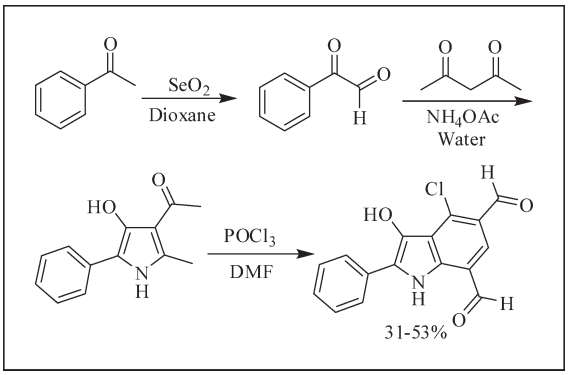
Synthesis of New 2-Aryl-4-chloro-3-hydroxy-1*H*-indole-5,7-dicarbaldehydes *via* Vilsmeier-Haack Reaction

Bagher Eftekhari-Sis,[a]* Maryam Zirak,[b] Ali Akbari,[a] and Mohammed M. Hashemi[c]

[a]Department of Chemistry, Faculty of Science, University of Maragheh, Maragheh, Iran
[b]Department of Organic Chemistry, Faculty of Chemistry, Tabriz University, Tabriz, Iran
[c]Department of Chemistry, Sharif University of Technology, Tehran, Iran
*E-mail: eftekharisis@mhec.ac.ir

Received August 12, 2009
DOI 10.1002/jhet.338
Published online 4 March 2010 in Wiley InterScience (www.interscience.wiley.com).



New 2-aryl-4-chloro-3-hydroxy-1*H*-indole-5,7-dicarbaldehydes were synthesized in three steps from acetophenone derivatives. By oxidation of acetophenones to aryl glyoxals using selenium dioxide and condensation with acetylacetone in the presence of ammonium acetate in water 3-acetyl-5-aryl-4-hydroxy-2-methyl-1*H*-pyrrols were obtained. 2-Aryl-4-chloro-3-hydroxy-1*H*-indole-5,7-dicarbaldehydes were synthesized *via* Vilsmeier-Haack reaction of pyrrole derivatives in moderate yields.

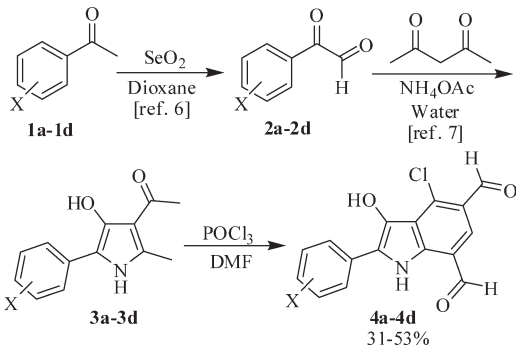
J. Heterocyclic Chem., **47**, 463 (2010).

INTRODUCTION

The synthesis of indoles has occupied organic chemists for well over a century [1]. And the invention of new synthetic routes to substituted indoles continues to command wide interest due to the numerous natural products [2], physiologically active natural products and important pharmaceuticals [3] whose structures incorporate this heterocyclic system. Indole derivatives are used as neuroprotective agents affecting oxidative stress [3f], potent opioid receptor agonists [3g], highly functionalized pharmacophores [3h], potent PPAR-γ binding agents with potential application for the treatment of osteoporosis [3i], drugs for the treatment of peripheral neuropathy and neurodegenerative diseases [3j,k], glucokinase activators [3l,m], the cytotoxic antibiotic CC-1065 and prodrugs [3n], PPAR-delta activators for the treatment of cardiovascular diseases [3o] and dyestuffs [4]. The combination of traditional and modern methods has provided accessibility to a wide variety of structural variations of this important class of heterocycles [3e,5]. A number of useful strategies are now available for the synthesis of indoles substituted on the five-membered ring, the majority of which involve the elaboration of the heterocyclic system from aniline, *o*-halo aniline, or other 2-substituted aniline derivatives. In contrast, few existing methods provide efficient and regiocontrolled access to indoles that are highly substituted on the benzenoid ring. Herein we disclose a method, based on Vilsmeier-Haack reaction of 3-acetyl-4-hydroxy-2-methyl-5-phenyl-1*H*-pyrrols **3**, to provide new highly substituted indoles **4** with substituted on both five-membered and benzenoid ring of indole (Scheme 1).

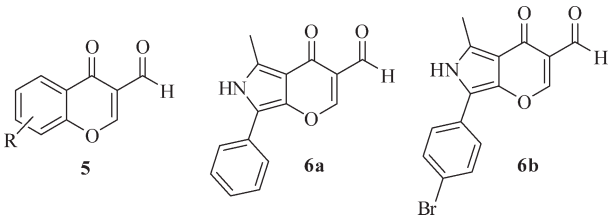
The Vilsmeier–Haack reaction is a widely used method for the formylation of activated aromatic and heteroaromatic compounds [8]. The reactions of aliphatic substrates [9], particularly carbonyl compounds [10] with chloromethylene iminium salts are highly versatile. They lead to multiple iminoalkylations in the presence of excess reagent and the resulting intermediates undergo cyclization to afford aromatic or heterocyclic compounds [11]. Multifunctional intermediates derived from these reactions (*e.g.*, β-chloroenaldehydes) are subsequently exploited for the synthesis of functionalized heterocycles or other valuable target molecules [12].

Scheme 1. Three steps synthesis of 2-aryl-4-chloro-3-hydroxy-1*H*-indole-5,7-dicarbaldehydes.



RESULTS AND DISCUSSION

The reaction of 2-hydroxyacetophenones with Vilsmeier-Haack reagent also involves an iminoalkylation-cyclization sequence, leading to the formation of 3-formyl chromones **5** [13]. Similarly we expected to synthesis the 5-methyl-4-oxo-7-phenyl-4,6-dihydro-pyrano[2,3-c]pyrrole-3-carbaldehyde **6a** from the reaction of 3-acetyl-4-hydroxy-2-methyl-5-phenyl-1*H*-pyrrol **3** with Vilsmeier-Haack reagent, but we did not obtained the expected compound **6a** instead the reaction gave compound **4**. In the case of 4-bromoacetophenone **1c**, not only **4c** was formed but also **6b** was obtained in low yield.



Four examples of the conversion of acetophenones **1a–1d** to various 2-aryl-4-chloro-3-hydroxy-1*H*-indole-5,7-dicarbaldehydes **4a–4d** are listed in Table 1.

As shown in Scheme 2, the proposed mechanism involves the addition of enol **7** to the 2 equiv. chloromethyleneiminium salt **8**, then bis-iminium salt **9** undergoes iminoalkylation to result enamine **10**, that undergo cyclization and elimination of dimethylamine to afford the bis-iminium salt **12** which on hydrolysis leads to the formation of 2-aryl-4-chloro-3-hydroxy-1*H*-indole-5,7-dicarbaldehydes **4** [14].

4-Chloro-2-phenyl-5,7-bis-phenyliminomethyl-1*H*-indol-3-ol **14** and 4-chloro-5,7-bis[(2,4-dinitrophenyl)-hydrazonomethyl]-2-phenyl-1*H*-indol-3-ol **16** were synthesized from the reaction of **4a** with aniline **13** and 2,4-dinitrophenylhydrazine **15** in the presence of catalytic amount of H_2SO_4 respectively (Scheme 3).

In conclusion, we have reported the synthesis of new 2-aryl-4-chloro-3-hydroxy-1*H*-indole-5,7-dicarbaldehydes *via* Vilsmeier-Haack reaction starting from acetophenone derivatives.

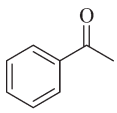
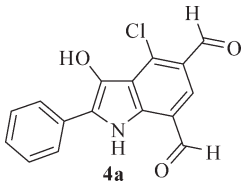
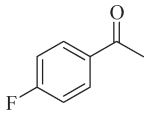
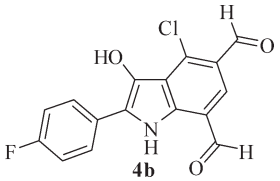
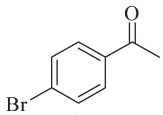
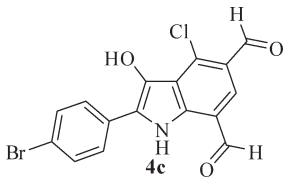
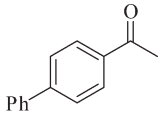
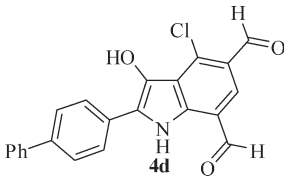
EXPERIMENTAL

General methods. Chemical shifts of the ^{1}H NMR spectra are reported in δ (ppm) from tetramethylsilane with the solvent as the internal standard (deuteriodimethyl sulfoxide, δ = 2.5 ppm), and coupling constants *J* were measured in Hz. Data are reported as follows: chemical shifts, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, dd = doublet of doublets, m = multiplet, br = broad). ^{13}C NMR spectra were recorded with complete proton decoupling. Chemical shifts are reported in ppm from tetramethylsilane with the solvent as the internal standard (deuteriodimethyl sulfoxide, δ = 39.0 ppm). Elemental analyses were carried out by using a CHN analyzer. IR analyses were performed with an FT-IR spectrophotometer. IR spectra of compounds are expressed by wavenumber (cm^{-1}).

General procedure for synthesis of 2-aryl-4-chloro-3-hydroxy-1H-indole-5,7-dicarbaldehydes 4. $POCl_3$ (3 mmol) was added dropwise to dimethylformamide (DMF) (1.5 mL)

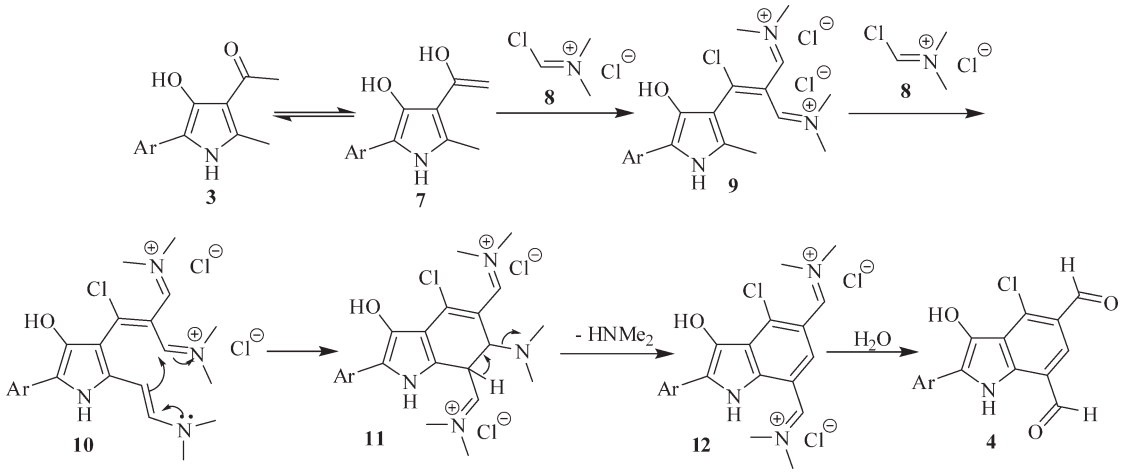
Table 1

Synthesis of 2-aryl-4-chloro-3-hydroxy-1*H*-indole-5,7-dicarbaldehydes **4** *via* Vilsmeier-Haack reaction.

Acetophenone **1**	Indole **4**	Yield (%)[a]
 **1a**	 **4a**	31
 **1b**	 **4b**	42
 **1c**	 **4c**	53
 **1d**	 **4d**	35

[a] Yield of indole from pyrrole (**3**).

Scheme 2. Proposed mechanism for conversion of pyrroles **3** to indoles **4**.



with stirring at 30–35°C, after the addition, the mixture was stirred at 50°C for 1 h. Then the solution of 3-acetyl-5-aryl-4-hydroxy-2-methyl-1*H*-pyrrol **3** (0.5 mmol) at least amount of DMF was added dropwise with stirring to the above mixture. After that the mixture was stirred at 45–55°C for 2 h, kept over the night at room temperature and poured over mixture of ice and water (10 g). Product was stirred for 0.5 h, then filtered off and recrystallized from ethanol.

4-Chloro-3-hydroxy-2-phenyl-1H-indole-5,7-dicarbaldehyde (4a). A yellow solid, mp: decomposed at 258.2–261.2°C; IR (KBr) 3553, 3343, 3053, 2853, 1671, 1580, 1425, 1025, 902, 812, 683 cm^{-1}; ^1H NMR (500 MHz, DMSO-d_6): δ 11.55 (s, 1H, NH, Exchanged with D_2O), 10.49 (s, 1H, CHO), 10.39 (s, 1H, CHO), 8.75 (s, 1H, OH, Exchanged with D_2O), 8.17 (s, 1H, CH), 8.01 (d, J = 7.5 Hz, 2H, CH), 7.51 (t, J = 7.45 Hz, 2H, CH), 7.37 (t, J = 7.3 Hz, 1H, CH) ppm; ^{13}C NMR (125 MHz, DMSO-d_6): δ 192.6, 189.5, 136.6, 134.6, 134.4, 130.9, 130.7, 129.3, 128.4, 127.7, 127.3, 124.8, 122.1, 119.8 ppm; Anal. Calcd. for $C_{16}H_{10}ClNO_3$: C, 64.12; H, 3.36; N, 4.67. Found: C, 63.98; H, 3.50; N, 4.72.

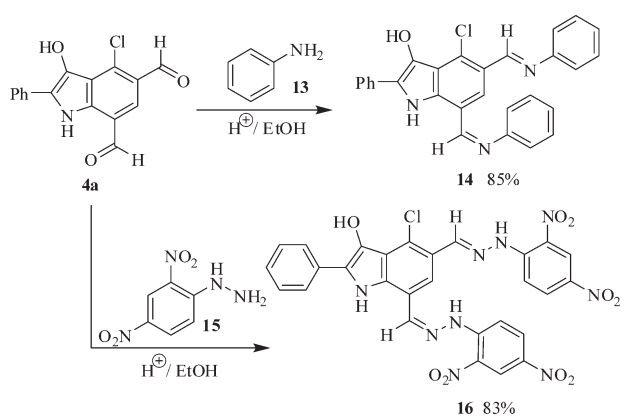
4-Chloro-2-(4-fluorophenyl)-3-hydroxy-1H-indole-5,7-dicarbaldehyde (4b). A yellow solid, mp: decomposed at 286.2–289.3°C; IR (KBr) 3553, 3360, 3058, 2843, 1670, 1584, 1471, 1030, 901, 834, 634 cm^{-1}; ^1H NMR (500 MHz, DMSO-d_6): δ 11.60 (s, 1H, NH, Exchanged with D_2O), 10.48 (s, 1H, CHO), 10.37 (s, 1H, CHO), 8.74 (s, 1H, OH, Exchanged with D_2O), 8.16 (s, 1H, CH), 8.04 (dd, $J_{H,F}$ = 8.07 Hz, $J_{H,H}$ = 5.75 Hz, 2H, CH), 7.35 (t, J = 8.75 Hz, 2H, CH) ppm; ^{13}C NMR (125 MHz, DMSO-d_6): δ 192.5, 189.6, 161.3, 136.6, 134.5, 134.4, 129.9, 127.5, 127.1, 124.8, 122.0, 119.9, 116.4, 116.2 ppm; Anal. Calcd. for $C_{16}H_9ClFNO_3$: C, 60.49; H, 2.86; N, 4.41. Found: C, 60.60; H, 2.73; N, 4.16.

2-(4-Bromophenyl)-4-chloro-3-hydroxy-1H-indole-5,7-dicarbaldehyde (4c). A yellow solid, mp: decomposed at 268.9–272.5°C; IR (KBr) 3540, 3352, 3030, 2839, 1670, 1585, 1465, 1030, 902, 814, 633 cm^{-1}; ^1H NMR (500 MHz, DMSO-d_6): δ 11.63 (s, 1H, NH, Exchanged with D_2O), 10.47 (s, 1H, CHO), 10.38 (s, 1H, CHO), 8.74 (s, broad, 1H, OH, Exchanged with D_2O), 8.18 (s, 1H, CH), 7.97 (d, J = 8.4 Hz, 2H, CH), 7.35 (d, J = 8.35 Hz, 2H, CH) ppm; ^{13}C NMR (125 MHz, DMSO-d_6): δ 192.5, 189.5, 136.7, 135.4, 134.7, 132.2, 130.2, 129.6, 127.7, 126.7, 124.9, 122.0, 121.4, 119.9 ppm; Anal. Calcd. for $C_{16}H_9BrClNO_3$: C, 50.76; H, 2.40; N, 3.70. Found: C, 50.82; H, 2.53; N, 3.66.

2-Biphenyl-4-yl-4-chloro-3-hydroxy-1H-indole-5,7-dicarbaldehyde (4d). A yellow solid, mp: decomposed at 204.1–205.9°C; IR (KBr) 3561, 3419, 3033, 2922, 2857, 1670, 1598, 1468, 1427, 1029, 901, 840, 766, 697 cm^{-1}; ^1H NMR (500 MHz, DMSO-d_6): δ 11.60 (s, 1H, NH, Exchanged with D_2O), 10.49 (s, 1H, CHO), 10.40 (s, 1H, CHO), 8.82 (s, 1H, OH, Exchanged with D_2O), 8.17 (s, 1H, CH), 8.12 (d, J = 7.1 Hz, 2H, CH), 7.83 (d, J = 7.0 Hz, 2H, CH), 7.76 (d, J = 5.8 Hz, 2H, CH), 7.49 (m, 2H, CH), 7.39 (m, 1H, CH) ppm; ^{13}C NMR (125 MHz, DMSO-d_6): δ 192.6, 189.4, 140.5, 140.0, 136.6, 134.6, 134.4, 132.3, 130.9, 130.7, 129.7, 129.3, 128.4, 127.7, 127.3, 124.8, 122.1, 119.8 ppm; Anal. Calcd. for $C_{22}H_{14}ClNO_3$: C, 70.31; H, 3.75; N, 3.73. Found: C, 70.51; H, 3.68; N, 3.75.

7-(4-Bromophenyl)-5-methyl-4-oxo-4,6-dihydro-pyrano [2,3-c]pyrrole-3-carbaldehyde (6b). In addition to 2-(4-bromophenyl)-4-chloro-3-hydroxy-1*H*-indole-5,7-dicarbalde-hyde **4c**, 5-methyl-4-oxo-7-phenyl-4,6-dihydro-pyrano[2,3-c]pyrrole-3-carbaldehyde **6b** was obtained in the case of 4-bromoacetophenone. Ratio of **4c**/**6a** was obtained 68/32, according to ^1H NMR spectrum of the mixture of **4c** and **6a**. This product

Scheme 3



was characterized only in mixture with **4c** using ^{1}H NMR spectrum and eliminate from mixture with washing of solid with warm 85% ethanol. ^{1}H NMR (500 MHz, DMSO-d_6): δ 11.75 (s, 1H, NH, Exchanged with D_2O), 10.43 (s, 1H, CHO), 8.63 (s, 1H, CH), 7.57 (d, J = 8.2 Hz, 2H, CH), 7.36 (d, J = 8.2 Hz, 2H, CH), 2.5 (s, 3H, CH_3) ppm.

4-Chloro-2-phenyl-5,7-bis-phenyliminomethyl-1H-indol-3-ol (14). To mixture of 4-chloro-3-hydroxy-2-phenyl-1*H*-indole-5,7-dicarbaldehyde **4a**. (0.2 mmol) and 3 drops of concentrate H_2SO_4 in boiling ethanol (5 mL), was added Aniline **13** (0.4 mmol), and stirred at the same temperature for the 5 min. Then the heat was removed and solution was cooled to room temperature and product was obtained as pale yellow crystals in 85% yield by filtration and washing with 5 mL of ethanol. mp: decomposed at 173.6–175.1°C; IR (KBr) 3559, 3053, 2849, 2585, 2060, 1677, 1557, 1497, 1321, 1015, 741, 685, 606 cm^{-1}; ^{1}H NMR (500 MHz, DMSO-d_6): δ 11.34 (s, 1H, NH, Exchanged with D_2O), 9.20 (s, 1H, HC=NPh), 9.05 (s, 1H, HC=NPh), 8.52 (s, 1H, OH, Exchanged with D_2O), 8.00 (d, J = 7.55 Hz, 1H, CH), 7.5–7.04 (m, 15H, CH) ppm; Anal. Calcd. for $C_{28}H_{20}ClN_3O$: C, 74.74; H, 4.48; N, 9.34. Found: C, 74.68; H, 4.47; N, 9.21.

4-Chloro-5,7-bis-[(2,4-dinitrophenyl)hydrazonomethyl]-2-phenyl-1H-indol-3-ol (16). To the solution of 2,4-dinitrophenylhydrazine **15** (0.6 mmol) and 3 drops of concentrate H_2SO_4 in mixture of ethanol/water (3/2 mL), was added the hot solution of 4-chloro-3-hydroxy-2-phenyl-1*H*-indole-5,7-dicarbaldehyde **4a** (0.2 mmol) in ethanol (5 mL), and stirred for the 5 min. Then solution was cooled to room temperature and product was obtained as dark purple solid in 83% yield by filtration and washing with 5 mL of mixture of ethanol/water (3/2 mL). mp: 326.8–328.5°C. Don't soluble in solvents such as DMSO-d_6, Aceton-d_6 and *etc*. for taking NMR spectra. IR (KBr) 3539, 3428, 3270, 3087, 1613, 1508, 1422, 1329, 1208, 1131, 920, 827, 734, 597 cm^{-1}; Anal. Calcd. for $C_{28}H_{18}ClN_9O_9$: C, 50.96; H, 2.75; N, 19.10. Found: C, 51.09; H, 2.64; N, 18.93. In comparing of IR spectrum of **16** with IR spectrum of **4a**, peak of the C—H of the aldehyde group at 2850 cm^{-1} for **4a** was eliminated in **16** IR spectrum, and the C=O peak of **4a** at 1673 cm^{-1} was replaced with C=N peak of **16** at 1613 cm^{-1}.

Acknowledgments. The authors thank the research council of the University of Maragheh and Mr. S. Taheri (Sharif University of Technology) for taking NMR Spectra.

REFERENCES AND NOTES

[1] Saxton, J. E. Nat Prod Rep 1997, 14, 559.

[2] (a) Lounasmaa, M.; Tolvanen, A. Nat Prod Rep 2000, 17, 175; (b) Faulkner, D. J. Nat Prod Rep 1999, 16, 155.

[3] (a) Kam, T.-S.; Choo, Y.-M. Helv Chim Acta 2004, 87, 991; (b) Kuethe, J. T.; Wong, A.; Qu, C.; Smitrovich, J.; Davies, I. W.; Hughes, D. L. J Org Chem 2005, 70, 2555; (c) Van Zandt, M. C.; Jones, M. L.; Gunn, D. E.; Geraci, L. S.; Jones, J. H.; Sawicki, D. R.; Sredy, J.; Jacot, J. L.; DiCioccio, A. T.; Petrova, T.; Mitschler, A.; Podjarny, A. D. J Med Chem 2005, 48, 3141; (d) Takayama, H.; Tsutsumi, S. I.; Kitajima, M.; Santiarworn, D.; Liawruangrath, B.; Aimi, N. Chem Pharm Bull 2003, 51, 232; (e) Humphrey, G. R.; Kuethe, J. T. Chem Rev 2006, 106, 2875; (f) Stolc, S.; Snirc, V.; Majekova, M.; Gasparova, Z.; Gajdosikova, A.; Stvrtina, S. Cell Mol Neurobiol 2006, 26, 1493; (g) Takayama, H.; Misawa, K.; Okada, N.; Ishikawa, H.; Kitajima, M.; Hatori, Y.; Murayama, T.; Wongseripipatana, S.; Tashima, K.; Matsumoto, K.; Horie, S. Org Lett 2006, 8, 5705; (h) Kuethe, J. T. Chimia 2006, 60, 543; (i) Hopkins, C. R.; O'Neil, S. V.; Laufersweiler, M. C.; Wang, Y.; Pokross, M.; Mekel, M.; Evdokimov, A.; Walter, R.; Kontoyianni, M.; Petrey, M. E.; Sabatakos, G.; Roesgen, J. T.; Richardson, E.; Demuth, T. P. Bioorg Med Chem Lett 2006, 16, 5659; (j) Pruss, R.; Jamot, L.; Drouot, C. FR 2,885,905, 2005; Chem Abstr 2007, 146, 27812; (k) Froissant, J.; Marguet, F.; Olivier-Bandini, A.; Puech, F. PCT Int Appl. WO 2,006,111,648, 2006; Chem Abstr 2006, 145, 455025; (l) Yasuma, T.; Ujikawa, O.; Iwata, H. PCT Int Appl. WO 2,006,112,549, 2006; Chem Abstr 2006, 145, 454930; (m) Heinrich, T.; Blaukat, A.; Staehle, W.; Greiner, H.; Kordowicz, M. Ger Offen DE 102,005,019,094, 2006; Chem Abstr 2006, 145, 45499; (n) Tietze, L. F.; Major, F. Eur J Org Chem 2006, 10, 2314; (o) Bischoff, H.; Dittrich-Wengenroth, E.; Wuttke, M.; Heckroth, H.; Thielemann, W.; Woltering, M.; Otteneder, M. PCT Int Appl. WO 2,004,005,253, 2004; Chem Abstr 2004, 140, 93922.

[4] (a) Sekar, N. Colourage 2003, 50, 65; (b) Diwu, Z.; Zhang, J.; Tang, Y. US Pat. 2,006,223,076, 2006; Chem Abstr 2006, 145, 392008.

[5] (a) Cacchi, S.; Fabrizi, G. Chem Rev 2005, 105, 2873; (b) Zeni, G.; Larock, R. C. Chem Rev 2004, 104, 2285; (c) Joule, J. A. In Science of Synthesis;Thomas, E. J., Ed.; Thieme: Stuttgart, 2000; Vol. 10, pp 361–652; (d) Sundberg, R. J. Indoles; Academic Press: London, 1996; (e) Gilchrist, T. L. J Chem Soc Perkin Trans 1 2001, 2491; (f) Gribble, G. W. J Chem Soc Perkin Trans 1 2000, 1045; (g) Rutherford, J. L.; Rainka, M. P.; Buchwald, S. L. J Am Chem Soc 2002, 124, 15168; (h) Kamijo, S.; Yamamoto, Y. Angew Chem Int Ed Engl 2002, 41, 3230; (i) Arisawa, M.; Terada, Y.; Nakagawa, M.; Nishida, A. Angew Chem Int Ed Engl 2002, 41, 4732; (j) Smith, A. B.; Kanoh, N.; Ishiyama, H.; Minakawa, N.; Rainier, J. D.; Hartz, R. A.; Cho, Y. S.; Cui, H.; Moser, W. H. J Am Chem Soc 2003, 125, 8228; (k) Siebeneicher, H.; Bytschkov, I.; Doye, S. Angew Chem Int Ed Engl 2003, 42, 3042; (l) Shimada, T.; Nakamura, I.; Yamamoto, Y. J Am Chem Soc 2004, 126, 10546; (m) Willis, M. C.; Brace, G. N.; Holmes, I. P. Angew Chem Int Ed Engl 2005, 44, 403; (n) Baran, P. S.; Guerrero, C. A.; Ambhaikar, N. B.; Hafensteiner, B. D. Angew Chem Int Ed Engl 2005, 44, 606; (o) Herzon, S. B.; Myers, A. G. J Am Chem Soc 2005, 127, 5342; (p) Dunetz, J. R.; Danheiser, R. L. J Am Chem Soc 2005, 127, 5776; (q) Taber, D. F.; Tian, W. J Am Chem Soc 2006, 128, 1058; (r) Tokuyama, H.; Fukuyama, T. Chem Rec 2002, 2, 37; (s) Battistuzzi, G.; Cacchi, S.; Fabrizi, G. Eur J Org Chem 2002, 2671; (t) Rodriguez, A. L.; Koradin, C.; Dohle, W.; Knochel, P. Angew Chem Int Ed Engl 2000, 39, 2488; (u) Kozmin, S. A.; Iwama, T.; Huang, Y.; Rawal, V. H. J Am Chem Soc 2002, 124, 4628; (v) Hartung, C. G.; Fecher, A.; Chapell, B.; Snieckus, V. Org Lett 2003, 5, 1899; (w) Fukuda, T.; Akashima, H.; Iwao, M. Tetrahedron 2005, 61, 6886; (x) Kaspar, L. T.; Ackermann, L. Tetrahedron 2005, 61, 11311; (y) Schmidt, A. M.; Eilbracht, P. J Org Chem 2005, 70, 5528; (z) Smith, A. B., III; Kürti, L.; Davulcu, A. H. Org Lett 2006, 8, 2167; (aa) Linnepe née Köhling, P.; Schmidt, A. M.; Eilbracht, P. Org Biomol Chem 2006, 4, 302; (bb) Sridharan, V.; Perumal, S.; Avendaño, C.; Menéndez, J. C. Synlett 2006, 91; (cc) Kearney, A. M.; Vanderwal, C. D. Angew Chem Int Ed Engl 2006, 45, 7803; (dd) Zhao, J.; Hughes, C. O.; Toste, F. D. J Am Chem Soc 2006, 128, 7436; (ee) Barluenga, J.; Jiménez-Aquino, A.; Valdés, C.; Aznar, F. Angew Chem Int Ed Engl 2007, 46, 1529; (ff) Trost, B. M.; McClory, A. Angew Chem Int Ed Engl 2007, 46, 2074; (gg) Blay, G.; Fernández, I.; Pedro, J. R.; Vila, C. Org Lett 2007, 9, 2601; (hh) Sanz, R.; Castroviejo, M. P.; Guilarte, V.; Pérez, A.; Fañanás, F. J. J Org Chem 2007, 72, 5113.

[6] Riley, H. A.; Gray, A. R. Org Synth 1943, 2, 509.

[7] Khalili, B.; Jajarmi, P.; Eftekhari-Sis, B.; Hashemi, M. M. J Org Chem 2008, 73, 2090.

[8] (a) Jutz, C. Adv Org Chem 1976, 9, 225; (b) Seshadri, S. J Sci Ind Res 1973, 32, 128; (c) Chatterjee, A.; Biswas, K. M. J Org Chem 1973, 38, 4002; (d) Sayah, B.; Léon, N. P.; Milet, A.; Guindet, J. P.; Vallée, Y. J Org Chem 2001, 66, 2522.

[9] Jones, G.; Stanforth, S. P. Org React 2000, 56, 355.

[10] Marson, C. M. Tetrahedron 1992, 48, 3659.

[11] (a) Meth-Cohn, O. Heterocycles 1993, 35, 539; (b) Pan, W.; Dong, D.; Wang, K.; Zhang, J.; Wu, R.; Xiang, D.; Liu, Q. Org Lett 2007, 9, 2421; (c) Xiang, D.; Yang, Y.; Zhang, R.; Liang, Y.; Pan, W.; Huang, J.; Dong, D. J Org Chem 2007, 72, 8593; (d) Beccalli, E. M.; Marchesini, A. J Org Chem 1987, 52, 3426; (e) Guzman, A.; Romero, M. J Org Chem 1990, 55, 5793; (f) Shrestha, S.; Hwang, S. Y.; Lee, K. H.; Cho, H. Bull Korean Chem Soc 2005, 26, 1138; (g) Asokan, C. V.; Anabha, E. R.; Thomas, A. D.; Jose, A. M.; Lethesh, K. C.; Prasanth, M.; Krishanraj, K. U. Tetrahedron Lett 2007, 48, 5641; (h) Ali, M. M.; Sana, S.; Tasneem, Rajanna, K. C.; Saiprakash, P. K. Synth Commun 2002, 32, 1351; (i) Lacova, M.; Loos, D.; Furdik, M.; Matulova, M.; El-Shaaer, H. M. Molecule 1998, 3, 149; (j) Chen, C. H.; Reynolds, G. A. J Org Chem 1979, 44, 3144; (k) Sivaprasad, G.; Sridhar, R.; Perumal, P. T. J Heterocycl Chem 2006, 43, 389; (l) Kumar, K. H.; Perumal, P. T. Chem Lett 2005, 34, 1346; (m) Sridhar, R.; Sivaprasad, G.; Perumal, P. T. J Heterocycl Chem 2004, 41, 405; (n) Selvi, S.; Perumal, P. T. Synth Commun 2001, 31, 2199.

[12] (a) Abramov, M. A.; Dehaen, W. Synthesis 2000, 1529; (b) Smeets, S.; Asokan, C. V.; Motmans, F.; Dehaen, W. J Org Chem 2000, 65, 5882.

[13] (a) Sabitha, G. Aldrichimica Acta 1996, 29, 13; (b) Nohara, A.; Umetani, T.; Sanno, Y. Tetrahedron Lett 1973, 22, 1995; (c) Nohara, A.; Umetani, T.; Sanno, Y. Tetrahedron 1974, 30, 3553; (d) Klutchko, S.; Kaminsky, D.; Von Strandtmann, M. US Pat. 4,098,799, 1978; Chem Abstr 1979, 90, 22813c.

[14] Thomas, A. D.; Asokan, J.; Asokan, C. V. Tetrahedron 2004, 60, 5069.