A Domino Spirocyclization to Form Lactams

Lutz F. Tietze*[a] and Peter L. Steck[a]

Dedicated to Professor Edwin Vedejs on the occasion of his 60th birthday

Keywords: Domino reactions / Aluminum / Spiro compounds / Michael additions / Lactams

Spirocyclic amides are easily obtained from primary amines, cycloenones and acrylic acid methyl ester. The key step is a two-component domino process that includes the formation of an amide followed by a Michael addition in the presence of trimethylaluminum.

Introduction

The domino concept has proven to be an elegant and highly efficient approach in organic synthesis.[1] These one-pot processes have been demonstrated to allow the formation of complex molecules from simple substrates in an short and efficient manner.[2−4] Domino reactions are not only economically beneficial since they save time and resources but they also reduce the waste formed in the synthesis and thus preserve our environment.

We recently developed a highly efficient access to the unique pentacyclic alkaloid cephalotaxine based on two transition-metal-catalyzed transformations.[5,6] In order to improve the pharmacological activity we have also synthesized several analogs of this natural product with varying ring sizes.[7,8] In our further efforts towards oxo-cephalotaxine systems we are currently investigating several compounds containing lactam structures.[9]

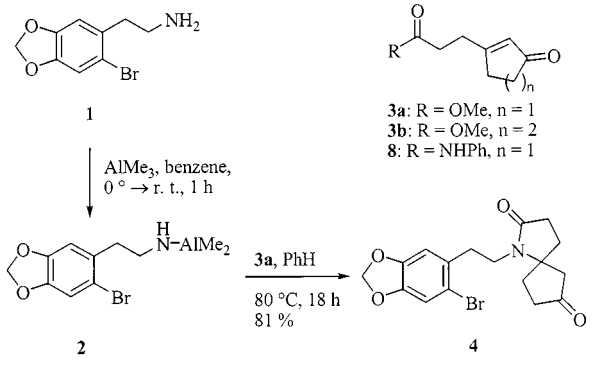
In 1977, Weinreb et al. reported a mild method for the preparation of amides from carboxylic esters using $AlMe_3$.[10] In this reaction trimethylaluminum reacts with ammonia, or primary or secondary amines with evolution of methane to give highly reactive dimethyl aluminum amides.[11] These reagents react readily with esters to form the corresponding carboxylic acid amides at room temperature, or at slightly elevated temperatures, in dichloromethane. This methodology has also been extended to the formation of carboxylic acid hydrazides from esters and hydrazine derivatives.[12] The carboxylic acid amide formation using aluminium amides has been used in several total syntheses of natural products.[11,13]

We now report the efficient formation of spirocyclic lactams such as **4** by a two compound domino process from primary dimethylaluminum amides and esters containing an enone moiety.

[a] Institut für Organische Chemie der Georg-August-Universität Göttingen
Tammannstraße 2, 37077 Göttingen, Germany
Fax: (internat.) +49-(0)551/399-476
E-mail: ltietze@gwdg.de

Results and Discussion

Retrosynthetically, the spirocyclic lactams such as **4** were envisioned to be synthesized from substrates containing an ester moiety as well as an α,β-unsaturated cyclic ketone. In this investigation we used cyclopentenones and cyclohexenones with a propionate side chain as starting material since Kim et al. have demonstrated a facile one-step synthesis of the desired 3-(3-oxo-cyclopent-1-enyl)propionic acid methyl ester **3a** by a phosphasilylation reaction from 2-cyclopentenone and acrylic acid methyl ester.[14] We were delighted to find that the previously synthesized, functionalized primary amine **1**[5] could be activated by trimethylaluminum to give the dimethyl aluminum amide **2**, which reacts with **3a** in benzene at 80 °C to form the spirocyclic lactam **4** in 81% yield (Scheme 1).



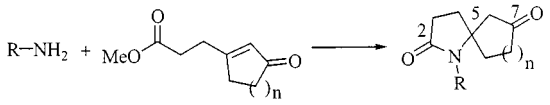
Scheme 1. Synthesis of spiro lactam **4**

We investigated the generality of this domino process with various primary amines and variations of the cycloenone ring size. The results are summarized in Table 1.

The reaction proceeds with high yields when benzyl- or (2-phenylethyl)amine are used (entries 2, 3). As expected, aniline reacts much slower under the same reaction conditions to give only 23% of the desired spirocycle **7** and 35% of the open amide **8** (entry 4). The reaction is also sensitive towards steric hindrance. This fact is emphasized by the reaction of aliphatic amines: 1-Butylamine reacts with an acceptable yield, whereas 2-butylamine gives only a low yield and no reaction was observed when *tert*-butylamine was

  1434−193X/01/1122−4353 $ 17.50+.50/0

Table 1. Results of the domino spirocyclization



3a,b 4-7, 9-14

Entry	Amine	Product	R	n	Yield, [%]
1	**1**	**4**		1	81
2	phenethylamine	**5**	$C_6H_5CH_2CH_2$	1	71
3	benzylamine	**6**	$C_6H_5CH_2$	1	79
4	aniline	**7**	C_6H_5	1	23
		+ **8**			35
5	*n*-butylamine	**9**	*n*-C_4H_9	1	53
6	*sec*-butylamine	**10**	$CH_3CHCH_2CH_3$	1	21
7	*tert*-butylamine	**11**	$(CH_3)C$	1	–
8	6-aminohexan-1-ol	**12**	$HO(CH_2)_6$	1	34
9	benzylamine	**13**	$C_6H_5CH_2$	2	80
10	phenethylamine	**14**	$C_6H_5CH_2CH_2$	2	41

used (entries 5–7). The reaction tolerates other functional groups such as an unprotected alcohol or aryl halide (entries 8, 1). In order to investigate the importance of the ring size of the enone moiety, 3-(3-oxocyclohex-1-enyl)propionic acid methyl ester (**3b**), obtained from cyclohexenone and methyl acrylate in 71% yield, was used as substrate. In the domino process with benzylamine 80% of the desired 6,5-spirocycle **13** was obtained (entry 9). In a similar reaction, phenethylamine gave the spiro compound **14**, although in lower yield.

We propose the following mechanism. In the first step, the dimethylaluminum amide reacts with the ester moiety, forming an open chain amide such as **8**. The amide nitrogen then acts as a nucleophile which adds to the Michael system, probably assisted by the aluminum species. The reaction of aniline and **3a** giving the open amide **8** in considerable amounts is an indication of this path, and furthermore the isolated amide **8** could be cyclized to form the spirocyclic lactam **7** by heating in benzene at 80 °C, although only with a low rate. This low rate is reasonable, since the intermediate aluminum carboxylic acid amide should have a much higher nucleophilicity than the amide itself. However, addition of trimethylaluminum or aluminum trichloride to **8** to form such an intermediate only led to decomposition of the starting material.

The structure of the spirolactams was mainly determined by ^{13}C NMR spectroscopy. In the spectra of the 5,5-spirocycles signals are found for C-7 at δ = 213.6–214.0, whereas the amide carbons C-2 resonate at δ = 174.7–174.9 and the spirocyclic C-5 at δ = 66.53–68.25. For the 6,5-spirocycles **13** and **14** the corresponding resonances are observed at δ = 208.0–208.1, 174.4 and 65.73–66.00.

Conclusion

We were able to demonstrate a highly efficient entry into spirocyclic lactam systems from primary amines, cycloalkenones and acrylic acid methyl ester. The involved domino process is proposed to include the formation of an carboxylic acid amide followed by a Michael addition. We are currently extending this methodology towards acyclic enones and are also applying it in the total synthesis of natural products and analogs containing a spirocycle.

Experimental Section

All reactions were performed under a nitrogen or argon atmosphere in flame-dried flasks, and the reactants were introduced by syringe. All solvents were dried by standard methods. All reagents obtained from commercial sources were used without further purification. Thin-layer chromatography was performed on precoated silica gel SIL G/UV_{254} plates (Macherey–Nagel GmbH & Co. KG), and silica gel 32–63 (0.032–0.064 mm) (Macherey–Nagel GmbH & Co. KG) was used for column chromatography. IR spectra were recorded as KBr pellets or as films with a Bruker IFS 25 or Vector 22 spectrometer. ^1H and ^{13}C NMR spectra were recorded with a Varian XL 200, VXR 200 and VXR 500 or a Bruker AM-300 with tetramethylsilane (TMS) as internal standard in [D]chloroform or [D_6]benzene. Mass spectra were measured at 70 eV with a Varian MAT 311A, high-resolution mass spectra with a Varian MAT 731 instrument.

General Procedure for the Synthesis of the Spirocyclic Lactams from Primary Amines and Esters: A 2 M solution of trimethylaluminum (2.05 equiv.) in toluene at 0 °C was added dropwise to a 1 M solution of the amine (2.0 equiv.) in benzene. The mixture was stirred at room temperature for 1 h followed by addition of the ester (1 equiv., 0.3 M solution in benzene) and then heated to 80 °C for 18 h. After cooling to 0 °C, HCl was added (5 mL per mmol ester) and the mixture stirred for 30 min. The aqueous layer was extracted four times with ethyl acetate. The combined organic layers were washed with brine, dried with Na_2SO_4 and the solvents evaporated in vacuo. The crude product was purified by column chromatography (ethyl acetate/pentane, 5:1).

1-[2-(6-Bromobenzo[1,3]dioxol-5-yl)ethyl]-1-azaspiro[4.4]nonane-2,7-dione (4): According to the general procedure, amine **1** (288 mg, 1.18 mmol) was reacted with trimethylaluminum (0.60 mL, 2 M solution in toluene, 1.21 mmol) and 3-(3-oxocyclopent-1-enyl)propionic acid methyl ester (**3a**; 100 mg, 0.59 mmol) to give **4** (181 mg, 0.48 mmol, 81%). IR (neat): $\tilde{\nu}$ = 3041, 2935, 1747, 1684, 1475 cm^{-1}. – ^1H NMR (300 MHz, $CDCl_3$): δ = 1.75–2.49 (m, 10 H), 2.93 (t, *J* = 7.5 Hz, 2 H), 3.20–3.59 (m, 2 H), 5.93 (s, 2 H), 6.72 (s, 1 H), 6.94 (s, 1 H). – ^{13}C NMR (75 MHz, $CDCl_3$): δ = 29.10, 32.51, 32.52, 34.90, 36.66, 39.73, 47.95, 66.58, 101.7, 110.8, 112.6, 114.4, 131.0, 145.5, 147.5, 174.9, 213.9. – MS (70 eV): *m*/*z* (%) = 379.0/381.0 (14), 300.1 (45), 228.0/226.0 (100), 213.0/215.0 (15), 166.1 (46). – $C_{17}H_{18}BrNO_4$ (379.0): calcd. C 53.70, H 4.77; found C 53.44, H 4.73. – HRMS calcd. 379.0419; found 379.0419.

1-Phenethyl-1-aza-spiro[4.4]nonane-2,7-dione (5): According to the general procedure, phenethylamine (142 mg, 1.18 mmol) was reacted with trimethylaluminum (0.60 mL, 2 M solution in toluene, 1.21 mmol) and 3-(3-oxocyclopent-1-enyl)propionic acid methyl ester (**3a**; 100 mg, 0.59 mmol) to give **5** (108 mg, 0.42 mmol, 71%). IR (neat): $\tilde{\nu}$ = 3025, 2942, 1745, 1675 cm^{-1}. – ^1H NMR (300 MHz, $CDCl_3$): δ = 1.78–2.49 (m, 10 H), 2.91 (t, *J* = 7.7 Hz, 2 H), 3.29–3.44 (m, 2 H), 7.19–7.33 (m, 5 H). – ^{13}C NMR (75 MHz, $CDCl_3$): δ = 29.09, 32.48, 32.56, 34.95, 36.61, 41.74, 47.83, 66.54, 126.6, 128.5, 128.9, 138.7, 174.7, 213.9. – MS (70 eV):

m/*z* (%) = 257.2 (42), 166.1 (100), 104.0 (46). − $C_{16}H_{19}NO_2$ (257.1): calcd. C 74.68, H 7.44; found C 74.44, H 7.64. − HRMS calcd. 257.1415; found 257.1415.

1-Benzyl-1-aza-spiro[4.4]nonane-2,7-dione (6): According to the general procedure, benzylamine (126 mg, 1.18 mmol) was reacted with trimethylaluminum (0.60 mL, 2 M solution in toluene, 1.21 mmol) and 3-(3-oxocyclopent-1-enyl)propionic acid methyl ester (**3a**; 100 mg, 0.59 mmol) to give **6** (113 mg, 0.46 mmol, 79%). IR (neat): $\tilde{\nu}$ = 3035, 2964, 1740, 1673 cm^{-1}. − ^1H NMR (300 MHz, $CDCl_3$): δ = 1.83−2.42 (m, 8 H), 2.47−2.65 (m, 2 H), 4.51 (s, 2 H), 7.22−7.33 (m, 5 H). − ^{13}C NMR (75 MHz, $CDCl_3$): δ = 29.12, 32.48, 32.91, 36.62, 42.67, 47.87, 66.75, 126.9, 127.4, 128.7, 137.7, 174.8, 213.9. − MS (70 eV): *m*/*z* (%) = 243.1 (95), 214.1 (37), 186.1 (35), 91.0 (100). − $C_{15}H_{17}NO_2$ (243.1): calcd. C 74.05, H 7.04; found C 74.08, H 7.20. − HRMS calcd. 243.1259; found 243.1259.

1-Phenyl-1-azaspiro[4.4]nonane-2,7-dione (7) and 3-(3-Oxocyclopent-1-enyl)-*N*-phenylpropionamide (8): According to the general procedure, aniline (110 mg, 1.18 mmol) was reacted with trimethylaluminum (0.60 mL, 2 M solution in toluene, 1.21 mmol) and 3-(3-oxocyclopent-1-enyl)propionic acid methyl ester (**3a**; 100 mg, 0.59 mmol) to give **7** (31 mg, 0.14 mmol, 23%) and **8** (47 mg, 0.20 mmol, 35%).

7: IR (neat): $\tilde{\nu}$ = 3310, 3061, 2926, 1743, 1693, 1598 cm^{-1}. − ^1H NMR (300 MHz, $CDCl_3$): δ = 2.18−2.55 (m, 8 H), 2.61−2.67 (m, 2 H), 7.10−7.13 (m, 2 H), 7.23−7.30 (m, 2 H), 7.39−7.48 (m, 2 H). − ^{13}C NMR (75 MHz, $CDCl_3$): δ = 29.57, 29.64, 32.93, 32.27, 36.52, 48.94, 68.25, 128.7, 129.2, 129.7, 129.9, 135.0, 174.7, 213.6. − MS (70 eV): *m*/*z* (%) = 229.1 (100), 200.0 (58), 186.0 (39), 173.0 (40), 172.0 (39). − $C_{14}H_{15}NO_2$ (229.1). − HRMS calcd. 229.1102; found 229.1102.

8: IR (neat): $\tilde{\nu}$ = 3309, 3057, 2929, 1737, 1669, 1600 cm^{-1}. − ^1H NMR (300 MHz, $CDCl_3$): δ = 2.36−2.41 (m, 1 H), 2.58−2.65 (m, 4 H), 2.79 (t, *J* = 6.9 Hz, 2 H), 5.95 (s, 1 H), 7.08 (t, *J* = 7.2 Hz, 1 H), 7.25−7.30 (m, 2 H), 7.52 (d, *J* = 7.3 Hz), 8.10 (br. s, 1 H). − ^{13}C NMR (75 MHz, $CDCl_3$): δ = 28.65, 31.90, 34.09, 35.32, 119.8, 124.2, 128.9, 137.9, 169.6, 182.3, 210.3. − MS (70 eV): *m*/*z* (%) = 229.1 (42), 109.0 (22), 93.0 (100). − $C_{14}H_{15}NO_2$ (229.1). − HRMS calcd. 229.1102; found 229.1102.

1-Butyl-1-azaspiro[4.4]nonane-2,7-dione (9): According to the general procedure, butylamine (86 mg, 1.18 mmol) was reacted with trimethylaluminum (0.60 mL, 2 M solution in toluene, 1.21 mmol) and 3-(3-oxocyclopent-1-enyl)propionic acid methyl ester (**3a**; 100 mg, 0.59 mmol) to give **9** (65 mg, 0.31 mmol, 53%). IR (neat): $\tilde{\nu}$ = 2959, 2873, 1745, 1682 cm^{-1}. − ^1H NMR (300 MHz, $CDCl_3$): δ = 0.89 (t, *J* = 7.2 Hz, 3 H), 1.25−1.37 (m, 2 H), 1.45−1.55 (m, 2 H), 1.86−2.50 (m, 10 H), 3.04−3.19 (m, 2 H). − ^{13}C NMR (75 MHz, $CDCl_3$): δ = 13.70, 20.35, 29.14, 31.68, 32.68, 32.91, 36.73, 39.49, 48.05, 66.53, 174.3, 213.9. − MS (70 eV): *m*/*z* (%) = 209.2 (100), 180.1 (88), 166.1 (82), 152.1 (32), 138.1 (43), 111.1 (71), 98.1 (35). − $C_{12}H_{19}NO_2$ (209.1): calcd. C 68.87, H 9.15; found C 68.64, H 9.03. − HRMS calcd. 209.1416; found 209.1416.

1-*sec*-Butyl-1-azaspiro[4.4]nonane-2,7-dione (10): According to the general procedure, racemic *sec*-butylamine (86 mg, 1.18 mmol) was reacted with trimethylaluminum (0.60 mL, 2 M solution in toluene, 1.21 mmol) and 3-(3-oxocyclopent-1-enyl)propionic acid methyl ester (**3a**; 100 mg, 0.59 mmol) to give **10** (26 mg, 0.12 mmol, 21%) as a 1:1 mixture of the two possible diastereomers. IR (neat): $\tilde{\nu}$ = 2966, 1744, 1679, 1505 cm^{-1}. − ^1H NMR (300 MHz, $CDCl_3$): δ = 0.85, 0.90 (t, *J* = 7.6 Hz, 3 H), 1.36, 1.43 (d, *J* = 7.0 Hz, 3 H), 1.47−1.57 (m, 2 H), 1.86−2.56 (m, 10 H), 3.66−3.72 (m, 1 H). − ^{13}C NMR (75 MHz, $CDCl_3$): δ = 10.28, 11.79, 18.20, 18.47, 26.40, 26.53, 29.68, 29.70, 32.78, 33.01, 36.63, 36.72, 38.18, 38.03, 46.83, 48.31, 48.90, 50.91, 67.18, 67.43, 174.4, 214.1. − MS (70 eV): *m*/*z* (%) = 209.2 (13), 194.2 (18), 180.2 (45), 179.2 (100), 154.2 (18), 119.1 (20), 98.1 (31). − $C_{12}H_{19}NO_2$ (209.1): HRMS calcd. 209.1416; found 209.1416.

1-(6-Hydroxyhexyl)-1-azaspiro[4.4]nonane-2,7-dione (12): According to the general procedure, 6-aminohexan-1-ol (138 mg, 1.18 mmol) was reacted with trimethylaluminum (0.60 mL, 2 M solution in toluene, 1.21 mmol) and 3-(3-oxocyclopent-1-enyl)propionic acid methyl ester (**3a**; 100 mg, 0.59 mmol) to give **12** (51 mg, 0.20 mmol, 34%). IR (neat): $\tilde{\nu}$ = 3402, 2932, 2859, 1744, 1672 cm^{-1}. − ^1H NMR (300 MHz, $CDCl_3$): δ = 1.29−2.46 (m, 4 H), 1.51−1.61 (m, 4 H), 1.85 (br. s, 1 H), 1.90-2.53 (m, 10 H), 3.14-3.19 (m, 2 H), 3.63 (t, *J* = 6.3 Hz, 2 H). − ^{13}C NMR (75 MHz, $CDCl_3$): δ = 25.23, 26.73, 29.17, 29.57, 32.47, 37.70, 32.97, 36.78, 39.51, 48.08, 62.52, 66.63, 174.5, 214.0. − MS (70 eV): *m*/*z* (%) = 253.3 (53), 235.2 (23), 224.2 (97), 210.2 (96), 196.2 (91), 182.2 (51), 166.1 (100), 111.1 (97), 98.1 (72). − $C_{14}H_{23}NO_3$ (253.1): calcd. C 66.37, H 9.15; found C 66.20, H 8.98. − HRMS calcd. 253.1678; found 253.1678.

1-Benzyl-1-azaspiro[4.5]decane-2,7-dione (13): According to the general procedure, benzylamine (117 mg, 1.10 mmol) was reacted with trimethylaluminum (0.56 mL, 2 M solution in toluene, 1.13 mmol) and 3-(3-oxocyclohex-1-enyl)propionic acid methyl ester (**3b**; 100 mg, 0.55 mmol) to give **13** (113 mg, 0.44 mmol, 80%). IR (neat): $\tilde{\nu}$ = 3031, 2947, 1711, 1684 cm^{-1}. − ^1H NMR (300 MHz, $CDCl_3$): δ = 1.53−2.54 (m, 12 H), 4.42, 4.61 (AB system, *J* = 15.8 Hz, 2 H), 7.26−7.30 (m, 5 H). − ^{13}C NMR (75 MHz, $CDCl_3$): δ = 19.90, 28.74, 29.94, 35.17, 40.07, 42.66, 50.59, 66.00, 127.2, 127.3, 128.6, 138.1, 174.4, 208.1. − MS (70 eV): *m*/*z* (%) = 257.1 (84), 214.1 (43), 200.1 (61), 91.0 (100). − $C_{17}H_{21}NO_2$ (271.1): calcd. C 74.68, H 7.44; found C 74.55, H 7.30. − HRMS calcd. 257.1415; found 257.1415.

1-Phenethyl-1-azaspiro[4.5]decane-2,7-dione (14): According to the general procedure, phenethylamine (133 mg, 1.10 mmol) was reacted with trimethylaluminum (0.56 mL, 2 M solution in toluene, 1.13 mmol) and 3-(3-oxocyclohex-1-enyl)propionic acid methyl ester (**3b**; 100 mg, 0.55 mmol) to give **14** (61 mg, 0.23 mmol, 41%). IR (neat): $\tilde{\nu}$ = 3027, 2934, 1710, 1681 cm^{-1}. − ^1H NMR (300 MHz, $CDCl_3$): δ = 1.53−2.47 (m, 12 H), 2.81−3.01 (m, 2 H), 3.19−3.29 (m, 1 H), 3.44−3.54 (m, 1 H), 7.18−7.34 (m, 5 H). − ^{13}C NMR (75 MHz, $CDCl_3$): δ = 19.59, 28.75, 29.63, 34.94, 35.34, 40.09, 41.73, 50.01, 65.73, 126.5, 128.4, 128.7, 138.8, 174.4, 208.0. − MS (70 eV): *m*/*z* (%) = 271.2 (31), 180.2 (100), 104.1 (56), 55.1 (36), 41 (35). − $C_{17}H_{21}NO_2$ (271.1): calcd. C 75.25, H 7.80; found C 75.01, H 7.70. − HRMS calcd. 271.1572; found 271.1572.

Thermal Cyclization of 8: A solution of amide **8** (25 mg, 0.08 mmol) in benzene (0.5 mL) was heated at 80 °C for 18 h. After chromatography 1-phenyl-1-azaspiro[4.4]nonane-2,7-dione (**7**) was obtained (3 mg, 0.013 mmol, 12%) and **8** reisolated (12 mg, 0.05 mmol, 64%).

Acknowledgments

This research was supported by the Deutsche Forschungsgemeinschaft (Sonderforschungsbereich 416) and the Fonds der Chemischen Industrie. We thank Brigitte Worbs for assistance in the synthesis and we are grateful to BASF AG, Bayer AG, Degussa-Hüls AG, Dragoco, Aventis AG, Schering AG and Wacker-Chemie GmbH for their donations of chemicals.

[1] L. F. Tietze, U. Beifuss, *Angew. Chem.* **1993**, *105*, 137−170; *Angew. Chem. Int. Ed. Engl.* **1993**, *32*, 131−163.
[2] L. F. Tietze, *Chem. Rev.* **1996**, *96*, 115−136.
[3] L. F. Tietze, A. Modi, *Med. Res. Rev.* **2000**, *20*, 304−322.
[4] L. F. Tietze, F. Haunert, in *Stimulating Concepts in Chemistry* (Eds.: M. Shibasaki, J. F. Stoddart, F. Vögtle), Wiley-VCH, Weinheim **2000**, pp. 39−64.
[5] L. F. Tietze, H. Schirok, *Angew. Chem.* **1997**, *109*, 1159−1160, *Angew. Chem. Int. Ed. Engl.* **1997**, *36*, 1124−1125.
[6] L. F. Tietze, H. Schirok, *J. Am. Chem. Soc.* **1999**, *121*, 10264−10269.
[7] L. F. Tietze, H. Schirok, M. Wöhrmann, *Chem. Eur. J.* **2000**, *6*, 510−518.
[8] L. F. Tietze, H. Schirok, M. Wöhrmann, K. Schrader, *Eur. J. Org. Chem.* **2000**, 2433−2444.
[9] P. L. Steck, M. Wöhrmann, L. F. Tietze, *abstracts 221st ACS National Meeting, San Diego, CA*, **2001**, ORGN 380.
[10] A. Basha, M. Lipton, S. M. Weinreb, *Tetrahedron Lett.* **1977**, 4171−4174.
[11] For a recent review on trimethylaluminum see: F. Bacher, *J. Prakt. Chem.* **1999**, *341*, 88−91.
[12] T. Hirabayashi, K. Itoh, S. Sakai, Y. Ishii, *J. Organomet. Chem.* **1970**, *25*, 33.
[13] A. Benderly, S. Stavchansky, *Tetrahedron Lett.* **1988**, *29*, 739−740.
[14] A. B. Smith III, G. K. Friestad, J. Barbosa, E. Bertounesque, J. J.-W. Duan, K. G. Hull, M. Iwashima, Y. Qiu, P. G. Spoors, B. A. Salvatore, *J. Am. Chem. Soc.* **1999**, *121*, 10478−10486.
[15] S. Kim, P. Ho Lee, *Tetrahedron Lett.* **1988**, *29*, 5413−5416.

Received June 5, 2001
[O01291]