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## Reactions of Allylmetal(Group IVb) Compounds Derived from Isopulegol with Thallium(III) Acetate

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Allylsilane **3a** synthesized from (–)-isopulegol (**1**), on treatment with thallium(III) acetate in dichloromethane, undergoes ring opening reaction to give a mixture of diastereoisomers of unsaturated aldehyde **4**. On the other hand, the corresponding germanium analog **3b** gives allyl acetate **8**. The difference of reactivity between these allylmetal(group IVb) compounds toward thallium(III) acetate is discussed in terms of bond energy of each carbon-metal bond.

KEY WORDS: Ring opening reaction/ Allylsilane/ Allylgermane/ Thallium(III) acetate/ Allylthallium(III) compound/

Allylmetal(group IVb) compounds occupy a very important role in synthetic organic chemistry.<sup>1)</sup> Allylsilanes bearing a highly nucleophilic double bond act as equivalent species of allyl anion and transfer the allyl group to various kinds of electrophiles including carbonyl compound,  $\alpha$ ,  $\beta$ -enone, acetal, acid chloride,  $\alpha$ -nitro olefin, and epoxide in the presence of Lewis acid catalysts.<sup>2)</sup> Recently we established a new method for the umpolung of reactivity of allylmetal(group IVb) compounds and applied it to the allylation reactions of aromatic compounds,<sup>3)</sup> alcohols,<sup>3a,4)</sup> carboxylic acids,<sup>3a,4)</sup> nitriles,<sup>5)</sup> and the nitrate group.<sup>6)</sup> In the allylation reactions, allylmetal compounds were converted into highly reactive allyl cationic species, allylthallium(III) or allyliodine(III) compounds, *via* the reactions with thallium(III) salts such as thallium(III) trifluoroacetate, thallium(III) nitrate, and arylthallium bis(trifluoroacetate), or with hypervalent organoiodine(III) compounds.

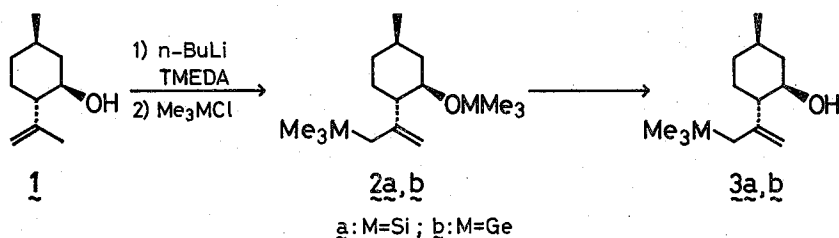
As one of the application of this allylation reaction, we have investigated reactions of allylmetal(group IVb) compounds **3** derived from (–)-isopulegol (**1**) with thallium(III) salts.

Hydroxyl allylsilane **3a** was prepared from (–)-isopulegol (**1**) in a straightforward fashion. Generation of the dianion of **1** [2 equiv. of *n*-butyllithium and 2 equiv. of tetramethylethylenediamine (TMEDA) in hexane at reflux for 3 h] followed by bis-silylation with chlorotrimethylsilane gave siloxy allylsilane **2a**.<sup>7)</sup> Chemoselective protodesilylation of **2a** using 10% sulfuric acid in tetrahydrofuran (THF) resulted in the formation of the desired hydroxyl allylsilane (**3a**) in 68% yield (from **1**). In order to compare the reactivity of allylmetal compounds toward thallium triacetate

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Reaction of Allylmetal(Group IVb) Compounds with Thallium(III) Acetate



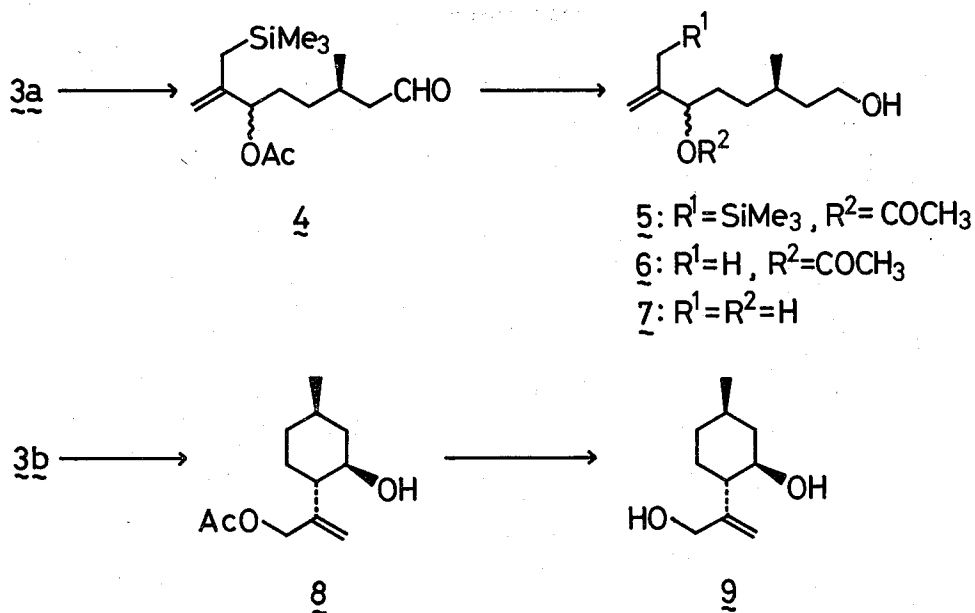
Scheme 1

(TTA), we also prepared hydroxyl allylgermane **3b**. Bis-germylation of the dianion derived from **1** with chlorotrimethylgermane, followed by selective hydrolysis of the germylether moiety of **2b** using methanol and water, afforded **3b** in high yield.

In a previous paper we reported that allylsilanes on treatment with TTA undergo an oxidative substitution reaction to give the corresponding allyl acetates in good yields.<sup>4a)</sup> The mode, however, was found to be much altered in the reaction of allylsilane **3a** with TTA. Reaction of **3a** with TTA in refluxing dichloromethane for 4 h gave no simple acetate **8**, but oxidative ring opening reaction of **3a** was observed. The major product obtained was found to be a 1:1 mixture of two diastereoisomers of unsaturated aldehyde **4**, in which the trimethylsilyl group of **3a** was kept unchanged. The structure of **4** was unambiguously established by its conversion to the known diol **7**.<sup>8)</sup> Reduction of **4** with sodium borohydride in methanol at 0°C followed by protodesilylation of the resulting alcohol **5** using boron trifluoride-acetic acid complex in dichloromethane at room temperature afforded **6** in 62% yield. Alkaline hydrolysis of **6** gave diol **7** as a mixture of stereoisomers.

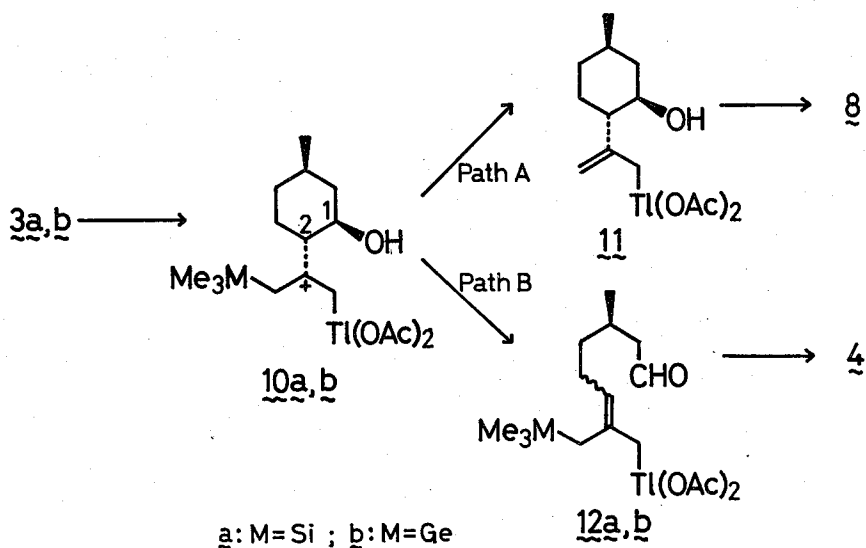
In contrast to the facile ring opening of allylsilane **3a** with TTA, allylgermane **3b** undergoes a normal type of reaction; the reaction of **3b** with TTA in dichloromethane at reflux afforded allyl acetate **8** via oxidative substitution in high yield. For the confirmation of the structure, allyl acetate **8** was converted to the known diol **9** by alkaline hydrolysis (67% yield).<sup>9)</sup>

In the oxidative substitution of allylmetal(group IVb) compounds with TTA giving allyl acetates, transient formation of the allylthallium diacetates, which act as species equivalent to allyl cation, was assumed to be involved.<sup>4a)</sup> On the other hand, formation of allylthallium diacetate **11** in the reaction of allylsilane **3a** with TTA may be suppressed by the presence of a hydroxyl group on the cyclohexane ring. Electrophilic attack of TTA to **3a** must produce a thallated carbocation **10a**, which may be stabilized by hyperconjugative interaction with the adjacent carbon-silicon  $\sigma$  bond. Two possible reaction courses may be considered for the further reaction of the cation **10a**: desilylation of **10a** generates allylthallium species **11**, from which allyl acetate **8** may be produced (path A); ring opening of **10a** caused by assistance of the  $\gamma$ -hydroxyl group yields unsaturated aldehyde **12a**, which also possesses the highly reactive allylthallium moiety in the molecule and may result in the formation of allyl acetate **4** (path B). The exclusive formation of ring opening product **4** from **3a** may be attributed to both the favorable steric arrangement between a



Scheme 2

vacant p-orbital of cationic carbon and C<sub>1</sub>-C<sub>2</sub> bond to be cleaved in the transition state leading to aldehyde **12a** and disappearance of the presumed steric interactions between C<sub>1</sub> and C<sub>2</sub> substituents. Allylgermane **3b**, however, produced selectively allyl acetate **8**, presumably *via* the formation of **11**. These results can be reasonably



Scheme 3

explained in terms of bond dissociation energies for carbon-metal(group IVb) bonds: C-Si (70 kcal. mole<sup>-1</sup>) and C-Ge (59 kcal. mole<sup>-1</sup>).<sup>10</sup> Degermylation of **10b**, therefore, proceeds selectively and gives allylthallium compound **11**.

#### ACKNOWLEDGEMENTS

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#### EXPERIMENTAL SECTION

Melting points were determined with a Yanagimoto micro melting point apparatus and are uncorrected. IR spectra were recorded with a JASCO IR-A-1 spectrophotometer. PMR spectra were obtained with JEOL JNM-FX 100, Hitachi R-40, and Varian XL-300 spectrometers. CMR spectra were taken on JEOL JNM-FX 100 and Varian XL-300 spectrometers. Chemical shifts are reported relative to internal tetramethylsilane. Mass spectra were determined on a Hitachi M-80 double-focusing mass spectrometer. Preparative thin layer chromatography (TLC) was carried out on precoated plates of silica gel (Merck, Silica gel F-254). Kieselgel 60 (Merck) was used for column chromatography.

**Materials**—(–)-Isopulegol and thallium(III) acetate are commercially available (Aldrich Chem. Co.).

**Synthesis of Allylmetal Compounds**—A Typical Procedure: Hydroxyl Allylsilane **3a**: To a solution of (–)-isopulegol (**1**) (1.0 g, 6.5 mmol) and TMEDA (1.5 g, 13 mmol) in hexane (15 ml) was added dropwise *n*-butyllithium (1.55M in hexane, 8.4 ml, 13 mmol) in nitrogen and the mixture was refluxed for 3 h. The resulting red dianion solution was cooled to –78°C and treated with chlorotrimethylsilane (2.1 g, 19.6 mmol). The mixture was allowed to warm to room temperature and stirred for 4 h. After the addition of ice to the mixture, extraction with ether, drying with Na<sub>2</sub>SO<sub>4</sub> and then evaporation *in vacuo* afforded a crude oil of siloxy allylsilane **2a**, which was treated with 10% aqueous H<sub>2</sub>SO<sub>4</sub> (2 ml) in THF (20 ml) at 0°C for 1 h. After the addition of cold water, the mixture was extracted with ether. A usual work-up gave an oil, which was purified by silica gel column chromatography using hexane-ethyl acetate (9:1) to give hydroxyl allylsilane **3a** (1.0 g, 68%). IR  $\nu_{\text{max}}^{\text{CHCl}_3}$  cm<sup>-1</sup>: 3580, 3450, 1620, 1445, 1245, 1040, 850. MS *m/z*: 226 (M<sup>+</sup>), 211, 193, 169, 143, 121, 93, 75. High-resolution MS: Found 226.1763. Calcd for C<sub>13</sub>H<sub>26</sub>OSi (M<sup>+</sup>) 226.1753. PMR (CDCl<sub>3</sub>)  $\delta$ : 0.03 ppm (9H, s, SiMe<sub>3</sub>), 0.80–1.10 (2H), 0.92 (3H, d, *J*=6Hz, Me), 1.20–2.15 (9H), 3.50 (1H, dt, *J*=5, 10 Hz, CHOH), 4.75 (2H, m, C=CH<sub>2</sub>).

Hydroxyl Allylgermane **3b**: A crude oil of **2b** obtained from the reaction of (–)-isopulegol (**1**) (1.0 g, 6.5 mmol) with chlorotrimethylgermane (3.0 g, 19.5 mmol) was treated with MeOH (18 ml)-H<sub>2</sub>O (2 ml) at room temperature for 1 h. A usual work-up gave an oil, which was purified by silica gel column chromatography using hexane-ethyl acetate (9:1) to afford hydroxyl allylgermane **3b** (1.57 g, 89%). IR  $\nu_{\text{max}}^{\text{CHCl}_3}$  cm<sup>-1</sup>: 3570, 3450, 1620, 1445, 1200, 1040, 820. MS *m/z*: 272 (M<sup>+</sup>), 257, 239,

189, 162, 121, 119 (base peak), 117, 115, 93, 81. High-resolution MS: Found 272.1202. Calcd for  $C_{13}H_{26}OGe$  ( $M^+$ ) 272.1194. PMR ( $CDCl_3$ )  $\delta$ : 0.19 (9H, s,  $GeMe_3$ ), 0.84–1.08 (2H), 0.96 (3H, d,  $J=6$ Hz, Me), 1.10–1.28 (1H, m), 1.44–1.60 (1H, m), 1.64–1.84 (5H), 2.00–2.10 (2H), 3.53 (1H, dt,  $J=5, 10$  Hz,  $CHOH$ ), 4.75 (2H, m,  $C=CH_2$ ).

**Oxidative Ring Opening of Allylsilane 3a**—A solution of hydroxyl allylsilane **3a** (315 mg, 1.35 mmol) in dichloromethane (4 ml) was added dropwise to a stirred suspension of TTA (569 mg, 1.35 mmol) in dichloromethane (4 ml) at room temperature in nitrogen. After being refluxed for 4 h, the reaction mixture was poured into cold brine and extracted with ether. A usual work-up and purification of the resulting crude product by silica gel column chromatography using hexane-ethyl acetate (9:1) afforded unsaturated aldehyde **4** (175 mg, 45%), which was contaminated with a small amount of impurity.  $IR_{\nu_{max}}^{CHCl_3}$   $cm^{-1}$ : 2820, 2720, 1740 (shoulder), 1730, 1640, 1460, 1370, 1240, 1020, 840. MS  $m/z$ : 284 ( $M^+$ ), 269, 255, 224, 143, 133, 117 (base peak), 108, 93, 73. PMR ( $CDCl_3$ )  $\delta$ : 0.06 (9H, s,  $SiMe_3$ ), 0.97, 0.98 (total 3H, each d,  $J=6$ Hz,  $CHMe$ ), 1.1–2.5 (9H), 2.07 (3H, s,  $COCH_3$ ), 4.70, 4.86 (each 1H,  $C=CH_2$ ), 5.08 (1H, t,  $J=6$ Hz,  $CHOAc$ ), 9.74 (1H, t,  $J=2$ Hz,  $HC=O$ ). CMR ( $CDCl_3$ )  $\delta$ : 201.2 (d), 169.3, 144.7, 144.6 (each s), 109.0, 108.8 (each t), 76.8, 76.5 (each d), 50.8, 50.7, 32.4, 32.3, 30.2 (each t), 27.8, 27.7 (each d), 22.6 (t), 21.0, 19.9, 19.7,  $-1.2$  (each q).

**Reduction of Unsaturated Aldehyde 4**—To a stirred solution of sodium borohydride (27 mg, 0.7 mmol) in methanol (1 ml) was added dropwise a solution of **4** (20 mg, 0.07 mmol) in methanol (0.5 ml) at  $0^\circ C$  and the mixture was stirred for 1.5 h at  $0^\circ C$ . The reaction mixture was poured into cold water and extracted with ether. A usual work-up and purification by preparative TLC [hexane-ethyl acetate (2:1)] gave alcohol **5** (15 mg, 76%).  $IR_{\nu_{max}}^{CHCl_3}$   $cm^{-1}$ : 3620, 3450, 1720, 1630, 1370, 1240, 1040, 840. PMR ( $CDCl_3$ )  $\delta$ : 0.06 (9H, s,  $SiMe_3$ ), 0.92 (3H, d,  $J=6$ Hz,  $CHMe$ ), 1.0–1.8 (10H), 2.08 (3H, s,  $COCH_3$ ), 3.66 (2H, t,  $J=6$ Hz,  $CH_2OH$ ), 4.68, 4.86 (each 1H,  $C=CH_2$ ), 5.08 (1H, t,  $J=6$ Hz,  $CHOAc$ ).

**Protodesilylation of Hydroxyl Allylsilane 5**—Boron trifluoride-acetic acid complex (11 mg, 0.06 mmol) was added to a solution of **5** (15 mg, 0.05 mmol) in dichloromethane (0.2 ml) at room temperature and the solution was stirred for 5 min. The reaction mixture was poured into a cold aqueous sodium bicarbonate solution and extracted with ether. The extract was washed with water and brine and dried over  $Na_2SO_4$ . A usual work-up gave a crude oil, which was purified by preparative TLC [hexane-ethyl acetate (2:1)] to give alcohol **6** (9 mg, 82%).  $IR_{\nu_{max}}^{CHCl_3}$   $cm^{-1}$ : 3620, 3450, 1735, 1650, 1450, 1375, 1240, 1020, 900. PMR ( $CDCl_3$ )  $\delta$ : 0.92 (3H, d,  $J=6$ Hz,  $CHMe$ ), 1.0–1.8 (8H), 1.72 (3H, s,  $CMc$ ), 2.06 (3H, s,  $COCH_3$ ), 3.66 (2H, t,  $J=6$ Hz,  $CH_2OH$ ), 4.88, 4.94 (each 1H,  $C=CH_2$ ) 5.14 (1H, t,  $J=6$ Hz,  $CHOAc$ ).

**Hydrolysis of Acetate 6**—Acetate **6** (21 mg, 0.1 mmol) was treated with an aqueous  $NaOH$ - $MeOH$  solution at room temperature. Purification by preparative TLC [hexane-ethyl acetate (1:1)] produced diol **7<sup>b</sup>** (15 mg, 85%).  $IR_{\nu_{max}}^{CHCl_3}$   $cm^{-1}$ : 3620, 3440, 1650, 1460, 3180, 1050, 900. PMR ( $CDCl_3$ )  $\delta$ : 0.90 (3H, d,  $J=6$ Hz,

CHMe), 1.0–1.8 (7H), 1.70 (3H, s, CMe), 2.00 (2H, br.s, 2×OH). 3.66 (2H, t,  $J=6$ Hz, CH<sub>2</sub>OH), 4.02 (1H, t,  $J=6$ Hz, CHOH), 4.80, 4.90 (each 1H, C=CH<sub>2</sub>). CMR (CDCl<sub>3</sub>)  $\delta$ : 147.6, 147.5 (each s), 111.1, 110.9 (each t), 76.2, 75.8 (each d), 60.7, 39.7, 32.7, 32.5, 32.3, 32.0 (each t), 29.6, 29.3 (each d), 19.7, 17.6, 17.4 (each q).

**Reaction of Hydroxyl Allylgermane 3b with TTA**—A solution of **3b** (271 mg, 1 mmol) in dichloromethane (3 ml) was added to a stirred suspension of TTA (421 mg, 1 mmol) in dichloromethane (7 ml) at room temperature in nitrogen and the mixture was refluxed for 1 h. After being cooled, the reaction mixture was poured into a cold brine and extracted with ether. A usual work-up and purification of the resulting crude product by silica gel column chromatography using hexane-ethyl acetate (7:1) afforded hydroxyl allylacetate **8** (183 mg, 86%) IR<sub>max</sub><sup>CHCl<sub>3</sub></sup> cm<sup>-1</sup>: 3575, 3475, 1725, 1640, 1440, 1370, 1220, 1040, 910. MS  $m/z$ : 214 (M<sup>+</sup>), 152, 137, 123, 108, 93, 81, 69, 42 (base peak). High-resolution MS: Found 214.1566. Calcd for C<sub>12</sub>H<sub>22</sub>O<sub>3</sub> (M<sup>+</sup>) 214.1567. PMR (CDCl<sub>3</sub>)  $\delta$ : 0.95 (3H, d,  $J=6$ Hz, CHMe), 0.80–2.20 (10H), 2.10 (3H, s, COCH<sub>3</sub>), 2.36 (1H, br.s, OH), 3.56 (1H, dt,  $J=5, 10$  Hz, CHOH), 4.60 (2H, s, CH<sub>2</sub>O), 5.13, 5.20 (each 1H, C=CH<sub>2</sub>). CMR (CDCl<sub>3</sub>)  $\delta$ : 170.3, 145.5 (each s), 112.9 (t), 72.1 (d), 65.7 (t), 50.7 (d), 43.2, 34.5 (each t), 31.5 (d), 30.7 (t), 22.1, 20.9 (each q).

**Hydrolysis of Allylacetate 8**—Alkaline hydrolysis of **8** (95 mg, 0.45 mmol) was carried out using NaOH (90 mg, 2.25 mmol) in aqueous methanol at room temperature. Preparative TLC [hexane-ethyl acetate (1:1)] afforded diol **9<sup>b</sup>** (51 mg, 67%), which was recrystallized from hexane. mp 98–99°C.  $[\alpha]_D^{25} = -46.9^\circ$  ( $c, 0.7$  in CHCl<sub>3</sub>). IR<sub>max</sub><sup>CHCl<sub>3</sub></sup> cm<sup>-1</sup>: 3620, 3400, 1640, 1450, 1380, 1100, 1010, 910. PMR (CDCl<sub>3</sub>)  $\delta$ : 0.96 (3H, d,  $J=6$ Hz, CH<sub>3</sub>), 0.80–2.20 (8H), 2.34 (2H, br.s, 2×OH), 3.54 (1H, dt,  $J=5, 10$ Hz, CHOH), 4.10 (2H, s, CH<sub>2</sub>OH), 5.04, 5.20 (each 1H, C=CH<sub>2</sub>).

## REFERENCES

- (1) (a) E. W. Colvin, "Silicon in Organic Synthesis," Butterworths, London, 1981, Ch. 9; (b) W. P. Weber, "Silicon Reagents for Organic Synthesis," Springer-Verlag, Berlin, 1983, Ch. 11; (c) M. Kosugi and T. Migita, *J. Synth. Org. Chem. Jpn.*, **38**, 1142 (1980).
- (2) (a) H. Sakurai, *Pure Appl. Chem.*, **54**, 1 (1982); (b) A. Hosomi and H. Sakurai, *J. Synth. Org. Chem. Jpn.*, **43**, 406 (1985); (c) T. Hayashi, *ibid.*, **43**, 419 (1985).
- (3) (a) M. Ochiai, M. Arimoto, and E. Fujita, *Tetrahedron Lett.*, **22**, 4491 (1981); (b) M. Ochiai, E. Fujita, M. Arimoto, and H. Yamaguchi, *Chem Pharm Bull.*, **30**, 3994 (1982); (c) *Idem, ibid.*, **31**, 86 (1983); (d) *Idem, ibid.*, **33**, 41 (1985); (e) M. Ochiai and E. Fujita, *J. Synth. Org. Chem. Jpn.*, **40**, 508 (1982).
- (4) (a) M. Ochiai, E. Fujita, M. Arimoto, and H. Yamaguchi, *Chem. Pharm. Bull.*, **32**, 5027 (1984); (b) *Idem, J. Chem. Soc., Chem. Comm.*, 1108 (1982); (c) *Idem, Chem. Pharm. Bull.*, **33**, 989 (1985).
- (5) M. Ochiai, S. Tada, M. Arimoto, and E. Fujita, *Chem. Pharm. Bull.*, **30**, 2836 (1982).
- (6) M. Ochiai, E. Fujita, M. Arimoto, and H. Yamaguchi, *Chem. Pharm. Bull.*, **32**, 887 (1984).
- (7) B. M. Trost and D. M. T. Chan, *J. Am. Chem. Soc.*, **105**, 2315 (1983).
- (8) H. Miyawaki and S. Miyazaki, Japan. Patent Kokai 7791812.
- (9) V. R. Tadwalkar and A. S. Rao, *Indian J. Chem.*, **9**, 1416 (1971).
- (10) R. C. Poller, "The Chemistry of Organotin Compounds," Logos Press Limited, London, 1970, Ch. 1.