Experimental Section

A typical procedure for the reaction of **1** with benzaldehyde: To a suspension of [Cp_2ZrHCl] (507 mg, 2.0 mmol) in CH_2Cl_2 (8 mL) was added 1-octene (0.62 mL, 4.0 mmol), and the resulting mixture was stirred for 30 min at ambient temperature. After the mixture had been stirred under an atmosphere of CO for 2 h, benzaldehyde (0.10 mL, 1.0 mmol) and $BF_3 \cdot OEt_2$ (0.24 mL, 2.0 mmol) were added at −20 °C, and the mixture was stirred at 0 °C for 1 h. The reaction mixture was treated with aqueous $NaHCO_3$ and extracted with ether (3 × 15 mL). The combined ethereal extracts were washed with saturated sodium chloride solution, dried over $MgSO_4$, and concentrated under reduced pressure to give a crude oil, which was purified by flash column chromatography (silica gel, hexane:EtOAc = 20:1 → 15:1 → 10:1) to give 1-hydroxy-1-phenyl-2-decanone (193 mg, 79 %). Spectroscopic data for 1-hydroxy-1-phenyl-2-decanone: mp 33.3–35.5 °C; ^{1}H NMR (400 MHz, $CDCl_3$): $\delta = 0.84-0.88$ (3H, m), 1.15–1.28 (10H, m), 1.43–1.55 (2H, m), 2.29 (1H, ddd, $J = 6.9, 7.9, 16.8$ Hz), 2.37 (1H, ddd, $J = 6.5, 8.2, 16.8$ Hz), 4.35 (1H, d, $J = 4.2$ Hz), 5.08 (1H, d, $J = 4.2$ Hz), 7.30–7.40 (5H, m); ^{13}C NMR (100.6 MHz, $CDCl_3$); $\delta = 14.0$, 22.5, 23.6, 28.87, 28.94, 29.1, 31.7, 37.7, 79.6, 127.4, 128.6, 128.9, 138.1; IR (KBr) $\tilde{\nu} = 3431$ (broad), 2917, 1716 cm^{-1}; EIMS m/z 248 [M^+]. Analysis calcd for $C_{16}H_{24}O_2$: C 77.38, H 9.74; found: C 77.14, H 9.57.

Received: February 6, 1998 [Z11448IE]
German version: *Angew. Chem.* **1998**, *110*, 1796–1798

Keywords: acylations · aldehydes · Lewis acids · nucleophilic additions · zirconium

---

[1] Reviews: a) P. Wipf, H. Jahn, *Tetrahedron* **1996**, *52*, 12853; b) J. A. Labinger in *Comprehensive Organic Synthesis*, *Vol. 8* (Eds.: B. M. Trost, I. Fleming), Pergamon Press, Oxford, **1991**, p. 667; c) J. Schwartz, J. A. Labinger, *Angew. Chem.* **1976**, *88*, 402; *Angew. Chem. Int. Ed. Engl.* **1976**, *15*, 333. Insertion reactions of CO and isocyanide compounds to alkylzirconocene chloride: d) C. A. Bertelo, J. Schwartz, *J. Am. Chem. Soc.* **1975**, *97*, 228; e) E. Negishi, D. R. Swanson, S. R. Miller, *Tetrahedron Lett.* **1988**, *29*, 1631.

[2] a) L. D. Durfee, I. P. Rothwell, *Chem. Rev.* **1988**, *88*, 1059; b) G. Erker, *Acc. Chem. Res.* **1984**, *17*, 103.

[3] a) D. Seyferth, R. M. Weinstein, R. C. Hui, W. L. Wang, C. M. Archer, *J. Org. Chem.* **1992**, *57*, 5620; b) T. Hiiro, Y. Morita, T. Inoue, N. Kambe, A. Ogawa, I. Ryu, N. Sonoda, *J. Am. Chem. Soc.* **1990**, *112*, 455.

[4] a) J. Collin, J.-L. Namy, F. Dallemer, H. B. Kagan, *J. Org. Chem.* **1991**, *56*, 3118; b) R. G. Finke, T. N. Sorrell, *Org. Synth. Coll. Vol. VI* **1988**, 807.

[5] The molar ratios of the reagents were varied as described in Table 1 so as to determine which reaction conditions led to the cleanest reaction mixture, judged by TLC.

[6] a) P. Wipf, W. Xu, *Tetrahedron* **1995**, *51*, 4551; b) K. Suzuki, T. Hasegawa, T. Imai, H. Maeta, S. Ohba, *ibid.* **1995**, *51*, 4483.

[7] The stereochemistry of the products was unequivocally determined by converting them into acetonide compounds in two steps (deprotection and formation of acetonide) and the measurment of their NOESY spectra.

[8] F. Chemla, J. F. Normant, *Tetrahedron* **1997**, *51*, 17265. The addition of $ZnCl_2$ to **1** and the stirring of the mixture at ambient temperature for 1.5 h prior to the addition of benzaldehyde gave only α-ketol **5,** and no trace of the acyl adduct to aldehyde corresponding to **2** was obtained.

[9] D. B. Carr, J. Schwartz, *J. Am. Chem. Soc.* **1977**, *99*, 638.

Highly Enantioselective One-Pot Synthesis of Chiral Tri- and Tetrasubstituted Ferrocenes from 1,1′-Ferrocenedicarbaldehyde[**]

Gabriel Iftime, Jean-Claude Daran, Eric Manoury,[*] Gilbert G. A. Balavoine[*]

Owing to the increasing involvement of ferrocene derivatives in various fields[1] such as asymmetric synthesis and catalysis[2] and materials chemistry (especially for nonlinear optics),[3] new methods for obtaining pure enantiomers of substituted ferrocenes with planar chirality are of current interest. Several efficient syntheses of chiral disubstituted ferrocenes are based on diastereoselective lithiation of ferrocenyl derivatives in the position *ortho* to substitutuents that exhibit asymmetric induction, such as tertiary amines,[4] acetals,[5] sulfoxides,[6] and oxazolines.[7] Recently, enantioselective *ortho* lithiation of nonchiral monosubstituted ferrocenes (direct synthesis)[8] with chiral tertiary amines as auxiliaries was reporeted. This led to disubstituted ferrocenes with enantioselectivities of up to 99 % *ee*.[8b] The enantioselective synthesis of C_2-symmetric tetrasubstituted ferrocene derivatives with planar chirality has so far received little attention, and all the reported methods followed the diastereoselective *ortho* lithiation strategy.[9] However, C_2-symmetric tetrasubstituted ferrocenes are important starting materials for the design of chiral ligands that have given enantiomeric excesses of up to 99 % in asymmetric syntheses.[10]

In 1981 Comins and Brown described a straightforward method in which the addition of a lithium amide to an aromatic aldehyde produced an aminal anion as a temporary protecting/directing group for *ortho* metalation.[11] Recently, Alexakis et al.[12] reported the enantioselective *ortho* lithiation of a benzaldehyde complex of tricarbonylchromium by applying the same strategy with chiral amides. We described a new method for the synthesis of 1,1′-disubstituted ferrocenes by a one-pot procedure based on the addition of the lithium salt of *N*-methylpiperazine to ferrocenecarbaldehyde. This produced an aminoaminal anion that protects the formyl group of one ring while its amino group directs the deprotonation in the other ring.[13]

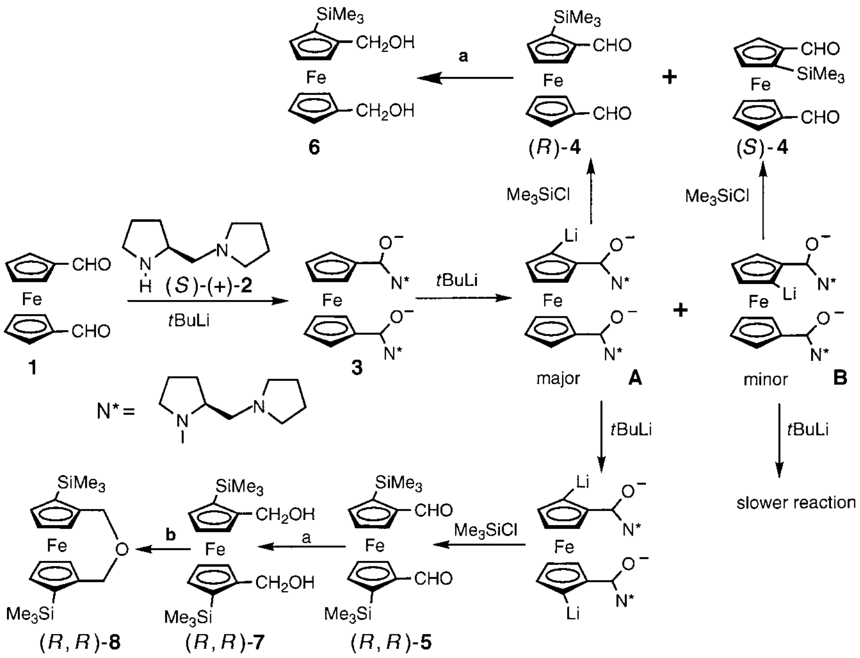
Here we report an extension of this procedure to the enantioselective synthesis of C_2-symmetric tetrasubstituted ferrocenes **5** from 1,1′-ferrocenedicarbaldehyde (**1**) by means of the lithium salt of (*S*)-(+)-1-(2-pyrrolidinylmethyl)pyrrolidine (**2**; Scheme 1). Treatment of the diaminal dianion **3** with *t*BuLi (1.5 equiv) at −78 °C followed by reaction with the electrophile trimethylsilyl chloride afforded (*R*)-**4**, which after hydrolysis and purification by flash chromatography was obtained in 29 % yield with an enantiomeric excess[14] of 96 %

---

[*] Dr. E. Manoury, Prof. G. G. A. Balavoine, Dr. G. Iftime,
Dr. J.-C.Daran
Laboratoire de Chimie de Coordination
205 route de Narbonne F-31004 Toulouse (France)
Fax: (+33) 561333131
E-mail: manoury@lcc-toulouse.fr
balavoin@lcc-toulouse.fr

[**] We gratefully acknowledge financial support from the Centre National de la Recherche Scientifique (CNRS) and a Doctoral fellowship (to G.I.) from the Ministère des Affaires Etrangeòres.

1433-7851/98/3712-1698 $ 17.50+.50/0



Scheme 1. Asymmetric synthesis of chiral ferrocenes. a) NaBH$_4$ (15 equiv)/MeOH/NaOH (2 N). b) TsCl (1 equiv)/toluene/4-Å molecular sieve.

(Table 1, entry 1).[15] No other substituted ferrocenes were detected, but the observation of significant amounts of insoluble brown material indicated partial decomposition of the ferrocene derivatives under these conditions. Increasing the temperature of the deprotonation step (− 45 °C) decreases the yield of **4** to 15 % without loss of enantioselectivity (entry 2). With an excess of *t*BuLi (3 equiv), bis-metalation occurs in the 2- and 2′-positions to give the C_2-symmetric disilylated compound **5**, which was isolated in 28 % yield (entry 4). No other regio- or stereoisomers were detected. The enantiomeric excess of **5** is very high (> 99 %), and the minor enantiomer could not be detected by NMR spectroscopy.[14] The molecular structure of **5** was elucidated by X-ray crystallography[16] (Figure 1), which confirmed that the compound is C_2-symmetric and substituted in the 2- and 2′-positions. The *R*,*R* configuration of the planar-chiral **5** is consistent with the *R* configuration obtained for **4**.

When the amount of *t*BuLi was sufficient to give the dilithiated precursor of **5**, a lower enantiomeric excess of **4** was obtained (entries 1, 3, and 4). Adding three equivalents of *t*BuLi in one portion (entry 5) or in two portions (entry 6: the monolithiated intermediate is obtained initially, as in entry 1) gave similar results. With a large excess of tBuLi (5 equiv, entry 7) the enantiomeric excess of **4** dropped to 56 %. This could be explained by faster conversion of the monolithiated intermediate **A** (Scheme 1) to the dilithiated species, which would give an **A**/**B** mixture enriched in the (*S*)-configured minor diastereoisomer **B**.

We also report the transformation of the tetrasubstituted ferrocene **5** into the first C_2-symmetric disubstituted ferrocenophane to be obtained as a pure enantiomer.[17] Reduction of **5** with an excess of NaBH$_4$ gave the diol **7** (71 % yield). By means of a procedure described by Hillman et al. and modified by us,[18] **7** was dehydrated with tosyl chloride (TsCl) in toluene in the presence of 4 Å molecular sieves at 50 °C.[19] The (*R*,*R*)-bis(trimethyl-

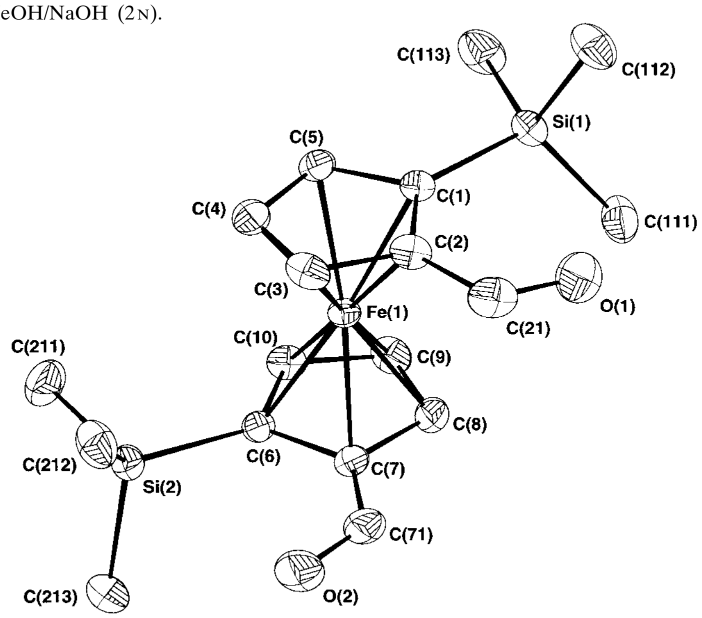


Figure 1. CAMERON representation of the molecular structure of **5** (single-crystal analysis[16]). The thermal ellipsoids correspond to 30 % probability. Selected distances [Å]: C(1)−Si(1) 1.876(2), C(6)−Si(2) 1.866(3), C(2)−C(21) 1.458(4), C(7)−C(71) 1.449(4), C(21)−O(1) 1.193(5), C(71)-O(2) 1.194(3).

Table 1. Direct synthesis of chiral tri- and tetrasubstituted ferrocenes from **1**.

Entry	Conditions[a]			Conversion	Yield	Yield	Total yield	*ee* (**4**)	*ee* (**5**)
	Equiv *t*BuLi	*T* [°C]	*t* [h]	[%]	(**4**) [%][b]	(**5**) [%][b]	(**1**+**4**+**5**) [%][b]	[%][c]	[%][d]
1	1.5	− 78	1	80	29	0	49	96	–
2	1.5	− 45	1	85	15	0	30	96	–
3	3.0	− 78	0.5	77	13	23	59	78	> 99
4	3.0	− 78	1	90	25	28	63	60	> 99
5	3.0	− 78	3	97	19	26	48	66	98
6	1) 1.5	− 78	1						
	2) 1.5	− 78	2	90	21	19	50	65	> 99
7	5.0	− 78	3	100	13	24	37	56	96

[a] 2.2 equiv **2**, electrophile = ClSiMe$_3$. [b] Yields of isolated products and recovered starting materials. [c] *R* configuration in all cases. [d] *R*,*R* configuration in all cases.

silyl)-β-oxatrimethyleneferrocene (**8**) was obtained in 44% yield (Scheme 1) and characterized by X-ray crystallography[16] (Figure 2). The geometry of the ferrocenophane unit (tilt angle: 11.4°) is similar to those of other 1,1′-β-oxatrimethyleneferrocenes.[19]

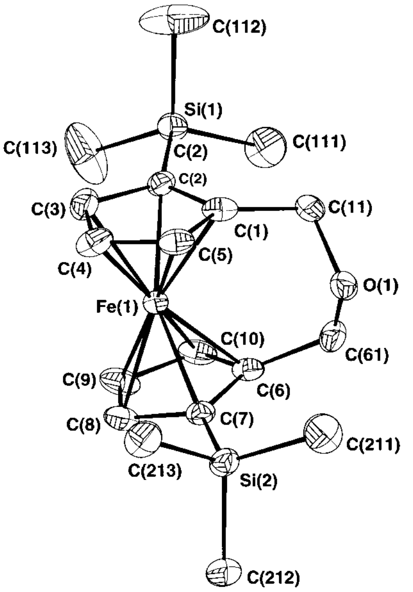


Figure 2. CAMERON representation of the molecular structure of **8** (single-crystal analysis[16]). The thermal ellipsoids correspond to 30% probability. Selected distances [Å]: C(2)–Si(1) 1.857(6), C(7)–Si(2) 1.864(6), C(1)–C(11) 1.45(1), C(6)–C(61) 1.52(1), C(11)–O(1) 1.45(1), C(61)–O(1) 1.40(1).

Here we have described the first direct and highly enantioselective synthesis of tri- and tetrasubstituted ferrocenes with exclusively planar chirality by using a chiral aminoamide as a temporary protecting/directing group. This method converts achiral 1,1′-ferrocenedicarbaldehyde into almost enantiomerically pure tetrasubstituted or trisubstituted ferrocenes in a one-pot procedure. We are now attempting to improve the yields and to extend the scope of this method.

Experimental Section

(*R*)-**4:** A solution of *t*BuLi in pentane (1.5 M, 575 μL) was added to a solution of (*S*)-**2** (150 mg) in dry ether(4 mL) at 0 °C under argon. After stirring for 30 min, 1,1′-ferrocenedicarbaldehyde (100 mg, 0.41 mmol) in dry ether (10 mL) was added. After stirring for 30 min at room temperature, the mixture was cooled to −78 °C, and 1.5 equiv of a solution of *t*BuLi in pentane (1.5 M, 410 μL) was added. After stirring for 1 h at −78 °C, trimethylsilyl chloride (270 μL, 5 equiv) was added. After aqueous workup and flash chromatography, (*R*)-**4** was isolated in 29% yield (37 mg). For physical data, see ref. [18].

(*R*,*R*)-**5** was prepared as (*R*)-**4** but with 3 equiv of *t*BuLi in the deprotonation step. After purification, 32 mg (25%) of (*R*)-**4** and 46 mg (29%) of (*R*,*R*)-**5** were obtained. ^{1}H NMR (250 MHz, $CDCl_3$, 23 °C): $\delta = 9.99$ (s, 2H), 5.04 (dd, $J = 2.5, 1.3$ Hz, 2H), 4.72 (t, $J = 2.5$ Hz, 2H), 4.49 (m, 2H), 0.31 (s, 18H); ^{13}C NMR (63 MHz, $CDCl_3$, 23 °C): $\delta = 193.7$ (CHO), 84.1, 80.3, 76.0, 75.7, 75.2, −0.1 ($SiMe_3$); GC-MS (IE, 70 eV) *m*/*z* (%): 387 [*M*+1] (31), 386 [*M*] (100), 371 (51), 191 (10); $[\alpha]_D = +419$ ($CHCl_3$, $c = 0.12$).

(*R*,*R*)-**7** was obtained by reduction of (*R*,*R*)-**5** with $NaBH_4$ in methanol (71%). ^{1}H NMR (250 MHz, $CDCl_3$, 23 °C): $\delta = 94.49$ (d, AB system, $J = 12.5$ Hz, 2H), 4.38 (d, AB system, $J = 12.5$ Hz, 2H), 4.36 (m, 2H), 4.26 (t, $J = 2.3$ Hz, 2H), 4.06 (dd, $J = 2.3, 1.3$ Hz, 2H), 3.42 (br s, 2H), 0.23 (s, 18H); ^{13}C NMR (63 MHz, $CDCl_3$, 23 °C): $\delta = 93.7$, 74.2, 70.7, 70.6, 69.6, 60.6, 0.2 ($SiMe_3$).$[\alpha]_D = -9.57$ (CH_2Cl_2, $c = 0.53$).

(*R*,*R*)-**8** was prepared in 44% yield by a modification of the procedure described by Hillman et al.[18] ^{1}H NMR (250 MHz, C_6D_6, 23 °C): $\delta = 94.47$ (dd, $J = 2.4, 1.3$ Hz, 2H), 4.29 (t, $J = 2.4$ Hz, 2H), 4.12 (dd, $J = 2.4, 1.3$ Hz, 2H), 4.02 (d, AB system, $J = 13.0$ Hz, 2H), 3.92 (d, AB system, $J = 13.0$ Hz, 2H), 0.37 (s, 18H); ^{13}C NMR (63 MHz, $CDCl_3$, 23 °C): $\delta = 87.3$, 76.5, 74.2, 73.0, 71.4, 64.0 (CH_2), 0.8 ($SiMe_3$); GC/MS (IE, 70 ev) *m*/*z* (%): 372 [*M*] (100); $[\alpha]_D = -27$ (CH_2Cl_2, $c = 0.7$).

Received: September 5, 1997
Revised version: March 5, 1998 [Z10896IE]
German version: *Angew. Chem.* **1998**, *110*, 1827–1829

Keywords: asymmetric synthesis · chirality · iron · metallocenes · metallocenophanes

---

[1] Review: A. Togni, T. Hayashi, *Ferrocenes*, VCH, Weinheim, **1995**.
[2] S. Borman, *Chem. Eng. News* **1996**, *July 22*, 38.
[3] N. Long, *Angew. Chem.* **1995**, *107*, 37; *Angew. Chem. Int. Ed. Eng.* **1995**, *34*, 21.
[4] a) D. Marquarding, H. Klusaceck, G. Gokel, P. Hoffmann, I. Ugi, *J. Am. Chem. Soc.* **1970**, *92*, 5389; b) C. Ganter, T. Wagner, *Chem. Ber.* **1995**, 1157.
[5] a) O. Riant, O. Samuel, H. B. Kagan, *J. Am. Chem. Soc.* **1993**, *115*, 5835; b) O. Riant, O. Samuel, T. Flessner, S. Taudien, H. B. Kagan, *J. Org. Chem.* **1997**, *62*, 6733.
[6] F. Rebière, O. Riant, L. Ricard, H. B. Kagan, *Angew. Chem.* **1993**, *105*, 644; *Angew. Chem. Int. Ed. Eng.* **1993**, *32*, 568.
[7] a) T. Sammakia, H. A. Latham, D. R. Schaad, *J. Org. Chem.* **1995**, *60*, 10; b) Y. Nishibayashi, S. Uemura, *Synlett* **1995**, 79; c) C. J. Richards, T. Damalidis, D. E. Hibbs, M. B. Hursthouse, *Synlett* **1995**, 74.
[8] a) D. Price, N. S. Simpkins, *Tetrahedron Lett.* **1995**, *36*, 6135; b) M. Tsukazaki, M. Tinkl, A. Roglans, B. J. Chapell, N. J. Taylor, V. Snieckus, *J. Am. Chem. Soc.* **1996**, *118*, 685; c) Y. Nishibayashi, Y. Arikawa, K. Ohe, S. Uemura, *J. Org. Chem.* **1996**, *61*, 1172.
[9] a) T. Hayashi, A. Yamamoto, M. Hojo, K. Kishi, Y. Ito, E. Nishioka, H. Miura, K. Yanagi, *J. Organomet. Chem.* **1989**, *370*, 129; b) J. Park, S. Lee, K. H. Ahn, C.-W. Cho, *Tetrahedron Lett.* **1995**, *36*, 7263; d) W. Zhang, Y. Adachi, T. Hirao, I. Ikeda, *Tetrahedron: Asymmetry* **1996**, *7*, 451; e) J. Park, S. Lee, K. H. Ahn, C.-W. Cho, *Tetrahedron Lett.* **1996**, *37*, 6137.
[10] a) T. Hayashi, A. Yamamoto, M. Hojo, Y. Ito, *J. Chem. Soc. Chem. Commun.* **1989**, 495; b) W. Zhang, T. Hirao, I. Ikeda, *Tetrahedron Lett.* **1996**, *37*, 4545; c) W. Zhang, T. Kida, Y. Nakatsuji, *ibid.* **1996**, *37*, 7995; d) K. H. Ahn, C.-W. Cho, J. Park, S. Lee, *Tetrahedron: Asymmetry* **1997**, *8*, 1179.
[11] D. L. Comins, J. D. Brown, *J. Org. Chem.* **1984**, *49*, 1078.
[12] A. Alexakis, T. Kanger, P. Mangeney, F. Rose-Munch, A. Perrotey, E. Rose, *Tetrahedron: Asymmetry* **1995**, *6*, 2135.
[13] G. Iftime, C. Moreau-Bossuet, E. Manoury, G. G. A. Balavoine, *Chem. Commun.* **1996**, 527.
[14] Determined by ^{1}H NMR spectroscopy with $Eu(hfc)_3$ by integration of the $SiMe_3$ signals of the two enantiomers of the corresponding diol, which was obtained by reduction with $NaBH_4$.
[15] $[\alpha]_D = -7.6$ ($c = 0.9$, $CHCl_3$)) for **6**. Comparison with an authentic sample of the enantiomerically pure diol (*S*)-**6** ($[\alpha_D = +8.1$; $c = 0.9$, $CHCl_3$) gave an *ee* of 94%. See also ref. [19].
[16] Crystal data for **5**: $C_{18}H_{26}O_2Si_2Fe$, $M_r = 386.42$; orthorhombic, space group $P2_12_12_1$, $a = 6.970(1)$, $b = 12.266(2)$, $c = 23.068(2)$ Å, $V = 1971.9(4)$ Å^3, $Z = 4$, $\rho_{calcd} = 1.302$ g cm^{-3}; $\mu = 8.882$ cm^{-1}; empirical absorption correction applied (ψ scan), $Mo_{K\alpha}$ radiation, $T = 293$ K, $\omega/2\theta$ scan (Enraf-Nonius CAD4 diffractometer); $2\theta_{max} = 56°$; of 4445 reflections collected, 3805 were independent ($Rm = 0.017$) and 3583 were regarded as observed ($I > 3\sigma(I)$); 210 parameters were refined; R/R_w 0.0346/0.0400, GOF = 0.849, $\Delta/\sigma = 0.095$, $[\Delta\rho]_{min}/[\Delta\rho]_{max}$ −0.41/0.75; Flack's parameter = 0.01(1). Crystal data for **8**: $C_{18}H_{28}O_1Si_2Fe$; $M_r = 372.4$; orthorhombic, space group $P2_12_12_1$, $a = 7.113(1)$, $b =$

11.963(2), $c = 22.865(4)$ Å, $V = 1945.7(3)$ Å^3, $Z = 2$, $\rho_{calcd} = 1.271$ g cm^{-3}; $\mu = 8.942$ cm^{-1}; no absorption correction applied; Mo$_{K\alpha}$ radiation; $T = 293$ K; F scan (Stoe IPDS diffractometer); F range 0–250°; of 7483 reflections collected, 2983 were independent ($Rm = 0.074$) and 2037 were regarded as observed ($I > 2\sigma(I)$); 210 parameters refined; R/R_w 0.0424/0.0460, GOF = 1.104, $\Delta/\sigma = 0.041$; $[\Delta\rho]_{min}/[\Delta\rho]_{max}$ $-0.37/0.56$; Flack's parameter = 0.00(3). The structures of **5** and **8** were solved with the programs SIR92 and CRYSTALS. Crystallographic data (excluding structure factors) for the structures reported in this paper have been deposited with the Cambridge Crystallographic Data Centre as supplementary publication no. CCDC-100607. Copies of the data can be obtained free of charge on application to CCDC, 12 Union Road, Cambridge CB2 1EZ, UK (fax: (+44) 1223-336-033; e-mail: deposit@ccdc.cam.ac.uk).

[17] Some racemic C_2-symmetric disubstituted ferrocenophanes have already been described: a) J. A. Winstead, R. R. McGuire, R. E. Cochoy, A. D. Brown, Jr., G. J. Gauthier, *J. Org. Chem.* **1972**, *37*, 2055; b) R. C. Petter, C. I. Milberg, *Tetrahedron Lett.* **1989**, *3*, 5085; c) D. L. Compton, T. B. Rauchfuss, *Organometallics* **1994**, *13*, 4367.

[18] M. Hillman, J. D. Austin, *Organometallics* **1987**, *6*, 1737.

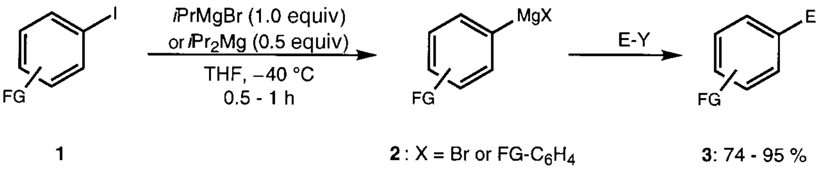
[19] G. Iftime, J. C. Daran, E. Manoury, G. G. A. Balavoine, *Organometallics* **1996**, *15*, 4808.

Preparation of Highly Functionalized Grignard Reagents by an Iodine–Magnesium Exchange Reaction and its Application in Solid-Phase Synthesis

Laure Boymond, Mario Rottländer, Gérard Cahiez,* and Paul Knochel*

In memoriam Henri Normant

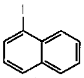
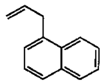
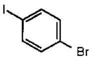
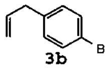
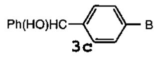
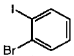
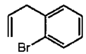
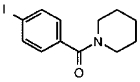
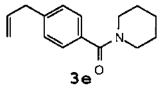
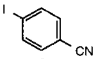
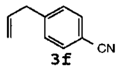
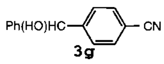
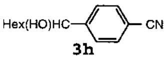
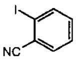
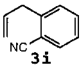
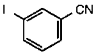
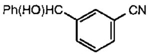
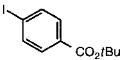
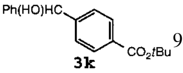
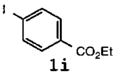
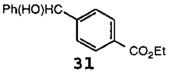
Organomagnesium reagents are extremely important in synthetic organic chemistry. Since their discovery, there has great interest in these versatile reagents, and numerous industrial applications have been reported.[1] Grignard reagents can be conveniently synthesized from organic halides and exhibit high reactivity and satisfactory chemoselectivity, which can be further improved by transmetalation.[2] However, very few functionalized organomagnesium reagents have been prepared due to the low functional-group tolerance of these reagents.[1] Here we report a general route to highly functionalized arylmagnesium halides of type **2**, which contain functional groups such as ester, amide, or cyano groups, or a halogenide substituent and were synthesized from functionalized aryl iodides of type **1** by an iodine–magnesium exchange reaction.[3] The reaction of **2** with electrophiles E–Y (aldehyde or allyl bromide) gave the expected aromatic products of type **3** in good to excellent yield (Scheme 1 and Table 1).



Scheme 1. Functional group (FG) = Br, CONR$_2$, CN, CO$_2$Et, CO$_2t$Bu; E–Y = aldehyde, allyl bromide.

Preliminary experiments showed that treatment of 1-iodonaphthalene (**1a**) with *i*PrMgBr or *i*Pr$_2$Mg in THF at 25 °C for 1 h or 0.5 h, respectively, gave the corresponding Grignard reagent **2a** in 90 % yield (GC analysis of aliquots of

Table 1. Synthesis of compounds **3** by iodine–magnesium exchange of aryl iodides **1 a–i** with *i*Pr$_2$Mg followed by reaction with an electrophile E–Y.

Entry	Aryl iodide **1**	T [°C]/t [h][a]	E–Y	Product **3**	Yield [%][b]
1	 **1a**	25/0.5	CH$_2$CHCH$_2$Br	 **3a**	80 (87)[c]
2	 **1b**	−40/0.5	CH$_2$CHCH$_2$Br	 **3b**	79[d]
3		−25/0.5	PhCHO	 **3c**	93
4	 **1c**	−25/0.5	CH$_2$CHCH$_2$Br	 **3d**	95
5	 **1d**	−25/0.5	CH$_2$CHCH$_2$Br	 **3e**	81
6	 **1e**	−40/1	CH$_2$CHCH$_2$Br	 **3f**	75[d]
7		−40/1	PhCHO	 **3g**	94
8		−40/1	n-C$_6$H$_{13}$-CHO	 **3h**	74
9	 **1f**	−40/0.5	CH$_2$CHCH$_2$Br	 **3i**	89
10	 **1g**	−40/0.5	PhCHO	 **3j**	89
11	 **1h**	−40/1	PhCHO	 **3k**	94 (91)[e]
12	 **1i**	−40/1	PhCHO	 **3l**	90 (90)[e]

[a] Reaction conditions for iodine–magnesium exchange. [b] Yield of analytically pure product. [c] Yield obtained by performing iodine–magnesium exchange with (*cyclo*-C$_5$H$_9$)$_2$Mg. [d] The allylation was performed in the presence of CuCN · 2 LiCl (10 mol %). [e] *i*PrMgBr (1.05 equiv) was used in this case.

---

[*] Prof. Dr. P. Knochel, Dipl.-Chem. M. Rottländer
Fachbereich Chemie der Universität
Hans-Meerwein-Strasse, D-35032 Marburg (Germany)
Fax: (+49) 6421-282189
E-mail: knochel@ps1515.chemie.uni-marburg.de
Prof. Dr. G. Cahiez, Dipl.-Ing. L. Boymond
Ecole Supérieure de Chimie Organique et Minérale
Department de Chimie
13, Boulevard de l'Hautil
F-95092 Cergy-Pontoise (France)
Fax: (+33) 1-4272-2273

[**] We thank the DFG (SFB 260, Leibniz-program), the BMBF (03 D00562), BASF AG, the Procope program, and CNRS for generous support.