Preparation of Monosilyl Ethers of Vicinal Diols

Øyvind Antonsen, Tore Benneche and Kjell Undheim

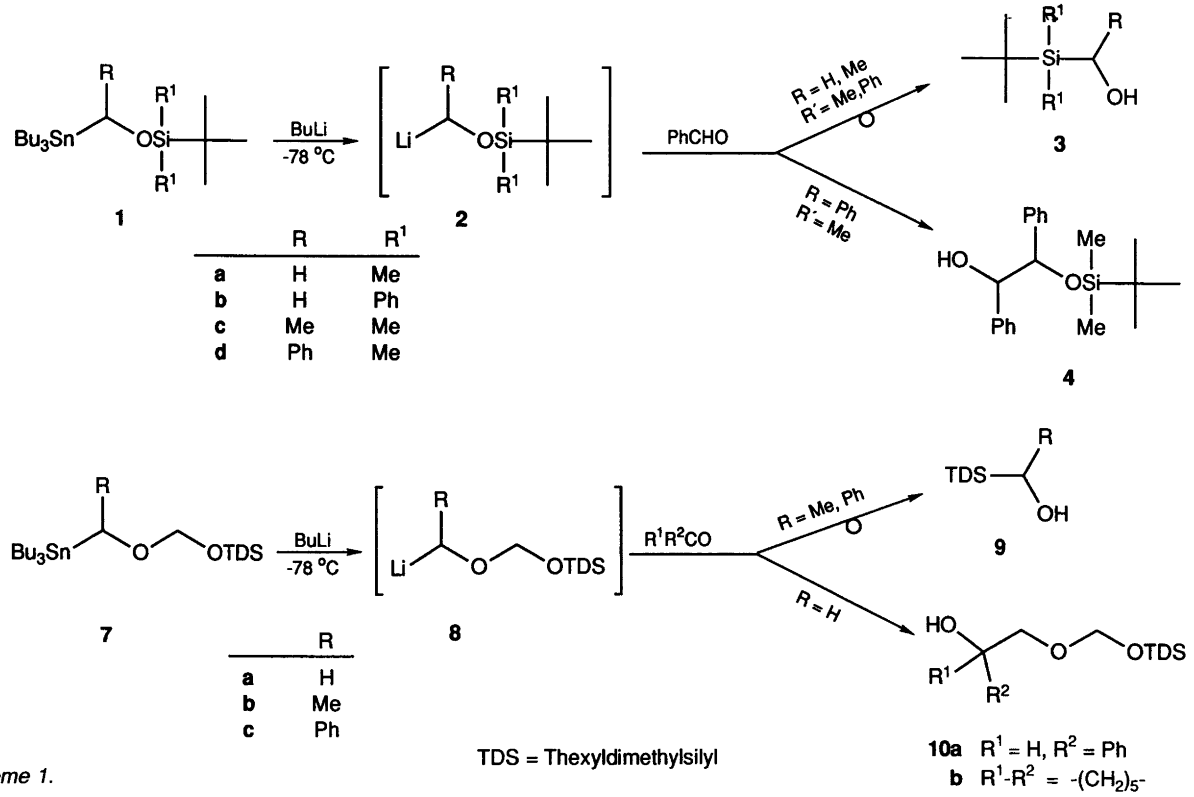
Department of Chemistry, University of Oslo, P.O. Box 1033 Blindern, N-0315 Oslo 3, Norway

Antonsen, Ø., Benneche, T. and Undheim, K., 1992. Preparation of Monosilyl Ethers of Vicinal Diols. – Acta Chem. Scand. 46: 757–760.

Monosilyl-protected vicinal diols can be prepared by lithiation of silyl derivatives of α-hydroxyalkylstannanes and subsequent addition to carbonyl compounds. Concurrent reaction of the lithium species initially formed is a reverse Brook rearrangement to yield α-hydroxyalkylsilanes. Alternatively, the monosilyl protected diols were prepared by a samarium(II) iodide mediated Barbier type reaction between α-haloalkoxysilanes and carbonyl compounds.

α-Alkoxyalkyllithium reagents are becoming important intermediates in the construction of functionalized carbon–carbon bonds.[1–3] They are available from the corresponding α-alkoxyalkylstannanes by cleavage of the tin–carbon bond in a stereospecific manner by alkyllithium reagents.[4] With a removable alkyl group, e.g. the acid-labile methoxymethyl (MOM) group, these reagents have been used in the preparation of monoprotected vicinal glycols which are formed from reactions with carbonyl compounds.[2]

In one of our projects the preparation of monoprotected glycols of acid-labile compounds was required. We therefore chose to investigate the use of α-silyloxystannanes in the synthesis of monosilylated glycols by tin–lithium exchange for subsequent reaction with carbonyl compounds. Difficulties were expected with this approach because of a possible reverse Brook rearrangement, the migration of the silicon from oxygen to carbon.[5] This rearrangement has been explored for the preparation of (α-hydroxyalkyl)-trialkylsilanes, and it has been reported that (α-trimethylsilyloxyalkyl)tributylstannanes in the presence of excess butyllithium at −78 °C undergoes the reverse Brook rearrangement.[6] The transmetallation–rearrangement process, however, is sensitive to steric effects from substituents on the silicon, on neighbouring carbon and on the tin.[6]

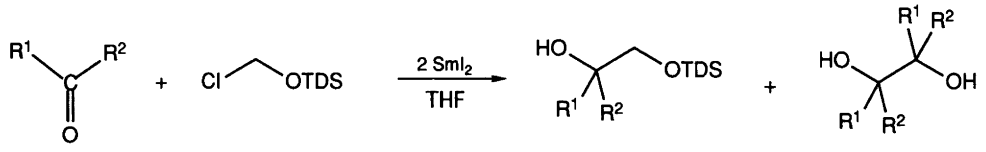


	R	R¹
a	H	Me
b	H	Ph
c	Me	Me
d	Ph	Me

	R
a	H
b	Me
c	Ph

TDS = Thexyldimethylsilyl

Scheme 1.



	R^1	R^2
a	H	*n*-Pent
b	Me	Ph
c	$-(CH_2)_5-$	

Scheme 2.

In our work we have studied α-tributylstannylalkyl derivatives of *t*-butyldimethyl- and *t*-butyldiphenyl-silyl ethers **1** which were available from earlier work.[7] On treatment of compounds **1a–c** with butyllithium at −78 °C, invariably rearrangement occurred concomitant with the tin–lithium exchange (Scheme 1). Even the *t*-butyldiphenylsilyl derivative **1b**, which contains the silyl group with the lowest tendency for reactions with carbanions,[8] failed to be trapped as its silyloxymethyllithium intermediate by carbonyl reagents. With the benzylic derivative **1d**, however, the *t*-butyldimethylsilyl group was sufficient to stop the rearrangement, and the lithiated carbanion was readily trapped by addition of benzaldehyde to yield the monoprotected glycol **4**. With the less reactive carbonyl group in cyclohexanone, the lithium compound **2d** gave only the reverse Brook rearrangement product **3**.

In an attempt to avoid the rearrangement reaction, we increased the distance between the silyl and the stannyl groups. Thus compounds **7** were prepared by reacting α-hydroxyalkylstannanes[7b] with chloromethyl dimethylthexylsilyl ether.[9,*] In this case the alkoxymethyllithium species **8a** was added preferentially to the carbonyl of benzaldehyde to give the monoprotected diol **10**. In contrast with **2d**, the lithium compound **8a** also reacted with cyclohexanone to form the addition product **10b**. The ethyl and benzyl derivatives, **7b** and **7c**, underwent reverse Brook rearrangement to give the α-silyl alcohols **9**. The observation that **7c** does rearrange while **2d** does not, indicates that factors other than the relative stabilities of the anions are important in this rearrangement process. The difficulties experienced led us to apply an alternative method for hydroxymethylation of the carbonyl group, *viz.* a Barbier-type reaction induced by samarium diiodide. The latter acts as an one-electron donor to effect inter- and intramolecular carbon–carbon bond formation between organohalides and carbonyl functions.[10]

The methodology has been extended to the preparation of monobenzyl ethers of vicinal glycols by the reaction between benzyl chloromethyl ether and carbonyl derivatives.[11] We have found that the silyl chloromethyl ether **11** is a good substrate for the samarium diiodide mediated Barbier-type reaction with carbonyl derivatives. The monoprotected diols were obtained in 45–70 % yield, depending on the carbonyl compound used. The minor product from the reaction **13** was due to the pinacol reaction. The substrate for the Barbier reaction, the silyl chloromethyl ether **11**, is readily available by sulfuryl chloride cleavage of the corresponding methylthiomethyl silyl ether.[9]

* Thexyl = 2,3-dimethyl-2-butyl.

Experimental

The NMR spectra were recorded in $CDCl_3$ at 300 MHz (^1H) and at 75 MHz (^{13}C) unless otherwise specified. Mass spectra were recorded under chemical ionization conditions using NH_3 for ionization unless otherwise specified. EI mass spectra were recorded at 70 eV ionizing voltage. The spectra are presented as *m/z* (% rel. int.).

Compounds available by literature methods. (*t*-Butyldimethylsilyloxymethyl)tributylstannane **1a**.[7a] (*t*-Butyldiphenylsilyloxymethyl)tributylstannane **1b**.[7a] [1-(*t*-Butyldimethylsilyloxy)ethyl]tributylstannane **1c**.[7b] [α-(*t*-Butyldimethylsilyloxy)benzyl]tributylstannane **1d**.[7b] Dimethylthexylsilyl chloromethyl ether **11**.[9]

General procedure for the reaction between stannanes **1** *or* **7** *and carbonyl compounds.* BuLi in hexane (1.6 M, 0.67 ml) was added over 1 min to a solution of the stannane **1** or **7** (1.0 mmol) in dry THF (2 ml) under N_2 at −78 °C, and the solution was stirred for 5 min before the neat carbonyl compound was added via a syringe. The reaction mixture was then allowed to reach ambient temperature overnight before diethyl ether was added and the ether solution washed with saturated NH_4Cl and H_2O, dried ($MgSO_4$) and evaporated to leave the crude product which was purified by flash chromatography on silica gel using pentane–ethyl acetate 10:1 for elution.

t-*Butyldimethylsilylmethanol* **3a**. Yield 58 %; colourless liquid. ^1H NMR (60 MHz): δ −0.1 [$(CH_3)_2Si$], 0.9 (*t*-Bu), 2.2 (OH), 3.4 (CH_2).

t-*Butyldiphenylsilylmethanol* **3b**. Yield 48 %; colourless liquid. Mol. wt. obs. 213.0743. Calc. for $C_{13}H_{13}OSi$ 213.0736 (*M*−*t*-Bu). ^1H NMR: δ 0.95 (OH), 1.10 (*t*-Bu), 4.06 (CH_2), 7.3–7.4 (6 H, m, Ar), 7.6–7.7 (4 H, m, Ar). ^{13}C NMR: δ 18.0 [$C(CH_3)_3$], 27.8 [$C(CH_3)_3$], 51.8 (CH_2),

127.8, 129.4, 133.1, 135.8 (Ar). MS: 271 (3, *M*+1), 269 (2), 214 (8), 213 (29), 192 (18), 193 (100), 151 (19).

1-(t-Butyldimethylsilyl)ethanol **3c**.[11] Yield 52 %.

α-(t-Butyldimethylsilyl)benzyl alcohol **3d**.[12] Yield 61 %.

2-t-Butyldimethylsilyloxy-1,2-diphenyl ethanol **4**. Yield 56 %; colourless liquid. ^{1}H NMR (200 MHz): δ −0.15 (CH_3Si), 0.03 (CH_3Si), 0.99 (*t*-Bu), 2.90 (OH), 4.6–4.8 (m, 2×CH), 7.1–7.4 (m, Ar).

General procedure for the preparation of [1-(t-butyldimethylsilyloxymethoxy)alkyl]tributylstannanes **7**. A solution of dimethylthexylsilyl chloromethyl ether (5.2 g, 25 mmol) in dichloromethane (20 ml) was added dropwise to a solution of the α-tributylstannyl alcohol (12.0 mmol) and diisopropylethylamine (10.3 ml, 60 mmol) in dichloromethane (20 ml) under N_2 at 0 °C. The mixture was stirred overnight at ambient temperature before diethyl ether was added, the ether solution washed with saturated NH_4Cl (aq.) and water, dried ($MgSO_4$) and evaporated to leave the crude product which was purified by flash chromatography on silica gel using first hexane and then hexane–ethyl acetate 10:1 for elution.

(Dimethylthexylsilyloxymethoxymethyl)tributylstannane **7a**. Yield 57 %, colourless liquid. Anal. $C_{22}H_{48}O_2SiSn$: C, H. ^{1}H NMR: δ 0.14 [$(CH_3)_2Si$], 0.89–0.93 and 1.26–1.70 (m, Thex, Bu), 3.75 ($SnCH_2O$), 4.73 (OCH_2O). ^{13}C NMR: δ −2.9 (CH_3Si), 8.9, 13.7, 18.5, 20.2, 25.0, 27.3, 29.1, 34.1 (Thex, Bu), 57.7 ($SnCH_2O$), 93.1 (OCH_2O). MS: 441 (16), 439 (19), 438 (21), 437 (100), 436 (42), 435 (72), 434 (30), 433 (35), 409 (4), 353 (21), 352 (9), 351 (18), 350 (7), 349 (7), 295 (8), 293 (7), 292 (5), 291 (47), 290 (17), 289 (35), 288 (14), 287 (20).

[1-(Dimethylthexylsilyloxymethoxy)ethyl]tributylstannane **7b**. Yield 63 %, colourless liquid. ^{1}H NMR: δ 0.13 (CH_3Si), 0.14 (CH_3Si), 0.77–0.98 and 1.25–1.70 (m, Me, Thex, Bu), 4.18 (q, *J* 7.5 Hz, CH), 4.72 [d, *J* 5.2 Hz, H_A (CH_2)], 4.90 [d, *J* 5.2 Hz, H_B (CH_2)]. ^{13}C NMR: δ −3.1 (CH_3Si), −2.7 (CH_3Si), 8.8, 13.7, 18.5, 20.2, 20.6, 25.0, 27.5, 29.2, 34.1 (Me, Thex, Bu), 67.7 (SnCH), 89.0 (OCH_2O). MS: 511/509/507/505 (0.3/0.3/0.6/0.4, *M*−1), 456 (4), 455 (18), 454 (4), 453 (20), 452 (24), 451 (100), 450 (42), 449 (73), 448 (31), 447 (41), 291 (2), 289 (2).

[α-(Dimethylthexylsilyloxymethoxy)benzyl]tributylstannane **7c**. Yield 63 %; colourless liquid. ^{1}H NMR: δ 0.08 (CH_3Si), 0.11 (CH_3Si), 0.74–0.92 and 1.20–1.65 (m, Thex, Bu), 4.69 [d, *J* 4.7 Hz, H_A (CH_2)], 4.88 [d, *J* 4.7 Hz, H_B (CH_2)], 5.16 (CH), 7.02–7.26 (m, Ar). ^{13}C NMR: δ −3.1 (CH_3Si), −2.8 (CH_3Si), 9.1, 13.7, 18.5, 20.2, 25.0, 27.4, 28.9, 34.1 (Thex, Bu), 73.6 (CH), 88.7 (CH_2), 124.2, 124.5, 128.0, 144.7 (Ar).

1-(Dimethylthexylsilyl)ethanol **9a**. Yield 76 %, colourless liquid. ^{1}H NMR (200 MHz): δ 0.0 (CH_3Si), 0.08 (CH_3Si), 0.85–0.95 (m, CH_3 in Thex), 1.28 (d, *J* 10 Hz, CH_3), 1.60–1.80 (m, *J* 7 Hz, CH in Thex), 2.04 (br s, OH), 3.69 (d, *J* 10 Hz, C*H*OH). ^{13}C NMR (50 MHz): δ − 6.2 (CH_3Si), −5.2 (CH_3Si), 18.8, 19.0, 21.4, 21.8 (CH_3), 24.1 (C in thexyl), 35.2 (CH in thexyl), 61.2 (C–OH).

α-(Dimethylthexylsilyl)benzyl alcohol **9b**. Yield 60 %, colourless liquid. ^{1}H NMR: δ −0.29 and 0.11 [$(CH_3)_2Si$], 0.85–0.95 (m, CH_3 in thexyl), 1.50–1.70 (m, CH in thexyl), 2.00 (OH), 4.38 (C*H*Ph), 7.30 (Ph). ^{13}C NMR: δ −3.2 and −2.3 [$(CH_3)_2Si$], 18.7 and 20.5 (CH_3 in thexyl), 25.6 (C in thexyl), 34.2 (CH in thexyl), 73.6 (C–OH). MS (EI): 250 (84, *M*), 181 (58), 171 (16), 166 (14), 165 (62), 163 (19), 149 (17), 135 (13), 129 (14), 75 (100).

2-(Dimethylthexylsilyloxymethoxy)-1-phenylethanol **10a**. Yield 52 %; colourless liquid. ^{1}H NMR: δ 0.08 (s, CH_3Si), 0.17 (CH_3Si), 0.86–0.91 (m, CH_3 in thexyl), 1.55–1.70 (m, CH in thexyl), 3.32 (d, *J* 2.2 Hz, OH), 3.55 [dd, *J* 10.7 and 8.9 Hz, H_A (CH_2CH)], 3.84 [dd, *J* 10.7 and 2.9 Hz, H_B (CH_2CH)], 4.87 (m, *J* 8.9 and 2.9 Hz, C*H*CH_2), 4.92 [d, *J* 5.3 Hz, H_A (OCH_2O)], 4.94 [d, *J* 5.3 Hz, H_B (OCH_2O)], 7.26–7.41 (Ph). ^{13}C NMR: δ −5.5 (CH_3Si), −2.9 (CH_3Si), 18.5, 20.2, 25.1, 34.2 (thexyl), 73.1, 75.1 (CH_2CH), 90.5 (OCH_2O). MS (CH_4): 311 (5, *M*+1), 209 (35), 207 (18), 195 (31), 179 (20), 173 (17), 161 (17), 149 (10), 105 (9), 89 (100).

1-(Dimethylthexylsilyloxymethoxymethyl)cyclohexanol **10b**. Yield 54 %; colourless liquid. Mol. wt. obs. 187.1148. Calc. for $C_9H_{19}O_2Si$ 187.1154 [*M* − (thexyl + CH_2O)]. ^{1}H NMR: δ 0.16 [$(CH_3)_2Si$], 0.86 [$(CH_3)_2C$], 0.89 [d, *J* 6.8 Hz, $(CH_3)_2CH$], 1.20–1.70 [m, $(CH_2)_5$, CH in Thex), 3.45 (CCH_2O), 3.47 (OH), 4.89 (OCH_2O). ^{13}C NMR: δ 0.15 (CH_3Si), 18.5, 20.2, 21.9, 25.0, 31.6, 34.1, 34.5 [$(CH_2)_5$, thexyl], 70.5 (C–OH), 76.9 (CH_2O), 90.8 (OCH_2O). MS (CH_4): 187 (12), 173 (3), 161 (5), 143 (4), 105 (10), 95 (47), 89 (100).

General procedure for the samarium(II) iodide mediated reaction between dimethylthexylsilyloxymethyl chloride **11** *and carbonyl compounds.* A solution of 1,2-diiodoethane (0.564 g, 2.0 mmol) in THF (10 ml) was added to a slurry of samarium metal powder (0.450 g, 3.0 mmol) in THF (30 ml) at ambient temperature under N_2 over 5 min, and the mixture was stirred for 1 h before dimethylthexylsilyloxymethyl chloride **11** (0.209 g, 1.0 mmol) in THF (10 ml) and the carbonyl compound (1.0 mmol) were added. After being stirred for 10 h, the reaction was quenched with saturated K_2CO_3 (aq.) and extracted with diethyl ether, the ether solution was washed with saturated K_2CO_3 (aq.) and brine, dried ($MgSO_4$) and evaporated and the product was purified by flash chromatography on silica gel using hexane–ethyl acetate 10:1 for elution.

1-Dimethylthexylsilyloxy-2-heptanol **12a**. Yield 27 %, colourless liquid. Mol. wt. obs. 273.2245. Calc. for $C_{15}H_{23}O_2Si$: 273.2250 (*M*–H). ^{1}H NMR: δ 0.07 [$(CH_3)_2Si$], 0.82 [$(CH_3)_2C$], 0.86 [d, *J* 7.0 Hz, $(CH_3)_2CH$], 0.80–0.90 and 1.20–1.40 [m, $CH_3(CH_2)_4$], 1.60 (m, CH in thexyl), 1.90 (m, OH), 3.20 (m, CH), 3.33 [d, *J* 9.7 Hz, H_A (CH_2)], 3.46 [d, *J* 9.7 Hz, H_B (CH_2)]. ^{13}C NMR: δ −3.6 [$(CH_3)_2Si$], 14.1 (CH_3), 18.5 and 20.3 (CH_3 in thexyl), 22.1, 22.6, 32.6 and 33.5 [$(CH_2)_4$], 24.9 (C in thexyl), 34.3 (CH in thexyl), 64.7 (2 × C–O). MS (EI): 274 (1, *M*), 273 (5), 259 (4), 201 (23), 189 (5), 185 (38), 173 (18), 149 (100).

1-Dimethylthexylsilyloxy-2-phenyl-2-propanol **12b**. Yield 44 %. Mol. wt. obs. 209.0997. Calc. for $C_{11}H_{17}O_2Si$: 209.0998 (*M*−thexyl). ^{1}H NMR: δ −0.01 (CH_3Si), 0.06 (CH_3Si), 0.8–0.9 (m, CH_3 in thexyl), 1.50 (CH_3CPh), 1.5–1.6 (m, CH), 2.99 (OH), 3.63 [d, *J* 9.6 Hz, H_A (CH_2)], 3.66 [d, *J* 9.6 Hz, H_B (CH_2)], 7.2–7.5 (m, Ar). ^{13}C NMR: δ −3.80 (CH_3Si), −3.75 (CH_3Si), 18.4 (2 × CH_3), 20.2 (2 × CH_3), 25.1 [$(CH_3)_2C$], 25.9 (CH_3CPh), 34.1 (CH), 71.5 (CH_2), 74.1 (*C*–Ph), 125.0, 126.6, 127.9, 145.4 (Ar). MS: 312 (1, $M+NH_4$), 294 (*M*, 1), 279 (2), 278 (5), 277 (23), 212 (6), 211 (18), 210 (100), 209 (26), 193 (48), 92 (25).

1-Dimethylthexylsilyloxymethylcyclohexanol **12c**. Yield 71 %. ^{1}H NMR: δ 0.10 [$(CH_3)_2Si$], 0.86 [$(CH_3)_2C$], 0.89 [d, *J* 6.9 Hz, $(CH_3)_2CH$], 1.2–1.8 [m, $(CH_2)_5$, CH], 2.27 (OH), 3.39 (CH_2O). ^{13}C NMR: δ −3.7 [$(CH_3)_2Si$], 18.4 (2×CH_3), 20.2 (2×CH_3), 21.9, 26.0, 34.2, (3×CH_2), 25.1 [$(CH_3)_2CH$], 34.2 (CH), 70.4 (CH_2O), 70.9 (*C*–Ph). MS: 273 (1, *M*+1), 257 (2), 256 (6), 255 (28), 190 (5), 189 (16), 188 (100), 187 (4), 95 (28), 92 (47).

References

1. Sawyer, J. S., Kucerovy, A., Macdonald, T. L. and McGarvey, G. J. *J. Am. Chem. Soc. 110* (1988) 842.
2. Johnson, C. R. and Medich, J. R. *J. Org. Chem. 53* (1988) 4131.
3. Chong, J. M. and Mar, E. K. *Tetrahedron 45* (1989) 7709.
4. Still, W. C. and Sreekumar, C. *J. Am. Chem. Soc. 102* (1980) 1207.
5. Brook, A. G. *Acc. Chem. Res. 7* (1974) 77.
6. Linderman, R. J. and Ghannam, A. *J. Org. Chem. 53* (1988) 2880.
7. (a) Majeed, A. J., Antonsen, Ø., Benneche, T. and Undheim, K. *Tetrahedron 45* (1989) 993; (b) Benneche, T., Antonsen, Ø., Gundersen, L.-L. and Undheim, K. *Acta Chem. Scand. 46* (1992) 172.
8. Hase, T. A. and Lahtinen, L. *Synth. Commun. 8* (1978) 573.
9. Gundersen, L.-L., Benneche, T. and Undheim, K. *Acta Chem. Scand. 43* (1989) 706.
10. (a) Girard, P., Namy, J. L. and Kagan, H. B. *J. Am. Chem. Soc. 102* (1980) 2693; (b) Souppe, J., Danon, L., Namy, J. L. and Kagan, H. B. *J. Organomet. Chem. 250* (1983) 227; (c) Molander, G. A., Etter, J. B. and Zinke, P. W. *J. Am. Chem. Soc. 109* (1987) 453.
11. Kumada, M., Imaki, N. and Yamamoto, K. *J. Organomet. Chem. 6* (1966) 490.
12. Wright, A. and West, T. *J. Am. Chem. Soc. 96* (1974) 3214.

Received October 31, 1991.