Available online at www.sciencedirect.com
SCIENCE DIRECT®
Tetrahedron Letters 45 (2004) 9197–9201
Tetrahedron Letters

Synthesis of 2-pyrone-4-carboxaldehydes from acetylene dicarboxaldehyde monoacetal

Rufine Akué-Gédu,[a,†] Jean-Pierre Hénichart,[b,†] Daniel Couturier[c] and Benoît Rigo[a,*,†]

[a]*Ecole des Hautes Etudes Industrielles, 13 rue de Toul, 59046 Lille, France*
[b]*Institut de Chimie Pharmaceutique Albert Lespagnol, Université de Lille 2, 59006 Lille, France*
[c]*Laboratoire d'Ingénierie Moléculaire, Université des Sciences et Technologies, 59655 Villeneuve d'Ascq, France*

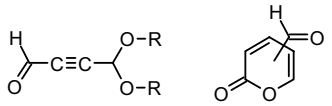
Received 6 October 2004; revised 14 October 2004; accepted 15 October 2004
Available online 2 November 2004

Abstract—Reaction of acetylene dicarboxaldehyde monoacetal with substituted Meldrum's acid leads good yields in 2-pyranones-4-carboxaldehydes substituted in position 3.

1. Introduction

Acetylene dicarboxaldehyde and its precursors monoacetals **1** and **2** are useful starting materials that have found many applications in dipolar cycloadditions,[1a–c] Diels–Alder,[1a,f–i] Michael,[1a,f,g,j] or Wittig[1k] reactions. As unsaturated aldehydes, **1** and **2** have a potential use in heterocyclic synthesis. We recently obtained a good yield in **1** starting from 2,5-dimethoxy-2,5-dihydrofuran,[2] and we now reacted this compound with some diesters in order to obtain protected aldehydes in the α-pyranone series (Fig. 1).

The α-pyranone target was chosen because to the best of our knowledge, in this system, only unsubstituted aldehydes **3** are described,[3a] while many methods for the synthesis of other 2-pyrones have been reported to date.[3b] The δ-lactone sub-unit frequently occurs in natural compounds, which present anti-inflammatory[4a] or stimul- ating[4b] properties. Some of these compounds are also inhibitors of the ATP metabolism,[4c] act as vasodilating and antiarrhythmic agents,[4d] are inhibitors of HIV-1 protease,[4e] or possess antimicrobial and cytotoxic activities.[4f] Furthermore α-pyrones are very useful substrates for Diels–Alder reactions with acetylene and olefin dienophiles producing benzene and cyclohexadiene derivatives.[4g]



1 R = Me
2 R = Et

3

Figure 1.

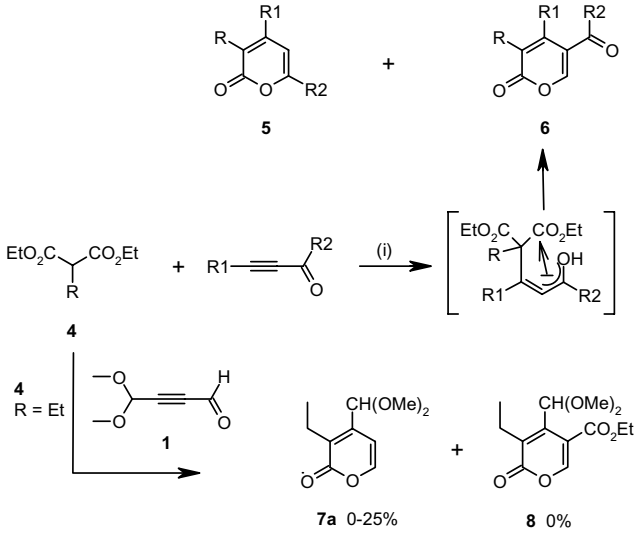
2. Results and discussion

Reaction of acetylenic ketones with ethyl diethyl malonate **4** has been described; depending on the catalyst-to-reagent ratio, α-pyranones **5** were obtained, or a rearrangement leading to esters **6** occurred.[5] When we used acetylenic aldehyde **1** and ester **4** (R = Et), whatever the conditions, only acetal **7a** was obtained in 0–25% yield and even traces of ester **8** were never observed (Scheme 1).

This reaction is rather similar to the condensation of acetylenic ketones with substituted Meldrum's acid **9**[6] described by Arcadi.[7] When we used acetylenic aldehyde **1** and ethyl Meldrum's acid **9** (R = Et) in these conditions (K_2CO_3, MeCN, TBAC), acetal **7a** was obtained in 75% yield after refluxing for 24 h (more than 48 h under reflux were necessary in the absence of a phase transfer agent). Modification of reaction parameters

Keywords: Acetylene dicarboxaldehyde; Meldrum's acid; 2-Pyranone-4-carboxaldehyde; Pyroglutamic acid.
* Corresponding author. Tel.: +33 2838 4858; fax: +33 2838 4804; e-mail: rigo@hei.fr
† Groupe de Recherche sur l'Inhibition de la Prolifération Cellulaire (EA 2692).

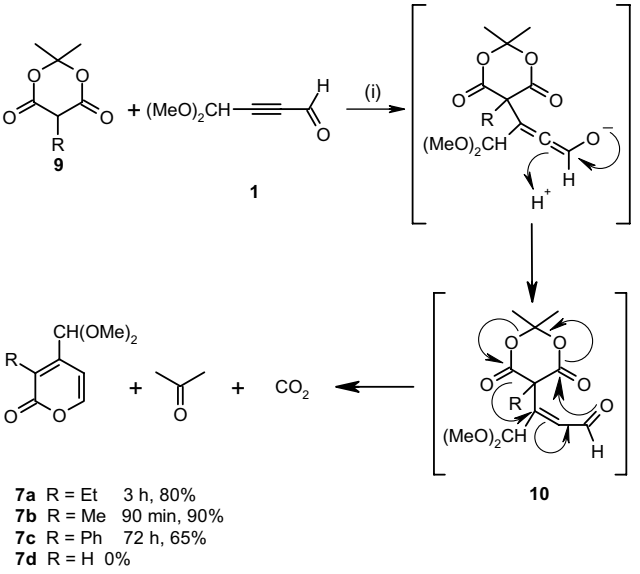
0040-4039/$ - see front matter © 2004 Elsevier Ltd. All rights reserved.
doi:10.1016/j.tetlet.2004.10.081



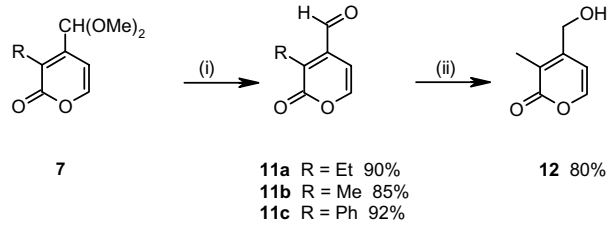
Scheme 1. Reagents and conditions: (i) EtONa/THF.

led to utilize TrisMethoxyEthoxyEthylAmine (TMEEA)[8] as phase transfer agent and THF as solvent; in that case, only 3 h under reflux were necessary to obtain 80% yield in **7a** (Scheme 2). It is noteworthy that the initial condensation leading to intermediate **10** is rather fast enough, even when 5% of TMEEA were used, while the yield in cyclized product **7a** is strongly dependent on the amount of the phase transfer agent. No improvements in the yields were obtained by using more than 50% of TMEEA.

As for the mechanism of the cyclization step, by analogy with the work of Shimizu,[5a] thermolysis of the α,β-unsaturated aldehyde **10** is plausible, because it is possible to observe the formation of this intermediate **10**[9] (or to isolate it by using preparative chromatography). Thus the large amount of phase transfer agent would be necessary in order to improve the proton exchange leading to **10**.



Scheme 2. Reagents and conditions: (i) K_2CO_3/TMEEA/THF.



Scheme 3. Reagents and conditions: (i) R = Me, Et:CF_3CO_2H/CH_2Cl_2/20 °C; R = Ph:HCl/H_2O/CH_2Cl_2/20 °C; (ii) R = Me:$NaBH_4$/MeOH, 0 °C.

While only decomposition was observed when Meldrum's acid (**9**, R = H) was opposed to acetylenic aldehyde **1**, the reaction is general for his mono substituted derivatives and good yields in protected aldehydes **7b** and **7c** were easily obtained (Scheme 2).

Some aspects of the reactivity of theses acetals were investigated: hydrolysis of the acetal function of pyranone **7a** took 50 h at room temperature in diluted hydrochloric acid (for **7c**: 20 h under reflux in HCl/CH_2Cl_2). Gorgues described a deprotection of acetals by formic acid.[1f,g] In a variation of this method, by using trifluoroacetic acid in dichloromethane, aldehydes **7a** and **7b** were rapidly obtained in very good yield (CH_2Cl_2, 45 min, 20 °C) (Scheme 3).

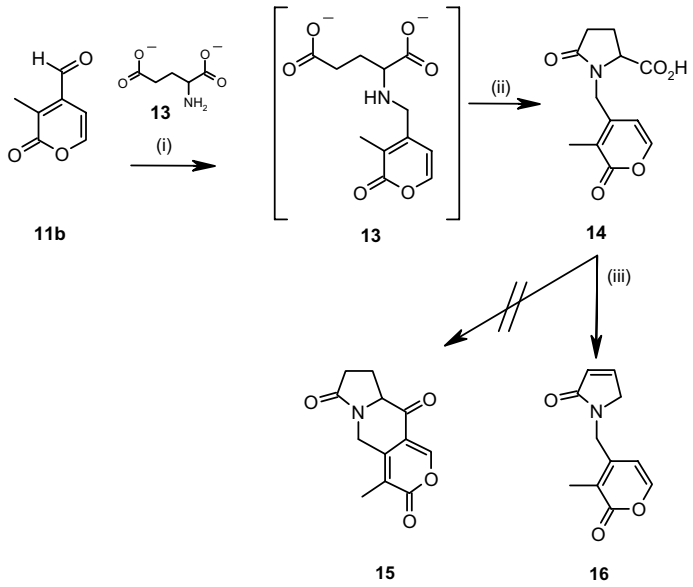
Because of our interest in pyroglutamic acid chemistry,[10] we realized the $NaBH_4$ reduction of the aldehyde group of **11b** (which led to 80% of alcohol **12**) and then the reductive alkylation of glutamic acid (Scheme 4). In that reaction, it is better to use the di-sodium salt of glutamic acid[11] than to start from the di-triethyl ammonium salt.[12] Indeed, removing triethyl ammonium salts from the crude acid **14** proved to be difficult. The substituted glutamic acid intermediate rapidly cyclized into pyroglutamic acid **14** that did not yield ketone **15** under Friedel–Crafts conditions: decarbonylation of activated acid **14** yielded an iminium salt that evolved to ene lactam **16**[13] (Scheme 4).

3. Conclusion

The easy synthetic pathways described in this work can now be considered as useful tools for the synthesis of α-pyranones-4-carboxaldehydes.

4. Experimental

Melting points were determined using an Electrothermal apparatus and are uncorrected. ^1H and ^{13}C NMR spectra were obtained on a Varian Gemini 2000 at 200 and 50 MHz, respectively. IR spectra were realized in ATR mode on a FTIR Bruker Tensor 27. Thin layer chromatography was performed on precoated Kieselgel 60F_{254} plates. Microanalyses were performed by the 'Service Central de Microanalyses of CNRS in Vernaison, France.



Scheme 4. Reagents and conditions: (i) (a) NaOH/MeOH/H_2O, 20 °C; (b) $NaBH_4$, 0 °C; (ii) HCl, reflux; (iii) TFAA, BF_3/ether.

4.1. 4-(Dimethoxymethyl)-3-ethyl-2*H*-pyran-2-one 7a

A stirred mixture of aldehyde **1** (23.1 g, 0.174 mol), ethyl Meldrum's acid **9** (R = Et) (30 g, 0.174 mol), TMEEA (29.1 g, 0.087 mol) in THF (300 mL) was refluxed for 3 h. The solvent was evaporated, the solid residue was washed with ethyl acetate, the organic phase was washed with slightly acidic water, then dried ($MgSO_4$). The yellow oil obtained after evaporation was purified by chromatography (200–400 mesh SiO_2, ethyl acetate/heptane 30:70), leading to 80% of acetal **7a** as a yellow oil, TLC R_f [ethyl acetate/heptane 70:30] = 0.45; IR ν cm^{-1}: 1770, 1710, 1630, 1560; ^1H NMR ($CDCl_3$) δ ppm: 1.14 (t, J = 7.5 Hz, 3H), 2.58 (q, J = 7.5 Hz, 2H), 3.36 (s, 6H), 5.29 (s, 1H), 6.45 (d, J = 5.6 Hz, 1H), 7.40 (d, J = 5.6 Hz, 1H). ^{13}C NMR ($CDCl_3$) δ ppm: 12.6, 19.8, 53.4, 99.0, 104.7, 129.2, 146.8, 147.7, 162.8.

Anal. Calcd for $C_{10}H_{14}O_4$, $0.5H_2O$: C, 57.96; H, 7.30; O, 34.74. Found: C, 60.37; H, 7.39; O, 32.18.

During the reaction, it is possible to observe a 50:50 mixture of *E*/*Z* addition compounds **10a**:

E-**10a**: ^1H NMR ($CDCl_3$) δ ppm: 1.06 (t, J = 7.3 Hz, 3H), 1.76 (s, 3H), 1.84 (s, 3H), 2.19 (q, J = 7.3 Hz, 2H), 3.33 (s, 6H), 5.47 (d, J = 1.4 Hz, 1H), 6.18 (dd, J = 6.8, 1.4 Hz, 1H), 10.28 (d, J = 6.8 Hz, 1H). *Z*-**10a**: ^1H NMR ($CDCl_3$): δ ppm: 1.04 (t, J = 7.5 Hz, 3H), 1.76 (s, 3 H), 1.84 (s, 3H), 1.75 (q, J = 7.5 Hz, 2H), 3.29 (s, 6H) 5.79 (d, J = 1.4 Hz, 1H), 6.74 (dd, J = 7.7, 1.4 Hz, 1H), 9.83 (d, J = 7.7 Hz, 1H).

4.2. 4-(Dimethoxymethyl)-3-methyl-2*H*-pyran-2-one 7b

This compound was obtained as for acetal **7a** (reflux 90 min, yellow oil, 90%): ^1H NMR ($CDCl_3$) δ ppm: 2.14 (s, 3H), 3.36 (s, 6H), 5.28 (s, 1H), 6.47 (d, J = 5.4 Hz, 1H), 7.36 (d, J = 5.4 Hz, 1H).

Anal. Calcd for $C_9H_{12}O_4$, H_2O: C, 53.46; H, 6.96; O, 39.56. Found: C, 53.12; H, 7.17; O, 39.79.

4.3. 4-(Dimethoxymethyl)-3-phenyl-2*H*-pyran-2-one 7c

This compound was obtained as for acetal **7a** (reflux 72 h, yellow oil, 65%); IR ν cm^{-1}: 1712, 1635, 1558, 1443; ^1H NMR ($CDCl_3$) δ ppm: 3.28 (s, 6H), 4.84 (s, 1H), 7.30–7.46 (m, 5H), 6.57 (d, J = 5.3 Hz, 1H), 7.50 (d, J = 5.3 Hz, 1H).

Anal. Calcd for $C_{14}H_{14}O_4$, H_2O: C, 63.63; H, 6.10; O, 30.27. Found: C, 63.27; H, 6.38; O, 30.48.

4.4. 3-Ethyl-2-oxo-2*H*-pyran-4-carbaldehyde 11a

A mixture of acetal **7a** (30 g, 0.151 mol) and trifluoroacetic acid (20.2 mL, 0.263 mol) in CH_2Cl_2 (100 mL) was stirred at room temperature for 45 min. The solvent was evaporated and the residue was dissolved in CH_2Cl_2, washed with water, then dried ($MgSO_4$). The organic phase was evaporated leading to a solid, which was recrystallized from ethyl acetate, giving a 90% yield of aldehyde **11a**; mp 35–36 °C; TLC R_f [ethyl acetate/heptane 70:30] = 0.50; IR ν cm^{-1}: 1715, 1690, 1625, 1570, 1480; ^1H NMR ($CDCl_3$) δ ppm: 1.29 (t, J = 7.5 Hz, 3H), 2.98 (q, J = 7.5 Hz, 2H), 6.56 (d, J = 5.6 Hz, 1H), 7.42 (d, J = 5.6 Hz, 1H), 10.33 (s, 1H). ^{13}C NMR ($CDCl_3$) δ ppm: 14.3, 18.4, 101.5, 137.5, 139.9, 148.8, 163.0, 188.6.

Anal. Calcd for $C_8H_8O_3$: C, 63.15; H, 5.30; O, 31.55. Found: C, 62.97; H, 5.54; O, 31.42.

4.5. 3-Methyl-2-oxo-2*H*-pyran-4-carbaldehyde 11b

This compound was obtained as for aldehyde **11a**, mp (ethyl acetate) 116–118 °C; IR ν cm^{-1}: 1700, 1683, 1627, 1540; ^1H NMR ($CDCl_3$) δ ppm: 2.42 (s, 3H), 6.57 (d, J = 5.5 Hz, 1H), 7.43 (d, J = 5.5 Hz, 1H), 10.36

(d, $J = 0.9$ Hz, 1H); ^{13}C NMR ($CDCl_3$) δ ppm: 11.0, 101.5, 131.9, 140.3, 148.5, 163.6, 188.5.

Anal. Calcd for $C_7H_6O_3$: C, 60.87; H, 4.38; O, 34.75. Found: C, 60.71; H, 4.38; O, 34.68.

4.6. 2-Oxo-3-phenyl-2*H*-pyran-4-carbaldehyde 11c

A solution of acetal **7c** (5.6 g, 0.023 mol), in a mixture of CH_2Cl_2 (100 mL), water (20 mL) and 36% HCl (22.3 mL, 0.23 mol), was stirred at room temperature for 68 h. The organic phase was washed with water, dried ($MgSO_4$) and then evaporated. The solid obtained was recrystallized from ethyl acetate, mp 167–168 °C; IR ν cm^{-1}: 1712, 1683, 1624, 1550, 1443; ^{1}H NMR ($CDCl_3$) δ ppm: 6.72 (d, $J = 5.5$ Hz, 1H), 7.39–7.54 (m, 5H), 7.55 (dd, $J = 5.5$, 0.8 Hz, 1H), 9.75 (d, $J = 0.8$ Hz, 1H); ^{13}C NMR ($CDCl_3$) δ ppm: 102.0, 128.4, 129.3, 130.1, 131.0, 134.4, 141.2, 150.5, 162.3, 190.1.

Anal. Calcd for $C_{12}H_8O_3$, $2H_2O$: C, 61.02; H, 5.12; O, 33.86. Found: C, 60.81; H, 4.96; O, 34.21.

4.7. 4-(Hydroxymethyl)-3-methyl-2*H*-pyran-2-one 12

Sodium borohydride (0.10 g, 2.6 mmol) was added to a cooled (0 °C) solution of aldehyde **11b** (0.4 g, 3 mmol) in methanol (10 mL). The mixture was stirred for 30 min and then the solvent was evaporated. The residue was dissolved in ethyl acetate and the solution was acidified with 1 N HCl. The aqueous phase was extracted with ethyl acetate and the combined organic phases were dried (Na_2SO_4) then evaporated, leading to 80% of alcohol **12** as hygroscopic crystals, which were not analyzed, IR ν cm^{-1}: 3390, 1680, 1625, 1550, 1380; ^{1}H NMR ($CDCl_3$) δ ppm: 2.02 (s, 3H), 3.36 (s, 1H, deuterium oxide exchangeable), 4.60 (s, 2H), 6.53 (d, $J = 5.4$ Hz, 1H), 7.40 (d, $J = 5.4$ Hz, 1H).

4.8. 1-[(3-Methyl-2-oxo-2*H*-pyran-4-yl)methyl]-5-oxoproline 14

Aldehyde **11b** (2.5 g, 18.1 mmol) in methanol (30 mL) was added to a stirred solution of glutamic acid (5.3 g, 36.2 mmol) and sodium hydroxide (2.9 g, 72.4 mmol) in water (10 mL). The mixture was stirred at room temperature for 3 h and then cooled at 0 °C. $NaBH_4$ powder (0.17 g, 4.5 mmol) was slowly added while keeping the same temperature. The solution was stirred at room temperature for 5 h and then acidified (pH 1) with 1 N HCl, giving a mixture of acids **13** (diacid form) and **14**. The mixture was refluxed for 2 h, water was evaporated and the residue was stirred with acetone. After filtration of solids and drying ($MgSO_4$), the solvent was evaporated, and the residue was purified by chromatography on SiO_2 (ethyl acetate/MeOH 50:50), giving acid **14** (80%), which was recrystallized from acetone, mp 181–182 °C, TLC R_f [ethyl acetate/MeOH 50:50] = 0.45; IR ν cm^{-1}: 1740, 1710, 1690, 1635, 1190; ^{1}H NMR ($CDCl_3$) δ ppm: 2.07 (s, 3H), 2.08–2.37 (m, 2H), 2.37–2.65 (m, 2H), 3.70 (s, 2H, deuterium oxide exchangeable), 3.95 (dd, $J = 8.2$, 3.4 Hz, 1H), 4.08 (d, $J = 15.8$ Hz, 1H), 4.72 (d, $J = 15.8$ Hz, 1H), 6.12 (d, $J = 5.4$ Hz, 1H), 7.31 (d, $J = 5.4$ Hz, 1H).

Anal. Calcd for $C_{12}H_{13}NO_5$, H_2O: C, 53.53; H, 5.62; O, 35.65. Found: C, 53.19; H, 6.01; O, 35.92.

4.9. 1-[(3-Methyl-2-oxo-2*H*-pyran-4-yl)methyl]-1,5-dihydro-2*H*-pyrrol-2-one 16

This is the lone product identified by NMR when a mixture of acid **14**, trifluoroacetic anhydride and boron trifluoride etherate were reacted in diverse conditions; ^{1}H NMR ($CDCl_3$) δ ppm: 2.09 (s, 3H), 3.93 (t, $J = 1.9$ Hz, 2H), 5.21 (s, 2H), 6.02 (d, $J = 5.4$ Hz, 1H), 6.27 (tt, $J = 9.7$, 1.9 Hz, 1H), 7.16 (tt, $J = 9.7$, 1.9 Hz, 1H), 7.32 (d, $J = 5.4$ Hz, 1H).

References and notes

1. (a) Gorgues, A. *Janssen Chim. Acta* **1986**, *4*, 21–26; (b) Gorgues, A.; Le Coq, A. *Tetrahedron Lett.* **1979**, *20*, 4829–4832; (c) Henkel, K.; Weygand, F. *Chem. Ber.* **1943**, *76B*, 812–821; (d) Ramanaiah, K. C. V.; Stevens, E. D.; Trudell, M. L.; Pagoria, P. F. *J. Heterocycl. Chem.* **2000**, *37*, 1597–1602; (e) Frère, P.; Belyasmine, A.; Gouriou, Y.; Jubault, M.; Gorgues, A.; Duguay, G.; Wood, S.; Reynolds, C. D.; Bryce, M. R. *Bull. Soc. Chim. Fr.* **1995**, *132*, 975–984; (f) Gorgues, A.; Simon, A.; Le Coq, A.; Hercouet, A.; Corre, F. *Tetrahedron* **1986**, *42*, 351–370; (g) Gorgues, A.; Stephan, D.; Belyasmine, A.; Khanous, A.; Le Coq, A. *Tetrahedron* **1990**, *46*, 2817–2826; (h) Gorgues, A.; Le Coq, A. *Chem. Commun.* **1979**, 767–768; (i) Stephan, D.; Gorgues, A.; Belyasmine, A.; Le Coq, A. *Chem. Commun.* **1988**, 263–264; (j) Blanco, L.; Bloch, R.; Bugnet, E.; Deloisy, S. *Tetrahedron Lett.* **2000**, *41*, 7875–7878; (k) Barrett, A. G. M.; Hamprecht, D.; Ohkubo, M. *J. Org. Chem.* **1997**, *62*, 9376–9378.
2. Akué-Gédu, R.; Rigo, B. *Tetrahedron Lett.* **2004**, *42*, 1829–1832.
3. (a) Kurek, J. T.; Vogel, G. *J. Heterocycl. Chem.* **1968**, *5*, 275–276; Klunder, A. J. H.; Bos, W.; Verlaak, J. M. M.; Zwanenburg, B. *Tetrahedron Lett.* **1981**, *22*, 4553–4556; (b) Staunton, J. In *Comprehensive Organic Chemistry*; Sammes, P. G., Ed.; Pergamon: Oxford, 1979; Vol. 4, pp 629–658; Stetter, H.; Kogelnik, X. *Synthesis* **1986**, 140–142; Larock, R. C.; Doty, M. J.; Han, X. *J. Org. Chem.* **1999**, *64*, 8770–8779; Bellina, F.; Biagetti, M.; Carpita, A.; Rossi, R. *Tetrahedron Lett.* **2001**, *42*, 2859–2863; Thibonnet, J.; Abarbri, M.; Parrain, J.-L.; Duchêne, A. *J. Org. Chem.* **2002**, *67*, 3941–3944; Anastasia, L.; Xu, C.; Negishi, E.-I. *Tetrahedron Lett.* **2002**, *43*, 5673–5676.
4. (a) Moreno-Manas, M.; Pleixats, R. *Adv. Heterocycl. Chem.* **1992**, *53*, 1–84; (b) Mors, W. B.; Magalhaes, M. T.; Gottlieb, O. R. *Fort. Chem. Org. Nat.* **1962**, *20*, 131–164; (c) Vleggaar, R. *Pure Appl. Chem.* **1986**, *58*, 239–256; (d) Leite, L.; Jansone, D.; Veveris, M.; Cirule, H.; Popelis, Y.; Melikyan, G.; Avetisyan, A.; Lukevics, E. *Eur. J. Med. Chem.* **1999**, *34*, 859–865; (e) Prasad, J. V. N. V.; Para, K. S.; Lunney, E. A.; Ortwine, D. F.; Dunbar, J. B.; Fergusson, D.; Tummino, P. J.; Hupe, D.; Tait, B. D.; Domagala, J. M.; Humblet, C.; Bhat, T. N.; Liu, B.; Guerin, D. M. A.; Baldwin, E. T.; Erickson, J. W.; Sawyer, T. K. *J. Am. Chem. Soc.* **1994**, *116*, 6989–6990; (f) Fairlamb, I. J. S.; Marrison, L. R.; Dickinson, J. M.; Lu, F.-J.; Schmidt, J. P. *Bioorg. Med. Chem.* **2004**, *12*, 4285–4299; (g) Afarinkia, K.; Vinader, V.; Nelson, T. D.; Posner, G. H. *Tetrahedron* **1992**, *48*, 9111–9171.
5. (a) Hachiya, I.; Shibuya, H.; Shimizu, M. *Tetrahedron Lett.* **2003**, *44*, 2061–2063; (b) See also: Ma, S.; Yin, S.; Li, L.; Tao, F. *Org. Lett.* **2002**, *4*, 505–507; Hachiya, I.;

Ogura, K.; Shimizu, M. *Synthesis* **2004**, *9*, 1349–1352.
6. For reviews on the chemistry of Meldrum's acid derivatives, see: McNab, H. *Chem. Soc. Rev.* **1978**, *7*, 345–358; Chen, B.-C. *Heterocycles* **1991**, *32*, 529–597.
7. Arcadi, C.; Cacchi, S.; Marinelli, F.; Pace, P. *Synlett* **1993**, *10*, 741–742, See also Ref. 5a.
8. Soula, G. *J. Org. Chem.* **1985**, *50*, 3717–3721; Stafford, A. J.; McMurry, J. E. *Tetrahedron Lett.* **1988**, *29*, 2531–2534; The use of the very efficient and inexpensive phase transfer agent TMEEA as phase transfer agent strongly accelerates many ionic reactions: Tamao, K.; Nakagawa, Y.; Ito, Y. *Org. Synth.* **1998**, *Coll. Vol. IX*, 539–547.
9. In his work,[7] Arcadi observed or isolated such intermediates.
10. Rigo, B.; Kolocouris, N. *J. Heterocycl. Chem.* **1983**, *20*, 893–898; Rigo, B.; Gautret, P.; Legrand, A.; El Ghammarti, S.; Couturier, D. *Synth. Commun.* **1994**, *24*, 2609–2615; Rigo, B.; Barbry, D.; Couturier, D. *Synth. Commun.* **1991**, *21*, 741–747; Al Akoum Ebrik, S.; Legrand, A.; Rigo, B.; Couturier, D. *J. Heterocycl. Chem.* **1999**, *36*, 997–1000; Bourry, A.; Akué-Gédu, R.; Hénichart, J.-P.; Sanz, G.; Rigo, B. *Tetrahedron Lett.* **2004**, *45*, 2097–2101.
11. Marchalin, S.; Kadlecikova, K.; Bar, N.; Decroix, B. *Synth. Commun.* **1998**, *28*, 3619–3624; Szemes, F.; Marchalin, S.; Bar, N.; Decroix, B. *J. Heterocycl. Chem.* **1998**, *35*, 1371–1375.
12. Bourry, A.; Akué-Gédu, R.; Rigo, B.; Hénichart, J.-P. *J. Heterocycl. Chem.* **2003**, *40*, 989–993.
13. Akué-Gédu, R.; Al Akoum Ebrik, S.; Witczak-Legrand, A.; Fasseur, D.; El Ghammarti, S.; Couturier, D.; Decroix, B.; Othman, M.; Debacker, M.; Rigo, B. *Tetrahedron* **2002**, *58*, 9239–9247.