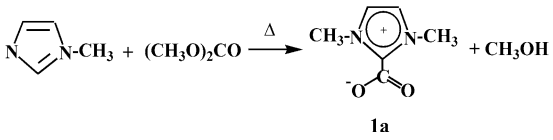
We have recently published the utilisation of imidazolium carboxylates of formula 1,3-dimethyl-imidazolium-2-carboxylate (**1a**) and 1-butyl, 3-methyl-imidazolium-2-carboxylate (**1b**) as CO_2 carriers in a transcarboxylation of acetophenone and methanol for the synthesis, in high yield and 100% selectivity, of benzoylacetate and monomethylcarbonate anions (Eq. 1).[1]



1a $R^1 = R^2 = CH_3$ **2a** $R^1 = R^2 = CH_3$
1b $R^1 = CH_3$, $R^2 = {}^nBu$ **2b** $R^1 = CH_3$, $R^2 = {}^nBu$ (1)

$R^3 = CH_3O$, $PhC(O)CH_2$
$MX = NaBF_4$, KPF_6, $NaBPh_4$

Previously, we reported the synthesis of 1,3-dimethyl-imidazolium-2-carboxylate (**1a**) from 1-methyl-imidazole and dimethylcarbonate according to Eq. 2.[2,3]



1a (2)

In this reaction, DMC acts as an alkylating/carboxylating agent. With the aim of setting up a new synthetic procedure for compounds **1a** and **1b** using CO_2 we set out to investigate direct carboxylation reactions of the corresponding 1,3-dialkylimidazolium chlorides with CO_2. Here we report the synthesis of 1,3-dialkylimidazolium-2-carboxylates **1a** and **1b** by carboxylation of the corresponding imidazolium chloride salt with a CO_2/Na_2CO_3 system at temperatures ranging from 80 to 135 °C. The synthesis of the 1,3-dialkyl-imidazolium-2-carboxylates using CO_2 and the subsequent transfer of the CO_2-moiety to C–H active compounds and alcohols represents a new synthetic strategy for obtaining, in high yields, organic carboxylates and alkylcarbonates avoiding the use of strong bases.

2. Synthesis of 1,3-dialkylimidazolium-2-carboxylates

The synthesis and full characterisation of the imidazolium carboxylates of formula 1,3-diisopropyl-4.5-dimethyl-imidazolium-2-carboxylate[4] **3** (Eq. 3) and 1,3-bis(2,6-diisopropylphenyl)imidazolium-2-carboxylate[5] **4** (Scheme 1) has been recently reported in the literature.

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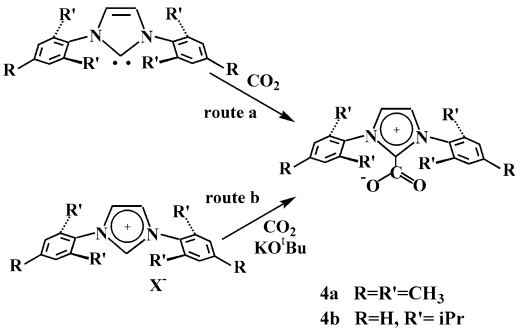
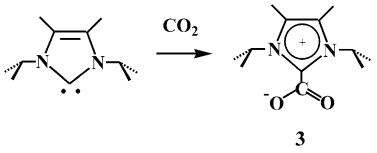


Scheme 1.

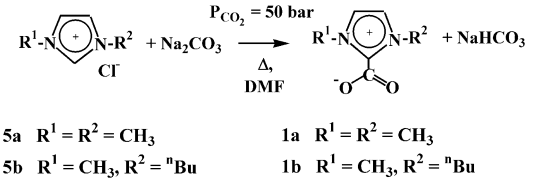
These carboxylates were synthesised by different procedures. Kuhn et al.[4] has reported the synthesis of 1, 3-diisopropyl-4.5-dimethyl-imidazolium-2-carboxylate **3** from the corresponding carbene and CO_2 as shown in Eq. 3



(3)

while Louie and co-workers[5] has reported the synthesis of 1,3-dimesitylimidazolium-2-carboxylate (**4a**) and 1,3-bis(2,6-diisopropylphenyl)imidazolium-2-carboxylate (**4b**) either by condensation of the corresponding carbene with CO_2 (Scheme 1, route a) or by reaction of the 1,3-dimesitylimidazolium and 1,3-bis(2,6-diisopropylphenyl)imidazolium salts with KO^{t}Bu under an atmosphere of CO_2 (Scheme 1, route b).

The synthesis of carboxylates **1a** and **1b** by procedures described in Eq. 3 and Scheme 1 is made difficult as the reaction of the imidazolium salts with KO^{t}Bu at room temperature caused dimerisation of the corresponding imidazole-2-ylidenes. As a matter of fact, the isolation of 1-butyl, 3-methyl-imidazol-2-ylidene requires more drastic conditions as reported by Seddon.[6] We have shown that 1,3-dialkylimidazolium-2-carboxylates **1a**[7] and **1b**[8] can be synthesised from 1,3-dialkylimidazolium chlorides and CO_2 through a Kolbe–Schmitt-type reaction carboxylating the imidazolium salts with Na_2CO_3/CO_2 in DMF according to Eq. 4.



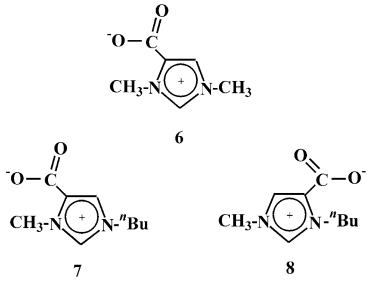
(4)

The reaction proceeds in high yield under strictly anhydrous conditions. Table 1 illustrates the dependence of the yield and the selectivity of the carboxylation products on the reaction conditions. The results show that the direct carboxylation can be carried out at relatively moderate temperatures (80 °C) in good yield without the formation of significant amounts of 4- and 5-carboxylate isomers (Scheme 2) that are formed at higher temperatures.

Moreover, optimal conditions for the synthesis of **1a** were obtained carrying out the reaction at 110 °C for 36 h (entry 2). Under these conditions, the 1,3-dimethylimidazolium-2-carboxylate is formed in high yield (92%) and selectivity (91%). Carrying out the reaction at 135 °C for 8 h causes the formation of the 4- and 5-carboxylate isomers in a relatively high yield (entries 3 and 6).[9]

3. Recycle of the imidazolium cation

As we have reported in a previous letter[1] the 1,3-dialkylimidazolium salt obtained as a product of the transcarboxylation reaction (**2a** and **2b**, Eq. 1) can be recovered easily and quantitatively from the reaction mixture. Due to the stability of the dialkylimidazolium cation under the reaction conditions, we set out to inves-

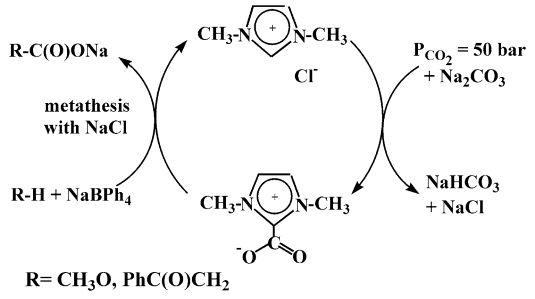


Scheme 2.

Table 1. Effect of temperature and reaction time on the yield and selectivity of the carboxylation reaction of 1,3-dimethylimizolium chloride (MMIM Cl) and 1-butyl, 3-methyl-imidazolium chloride (BMIM Cl) salts

Entry	Compound	Conditions		Yield[a] (%)	Selectivity (%)		
		Temperature (°C)	Time (h)		1,3-Dialkyl-imidazolium-2-COO$^-$	1,3-Dialkyl-imidazolium-4-COO$^-$	1,3-Dialkyl-imidazolium-5-COO$^-$
1	MMIM Cl	80	24	65	100	—	—
2	MMIM Cl	110	36	92	91	9	—
3	MMIM Cl	135	8	87	68	32	—
4	BMIM Cl	80	24	63	100	—	—
5	BMIM Cl	110	36	82	82	10	8
6	BMIM Cl	135	8	71	60	22	18

[a] Total conversion with respect to 1,3-dialkylimidazolium chlorides.



Scheme 3.

tigate the recycling of the cation in a new carboxylation reaction. Attempts to carboxylate the imidazolium cation starting from its BF_4^-, PF_6^-, and BPh_4^- salts (these anions were used in the transcarboxylation reaction,[1] Eq. 1) afforded a very low yield of the carboxylate product (<5%). Good results were obtained in the carboxylation reaction of 1,3-dialkylimidazolium chlorides (results shown in Table 1) and, in particular, 1,3-dimethylimidazolium-2-carboxylate was obtained with a higher yield and selectivity (entry 2, Table 1). In order to obtain 1,3-dialkylimidazolium chlorides, as products of the transcarboxylation reaction, Na^+ or K^+ chlorides had to be used which show a very low solubility in most organic solvents. We solved this problem by carrying out the transcarboxylation reaction using $NaBPh_4$ and recovering 1,3-dialkylimidazolium chloride from the reaction mixture by anion metathesis from 1,3-dialkylimidazolium tetraphenylborate.[10] It is possible, thus, to set up a two-step synthetic procedure for the synthesis of organic carboxylates and alkylcarbonates using CO_2 with recycling of the 1,3-dimethylimidazolium cation (Scheme 3).

The literature reports several examples of carboxylation with CO_2 of active methylene compounds, including acetophenone, by using a variety of catalysts such as metal phenoxides (MOPh, M = alkali metals[11,12] or Zn[13]), $La(OPr^i)_3$[14] complexes and organic bases like guanidine,[15] DBU,[16] diphenylcarbodiimide,[17] anilides.[18] These synthetic methodologies are usually affected by relatively low yields in benzoylacetate or require an excess of the catalyst for substrate quantitative conversion.[11] Here we present a new synthetic strategy for the synthesis of benzoylacetate in high yield avoiding the use of strong bases.

4. Conclusions

We describe a new easy synthesis of imidazolium carboxylates **1a** and **1b** by the direct carboxylation of dialkylimidazolium chlorides with CO_2. Coupling this carboxylation reaction to the transcarboxylation reaction of acetophenone or methanol previously reported[1] (Eq. 1) provides a new synthetic strategy for the synthesis of organic carboxylates and alkyl carbonates with CO_2 avoiding the use of strong bases. The dimethylimidazolium chloride (acting as a 'catalyst' in the synthetic process) can be effectively recycled from the reaction mixture by anion metathesis with NaCl.

Acknowledgements

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References and notes

1. Tommasi, I.; Sorrentino, F. *Tetrahedron Lett.* **2005**, *46*, 2141.
2. Holbrey, J. D.; Reichert, W. M.; Tkatchenko, I.; Bouajila, E.; Walter, O.; Tommasi, I.; Rogers, R. D. *Chem. Commun.* **2003**, 28.
3. Aresta, M.; Tkatchenko, I.; Tommasi, I. In *Ionic Liquids as Green Solvents: Progress and Prospects*; Rogers, R. D., Seddon, K. R., Eds.; ACS Symposium Series; ACS: Washington DC, 2003; Vol. 856, p 93.
4. Kuhn, N.; Steimann, M.; Weyers, G. *Z. Naturforsch.* **1999**, *54b*, 427.
5. Duong, H. A.; Tekavec, T. N.; Arif, A. M.; Louie, J. *Chem. Commun.* **2004**, 112.
6. K. R. Seddon has reported the synthesis and isolation of the 1-butyl,3-methyl-imidazol-2-ylidene by heating the corresponding imidazolium halide with strong bases under reduced pressure to separate the product, Earle J. M., Seddon R. K., U.S. Patent 0186803, 2003.
7. *Synthesis of 1,3-dimethylimidazolium-2-carboxylate* (**1a**). 5.21 g (0.039 mol) of 1,3-dimethylimidazolium chloride and 4.17 g (0.39 mol) of dry Na_2CO_3 were placed in a glass reactor of a magnetically stirred stainless steel autoclave under nitrogen atmosphere. 30 mL of dry DMF was added to the mixture. After closing, the autoclave was pressurised by CO_2 up to 50 bar, and the mixture was heated to 110 °C for 36 h under continuous stirring. The reaction was then stopped by cooling and depressurising the autoclave. The reaction mixture was transferred into a 100 mL Schlenk tube previously purged with nitrogen. The hot suspension (100 °C) was rapidly filtered under a N_2 atmosphere. By removing the solvent under reduced pressure, a white solid was obtained (5.03 g, 92% yield) fully characterised as a mixture of 1,3 dimethylimidazolium-2-carboxylate (91% of the mixture) and 1,3 dimethylimidazolium-4-carboxylate (9% of the mixture). *Characterisation of 1,3-dimethylimidazolium-2-carboxylate*. Anal. Calcd for $C_6H_8N_2O_2$: C, 51.42; H, 5.75; N, 19.99. Found: C, 51.68; H, 5.77; N, 19.77; IR (Nujol, KBr): 3152 (w), 3104 (s), 1665 (s), 1514 (m), 1247 (m), 1193 (w), 1103 (m) 1039 (w), 821 (m), 796 (s), 721 (m) cm^{-1}; ^1H NMR (D_2O, 500 MHz): δ 3.87 (s, 6H, *N*–CH_3), 7.32 (s, 2H, C4–*H* and C5–*H*); ^{13}C NMR (D_2O, 125 MHz): δ 36.64 (s, *N*–CH_3), 122.93 (s, C4 and C5), 139.43 (s, C2), 158.19 (s, *C*(O)O^-). The 1,3-dimethylimidazolium-4-carboxylate isomer was identified by comparison of its spectroscopic data with those of authentic samples obtained as described elsewere (Tommasi et al.,[3] Fischer J., Siegel W., Bomm V., Fischer M., Mundinger K., U.S. Patent 6 175 019, 2001). ^1H NMR (D_2O, 500 MHz): δ 3.77 (s, 3H, *N*1–CH_3), 3.90 (s, 3H, *N*3–CH_3), 7.68 (s, 1H, C5–*H*); ^{13}C NMR (D_2O, 125 MHz): δ 35.54 (s, *N*1–CH_3), 36.46 (s, *N*3–CH_3), 126.8 (s, *C*5), 130.52 (s, *C*4), 137.78 (t, C2, $^1J_{C-D} = 33$ Hz), 163.23 (s, –C(O)O–).
8. *Synthesis of 1-butyl, 3-methylimidazolium-2-carboxylate* (**1b**). 1-Butyl, 3-methyl imidazolium chloride (6.32 g, 0.036 mol) and 3.83 g (0.036 mol) of dry Na_2CO_3 were placed, under nitrogen atmosphere, in a glass reactor of a magnetically stirred stainless steel autoclave and to this was added 30 mL of dry DMF. After closing, the

autoclave, pressurised by CO_2 up to 50 bar, and the mixture was heated to 110 °C for 36 h. The reaction was stopped by cooling and depressurising the autoclave. The reaction mixture was transferred into a 100 mL Schlenk tube previously purged with nitrogen and filtered at room temperature. After evaporation of the solvent under reduced pressure, and recrystallisation from CH_3CN (4 °C), 5.4 g of a light yellow solid was obtained (82% yield) fully characterised as a mixture of 1-butyl,3-methylimidazolium-2-carboxylate (82% of the mixture), 1-butyl,3-methylimidazolium-4-carboxylate (10% of the mixture) and 1-butyl,3-methylimidazolium-5-carboxylate (8% of the mixture).

Characterisation of 1-butyl, 3-methylimidazolium-2-carboxylate (**1b**). Elemental analysis of the mixture: Anal. Calcd for $C_9H_{14}N_2O_2$: C, 59.32; H, 7.74; N, 15.37. Found: C, 59.73; H, 7.78; N, 15.18; IR (Nujol, KBr): 3145 (w), 3088 (s), 1662 (s), 1506 (m), 1323 (s) 1215 (w), 1172 (m), 1070 (s), 883 (m), 794 (s), 661 (m) cm^{-1}; ^1H NMR (D_2O, 500 MHz): δ 0.63 (m, 3H, *N*–CH_2–CH_2–CH_2–CH_3), 1.02 (m, 2H, *N*–CH_2–CH_2–CH_2–CH_3), 1.55 (m, 2H, *N*–CH_2–CH_2–CH_2–CH_3), 3.81 (m, 3H, *N*–CH_3), 4.25 (t, 2H, *N*–CH_2–CH_2–CH_2–CH_3), 7.34 (d, 1H, C4–*H*, $^3J_{H-H} = 1.8$ Hz), 7.39 (d, 1H, C5–*H*, $^3J_{H-H} = 1.8$ Hz); ^{13}C NMR (D_2O, 125 MHz): 13.08 (s, *N*–CH_2–CH_2–CH_2–CH_3), 19.16 (s, *N*–CH_2–CH_2–CH_2–CH_3), 32.27 (s, *N*–CH_2–CH_2–CH_2–CH_3), 36.88 (s, *N*–CH_3), 49.57 (s, *N*–CH_2–CH_2–CH_2–CH_3), 122.4 (s, C4), 123.39 (s, C5), 140.29 (s, C2), 158.15 (s, –*C*(O)O^-).

9. A mixture of 1-butyl, 3-methylimidazolium-4-carboxylate and 1-butyl, 3-methylimidazolium-5-carboxylate was obtained carrying out the carboxylation reaction at 135 °C for 8 h. The product mixture obtained as described in note 8 was reacted with a stoichiometric amount of HBF_4 as reported elsewhere.[3] After decarboxylation of 1-butyl, 3-methyl-imidazolium-2-carboxylate the pH was corrected to neutrality. A mixture of 1-butyl, 3-methylimidazolium-4-carboxylate (65%) and 1-butyl, 3-methylimidazolium-5-carboxylate (35%) was obtained by recrystallisation from CH_3CN.

   Spectroscopic characterisation of 1-butyl, 3-methyl imidazolium-4-carboxylate: ^1H NMR (D_2O, 500 MHz): δ 0.74 (m, 3H, *N*1–CH_2–CH_2–CH_2–CH_3), 1.17 (m, 2H, *N*1–CH_2–CH_2–CH_2–CH_3), 1.73 (m, 2H, *N*1–CH_2–CH_2–CH_2–CH_3), 3.95 (s, 3H, *N*3–CH_3), 4.42 (t, 2H, *N*1–CH_2–CH_2–CH_2–CH_3), 7.78 (s, 1H, C5–*H*); ^{13}C NMR (D_2O, 125 MHz): 13.09 (s, *N*1–CH_2–CH_2–CH_2–CH_3), 19.16 (s, *N*1–CH_2–CH_2–CH_2–CH_3), 31.55 (s, *N*1–CH_2–CH_2–CH_2–CH_3), 36.06 (s, *N*3–CH_3), 49.57 (s, *N*1–CH_2–CH_2–CH_2–CH_3), 125.26 (s, C5), 131.38 (s, C4), 137.53 (t, C2, $^1J_{C-D} = 32$ Hz), 163.03 (s, –*C*(O)O^-).

   Spectroscopic characterisation of 1-butyl, 3-methyl imidazolium-5-carboxylate. ^1H NMR (D_2O, 500 MHz): δ 0.74 (m, 3H, *N*1–CH_2–CH_2–CH_2–CH_3), 1.17 (m, 2H, *N*1–CH_2–CH_2–CH_2–CH_3), 1.73 (m, 2H, *N*1–CH_2–CH_2–CH_2–CH_3), 4.00 (s, 3H, *N*3–CH_3), 4.25 (t, 2H, *N*1–CH_2–CH_2–CH_2–CH_3), 7.72 (s, 1H, C4–*H*); ^{13}C NMR (D_2O, 125 MHz): 13.09 (s, *N*1–CH_2–CH_2–CH_2–CH_3), 19.16 (s, *N*1–CH_2–CH_2–CH_2–CH_3), 32.35 (s, *N*1–CH_2–CH_2–CH_2–CH_3), 36.14 (s, *N*3–CH_3), 49.67 (s, *N*1–CH_2–CH_2–CH_2–CH_3), 126.66 (s, C4), 130.78 (s, C5), 142.26 (t, C2, $^1J_{C-D} = 39$ Hz), 163.09(s, –*C*(O)O^-).

10. *Recycling of 1,3-dimethylimidazolium chloride.* The procedure for the synthesis of sodium benzoylacetate from 1,3-dimethylimidazolium-2-carboxylate and $NaBPh_4$ is described in a previous letter.[1] Following this procedure 1,3-dimethylimidazolium tetraphenylborate salt was obtained (3.24 g, 7.78 mmol) which was treated with NaCl (0.482 g, 8.25 mmol, 6% excess) and extracted with a water/THF biphasic system (20 mL of water and 75 mL of THF). After separation of the two phases 1,3-dimethylimidazolium chloride was recovered from the aqueous phase by precipitation with acetone followed by filtration and drying in vacuo (0.94 g, 7.1 mmol, 91% yield). $NaBPh_4$ was recovered from the organic phase by removing THF under reduced pressure and filtering the residual water suspension. After washing with diethyl ether and drying in vacuo, 2.27 g of $NaBPh_4$ (6.63 mmol, 85% yield) was recovered.

11. As examples see: Bottaccio G., Chiusoli G. P., Alneri E., Marchi M., Lana G., U.S. Patent 4,032, 555, 1977; Bottaccio, G.; Chiusoli, G. P.; Felicioli, M. G.; Tosi, E. *Gazz. Chim. Ital.* **1976**, *46*, 831.
12. Patmore E. L., Siegart W. R., Chafetz H., U.S. Patent 3,692,826, 1972.
13. Kunert, M.; Brauer, M.; Klobes, O.; Gorls, H.; Dinjus, E.; Anders, E. *Eur. J. Inorg. Chem.* **2000**, 1803.
14. Abe, H.; Inoue, S. *J. Chem. Soc., Chem. Commun.* **1994**, 1197.
15. Patmore E. L., U.S. Patent 3,694,496, 1972.
16. Mori, H. *Bull. Chem. Soc. Jpn.* **1988**, *61*, 435.
17. Chiba, K.; Tagaya, H.; Karasu, M.; Ono, T.; Hashimoto, K.; Moriwaki, Y. *Bull. Chem. Soc. Jpn.* **1991**, *64*, 966.
18. Chiba, K.; Tagaya, H.; Karasu, M.; Ishizuka, M.; Toshiyuki, Sugo *Bull. Chem. Soc. Jpn.* **1994**, *67*, 452.