74.96; H, 9.27. Found: C, 75.13; H, 9.33.

Ethyl 2,3,4-Trideoxy-2-*C*-isopropyl-6-*O*-benzyl-α-D-*erythro*-hex-3-enopyranoside (8). This product was prepared from **6** and isopropylmagnesium bromide as a syrup (50%): $[\alpha]_D$ −19.6° (*c* 0.7, $CHCl_3$). Anal. Calcd for $C_{18}H_{26}O_3$: C, 74.45; H, 9.02. Found: C, 74.41; H, 8.87.

Methyl 2,3,4-Trideoxy-4-*C*-*n*-butyl-6-*O*-(*tert*-butyldimethylsilyl)-α-D-*threo*-hex-2-enopyranoside (10). Prepared from **9** and *n*-butylmagnesium bromide as a colorless oil (60%): $[\alpha]_D$ −71.6° (*c* 0.72, $CHCl_3$). Anal. Calcd for $C_{17}H_{34}O_3Si$: C, 64.92; H, 10.9. Found: C, 64.65; H, 10.65.

Methyl 2,3,4-Trideoxy-4-*C*-isopropyl-6-*O*-(*tert*-butyldimethylsilyl)-α-D-*threo*-hex-2-enopyranoside (11). Prepared from **9** and isopropylmagnesium bromide as a syrup (60%): $[\alpha]_D$ −85.0° (*c* 1.4; $CHCl_3$). Anal. Calcd for $C_{16}H_{32}O_3Si$: C, 63.95; H, 10.74. Found: C, 64.13; H, 10.60.

Methyl 2,3,4-Trideoxy-4-*C*-phenyl-6-*O*-(*tert*-butyldimethylsilyl)-α-D-*threo*-hex-2-enopyranoside (12). Prepared from **9** and phenylmagnesium bromide as a syrup (88%): $[\alpha]_D$ −104.2° (*c* 0.8; $CHCl_3$). Anal. Calcd for $C_{19}H_{30}O_3Si$: C, 68.22; H, 9.04. Found: C, 68.41; H, 8.82.

Methyl 2,3,4-Trideoxy-4-*C*-*n*-butyl-6-*O*-(*tert*-butyldimethylsilyl)-α-D-*erythro*-hex-2-enopyranoside (14). Prepared from **13** and *n*-butylmagnesium bromide as a colorless oil (80%): $[\alpha]_D$ 33.2° (*c* 0.42, $CHCl_3$). Anal. Calcd for $C_{17}H_{34}O_3Si$: C, 64.92; H, 10.9. Found: C, 65.12; H, 10.72.

Methyl 2,3,4-Trideoxy-4-*C*-isopropyl-6-*O*-(*tert*-butyldimethylsilyl)-α-D-*erythro*-hex-2-enopyranoside (15). Prepared from **13** and isopropylmagnesium bromide as a syrup (76%): $[\alpha]_D$ 77.4° (*c* 0.44; CH_2Cl_2). Anal. Calcd for $C_{16}H_{32}O_3Si$: C, 63.95; H, 10.74. Found: C, 64.15; H, 10.50.

Methyl 2,3,4-Trideoxy-2-*C*-phenyl-6-*O*-(*tert*-butyldimethylsilyl)-α-D-*threo*-hex-3-enopyranoside (16). Prepared from **13** and phenylmagnesium bromide as a syrup (36%). Starting material (50%) was recovered unchanged: $[\alpha]_D$ 77.3° (*c* 0.7; $CHCl_3$). Anal. Calcd for $C_{19}H_{30}O_3Si$: C, 68.22; H, 9.04. Found: C, 68.33; H, 8.77.

Methyl 2,3,4-Trideoxy-2-*C*-methyl-6-*O*-benzyl-α-D-*threo*-hex-3-enopyranoside (22). Methyl iodide (568 mg, 4.0 mmol) was reacted with metallic Mg (97 mg, 4.0 mmol) in anhydrous ether. This solution was cooled at −30 °C, and CuI (285 mg, 1.5 mmol) was added in one portion under argon. Stirring was continued during 30 min at −30 °C, and a solution of **21**[13] (368 mg, 1.0 mmol) in ether (15 mL) was added. This mixture was allowed to warm slowly to room temperature and stirred for 6 h. The reaction was diluted with ether and treated with concentrated aqueous NH_4Cl and a few drops of NH_4OH while vigorously stirring. The ethereal layer was separated and dried over anhydrous sodium sulfate and concentrated in vacuo. The residue was rebenzoylated (Bz_2O/Py) and chromatographed on silica gel to yield the product, a thick oil (80 mg, 30%).

2-Benzothiazolyl 2,3-Dideoxy-4,6-*O*-isopropylidene-1-thio-α-D-*erythro*-hex-2-enopyranoside (23). A syrupy product prepared from 4,6-di-*O*-isopropylidene-D-glucal[10] and 2-mercaptobenzothiazole using the general conditions described above for (allylthio)benzothiazoles:[14] $[\alpha]_D$ 310.9° (*c* 0.7, $CHCl_3$). Anal. Calcd for $C_{16}H_{17}NO_3S_2$: C, 57.29; H, 5.11; N, 4.18; S, 19.12. Found: C, 57.40; H, 5.11; N, 4.15; S, 19.44.

1,5-Anhydro-4,6-*O*-isopropylidene-2,3-dideoxy-3-*C*-methyl-D-*ribo*-hex-1-enitol (24). Prepared from **23** and MeMgBr as a syrup: $[\alpha]_D$ 160.9° (*c* 1.4, $CHCl_3$). Anal. Calcd for $C_{10}H_{16}O_3$: C, 65.19; H, 8.75. Found: C, 65.10; H, 8.90.

1,5-Anhydro-4,6-*O*-isopropylidene-2,3-dideoxy-3-*C*-phenyl-D-*ribo*-hex-1-enitol (25). Prepared from **23** and PhMgBr as a syrup: $[\alpha]_D$ 244.3° (*c* 0.85, $CHCl_3$). Anal. Calcd for $C_{15}H_{18}O_3$: C, 73.15; H, 7.37. Found: C, 73.31; H, 7.60.

Acknowledgment. Financial support from DGICYT (PB90-0078) is gratefully acknowledged.

(13) Holder, N. L.; Fraser-Reid, B. *Can. J. Chem.* **1973**, *51*, 3357.

(14) Substitutions with subsequent allylic rearrangement have been previously reported to take place during the Mitsunobu reaction with dihydropyran derivatives (Dyong, I.; Weigand, J.; Thiem, J. *Liebigs Ann. Chem.* **1986**, 577). A minor component, possibly a 3-benzothiazolyl glycal derivative, was also detected.

Registry No. 1a, 23339-15-3; **1b**, 51385-38-7; **1c**, 80516-25-2; **1d**, 124944-63-4; **2**, 130619-57-7; **3**, 130641-42-8; **4**, 142041-72-3; **5**, 142041-73-4; **6**, 142041-74-5; **7**, 142041-75-6; **8**, 142041-76-7; **9**, 124944-67-8; **10**, 142041-77-8; **11**, 142041-78-9; **12**, 142041-79-0; **13**, 124944-66-7; **14**, 142041-80-3; **15**, 142041-81-4; **16**, 142041-82-5; **21**, 34254-52-9; **22**, 142041-83-6; **23**, 142041-84-7; **24**, 142041-85-8; **25**, 142041-86-9; BTZ-Cl, 615-20-3; BTZ-SH, 149-30-4; 4,6-D-isopropylidene-D-glucal, 51450-36-3.

Nickel-Catalyzed Geminal Dimethylation of Allylic Cyclic Dithioketals. A Convenient Procedure To Form a *tert*-Butyl Substituent at the Olefinic Carbon Atom

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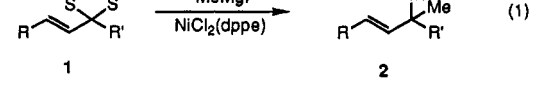
Received January 2, 1992

Much effort has been devoted to the introduction of a *tert*-butyl group or a quaternary carbon to olefinic carbon atom(s) with the aim of synthesizing crowded olefins.[1] Most of the procedures that have been developed use reagents containing a *tert*-butyl group. Although Tebbe-like reagents are effective for converting a carbonyl group into a *gem*-dimethyl substituent, their application to allylic carbonyl substrates is limited by poor regioselectivity.[2] We recently reported a series of nickel-catalyzed cross-coupling reactions of benzylic and allylic dithioacetals with Grignard reagents.[3-5] In the presence of $NiCl_2$(dppe), cinnamaldehyde dithioacetals **1** (R = Ar, R′ = H) react with MeMgI to give the geminally dimethylated products (eq 1, R = Ar, R′ = H).[4] We have extended this reaction to geminal dimethylation of allylic dithioketals and now report a facile procedure for the regioselective preparation of *tert*-butyl-substituted olefins **2** (eq 1, R′ ≠ H).



(1)

1 **2**

Dithioketals **1** were prepared according to a modified literature procedure.[6] Treatment of **1** with 4 equiv of MeMgI in the presence of 5 mol % of $NiCl_2$(dppe) in refluxing ether–THF for 10 h afforded *gem*-dimethyl

(1) For recent leading references, see: (a) Mulzer, J.; Lammer, O. *Angew. Chem., Int. Ed. Engl.* **1983**, *22*, 628. (b) Russell, G. A.; Tashtoush, H.; Ngoviwatchai, P. *J. Am. Chem. Soc.* **1984**, *106*, 4622. (c) Eisch, J. J.; Behrooz, M.; Galle, J. E. *Tetrahedron Lett.* **1984**, *25*, 4851. (d) Kirkuchi, O.; Yoshida, H. *Bull. Chem. Soc. Jpn.* **1985**, *58*, 131. (e) Ager, D. J. *J. Chem. Soc., Perkin Trans. 1* **1986**, 183. (f) Aguero, A.; Kress, J.; Osborn, J. A. *J. Chem. Soc., Chem. Commun.* **1986**, 531. (g) Smegal, J. A.; Meier, I. K.; Schwartz, J. *J. Am. Chem. Soc.* **1986**, *108*, 1322. (h) Palomo, C.; Aizpurua, J. M.; Garcia, J. M.; Ganboa, I.; Cossio, F. P.; Lecea, B.; Lopez, C. *J. Org. Chem.* **1990**, *55*, 2498.

(2) (a) Posner, G. H.; Brunelle, D. J. *Tetrahedron Lett.* **1972**, 239. (b) Meisters, A.; Mole, T. *J. Chem. Soc., Chem. Commun.* **1972**, 595. (c) Posner, G. H.; Brunelle, D. J. *Tetrahedron Lett.* **1973**, 935. (d) Meisters, A.; Mole, T. *Aust. J. Chem.* **1974**, *27*, 1655. (e) Reetz, M. T.; Westermann, J.; Steinbach, R. *Angew. Chem., Int. Ed. Engl.* **1980**, *19*, 900. (f) Reetz, M. T.; Westermann, J.; Steinbach, R. *J. Chem. Soc., Chem. Commun.* **1981**, 237. (g) Brown-Wensley, K. A.; Buchwald, S. L.; Cannizzo, L.; Ho, C. S.; Meinhardt, D.; Stille, J. R.; Straus, D.; Grubbs, R. H. *Pure Appl. Chem.* **1983**, *55*, 1733. (h) Pine, S. H.; Pettit, R. J.; Geib, G. D.; Cruz, S. G.; Gallego, C. H.; Tijerina, T.; Pine, R. D. *J. Org. Chem.* **1985**, *50*, 1212. (i) Reetz, M. T.; Westermann, J.; Kyung, S.-H. *Chem. Ber.* **1985**, *118*, 1150.

(3) For a review, see: Luh, T.-Y. *Acc. Chem. Res.* **1991**, *24*, 257.

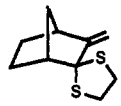
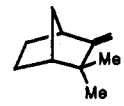
(4) (a) Yang, P.-F.; Ni, Z.-J.; Luh, T.-Y. *J. Org. Chem.* **1989**, *54*, 2261. (b) Tzeng, Y.-L.; Yang, P.-F.; Mei, N.-W.; Yuan, T.-M.; Yu, C. C.; Luh, T.-Y. *J. Org. Chem.* **1991**, *56*, 5289.

(5) Ni, Z.-J.; Mei, N.-W.; Shi, X.; Wang, M. C.; Tzeng, Y.-L.; Luh, T.-Y. *J. Org. Chem.* **1991**, *56*, 4035.

(6) Williams, J. R.; Sarkisian, G. M. *Synthesis* **1974**, 32.

0022-3263/92/1957-4550$03.00/0

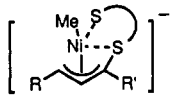
Table I. $NiCl_2(dppe)$[a] Geminal Dimethylation of Dithioketals

entry	R	R′	product	% yield
1	Ph	Me	**2a**	84
2	2-$MeOC_6H_4$	Me	**2b**	80
3	4-$MeOC_6H_4$	Me	**2c**	75
4	4-MeC_6H_4	Me	**2d**	86
5	Ph	Ph	**2e**	78
6	PhCH=CH	Me	**2f**	57[b]
7	cyclohexyl	Me	**2g**	69[c]
8	 **13**		 **14**	82

[a] dppe = $Ph_2PCH_2CH_2PPh_2$. [b] **8** (13%) and **9** (10%) were also obtained. [c] **10** (8%) and **11** (12%) were also obtained.

products **2** in good yields (Table I). For example, *β-tert*-butylstyrenes were conveniently synthesized (entries 1–4). Geminal dimethylation also occurred in the reaction of **1e** (entry 5).

We have previously shown that the chelated mercaptide anion (**3**) undergoes *reductive elimination exclusively at the ipso position*, where the sulfur atom was originally attached.[4b] Accordingly, the reaction of dithioketal **1** with MeMgI in the presence of $NiCl_2(dppe)$ catalyst would first generate an intermediate similar to **3** to initiate regioselective transfer of the first methyl group. Further reaction would lead to geminal dimethylation. The regioselective formation of the second carbon–carbon bond can be rationalized by conjugative preference[7] of the olefinic moiety of **2**. In order to test the validity of these suggestions, we have treated **4** with MeMgI under similar conditions. A mixture of diene **5** and dimethylated product **6** was obtained; no trace of geminal dimethyl compound **2h** (R = Me, R′ = Ph) was detected. As expected, after the regioselective introduction of the first methyl group at the ipso position, the π-allyl intermediate **7** gives **5** by β-elimination and **6** by reductive elimination. These results agree well with conjugative preference.[7]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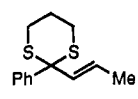
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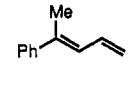
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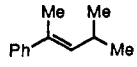
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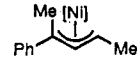
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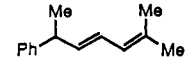
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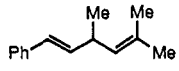
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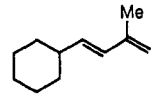
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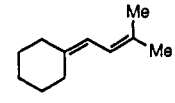
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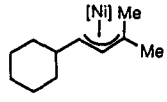
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When dienyl dithioketal **1f** was treated with MeMgI under the same conditions, geminal dimethylated product **2f** was the major product; regioisomers **8** and **9** were also obtained (entry 6).

The extension of this reaction to aliphatic substrates has been reasonably successful. Treatment of **1g** with MeMgI under the same conditions afforded **2g**, **10**, and **11** in 69, 8, and 12% yields, respectively (entry 7). The formation of **10** and **11** is due to the competitive β-elimination of intermediate **12**. It is noteworthy that in the reaction of a dithioketal derived from a strained ketone, β-elimination is discouraged, and the reductive elimination process that results in geminal dimethylation becomes predominant. Thus, dithioketal **13** was converted to camphene (**14**) in 82% yield under the reaction conditions (entry 8).

In summary, we have demonstrated a useful geminal dimethylation reaction of allylic dithioketals that allows a convenient synthesis of *β-tert*-butylstyrenes and related[4b] compounds. This process complements our previous work on the trimethylation of allylic ortho thioesters.

Experimental Section

General Procedure for Geminal Dimethylation of Dithioketal with the Grignard Reagent. To a THF (15 mL) solution of dithioacetal **1** (1.0 mmol) and $NiCl_2(dppe)$ (0.05 mmol) was added MeMgI (2.0 mL, 2 M in ether, 4 mmol). The mixture was refluxed for 10 h. Water (15 mL) was added, and the mixture was extracted with ether (20 mL × 2). The organic layer was washed with sodium hydroxide (10%, 20 mL) and then dried ($MgSO_4$). The solvent was evaporated in vacuo, and the residue was chromatographed on silica gel (hexane) to give the product.

(*E*)-3,3-Dimethyl-1-phenyl-1-butene (2a). Via the general procedure, the reaction of **1a** (222 mg, 1.0 mmol), MeMgI (2.0 mL of a 2 M solution in ether, 4 mmol), and $NiCl_2(dppe)$ (26.3 mg, 0.05 mmol) gave **2a**[8] (135 mg, 84%): ^1H NMR (200 MHz, $CDCl_3$) δ 1.14 (s, 9 H), 6.27 (d, J = 16.1 Hz, 1 H), 6.32 (d, J = 16.1 Hz, 1 H), 7.13–7.39 (m, 5 H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 29.6, 33.3, 124.6, 126.0, 126.7, 128.4, 138.0, 141.7.

(*E*)-3,3-Dimethyl-1-(2-methoxyphenyl)-1-butene (2b). Via the general procedure, the reaction of **1b** (252 mg, 1.0 mmol), MeMgI (2.0 mL of a 2 M solution in ether, 4 mmol), and $NiCl_2(dppe)$ (26.3 mg, 0.05 mmol) gave **2b** (152 mg, 80%): IR 3020, 2987, 1650, 1598, 1580, 977 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 1.14 (s, 9 H), 3.84 (s, 3 H), 6.25 (d, J = 16.2 Hz, 1 H), 6.67 (d, J = 16.2 Hz, 1 H), 6.89 (m, 2 H), 7.18 (m, 1 H), 7.45 (m, 1 H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 29.7, 33.6, 55.4, 110.8, 119.0, 120.6, 126.1, 127.1, 127.7, 142.3, 156.4; MS m/z (relative intensity) 190 (M^+, 62), 175 (100), 121 (21), 91 (22); exact mass calcd for $C_{13}H_{18}O$ 190.1357, found 190.1355.

(*E*)-3,3-Dimethyl-1-(4-methoxyphenyl)-1-butene (2c). Via the general procedure, the reaction of **1c** (252 mg, 1.0 mmol), MeMgI (2.0 mL of a 2 M solution in ether, 4 mmol), and $NiCl_2(dppe)$ (26.3 mg, 0.05 mmol) gave **2c** (143 mg, 75%): IR 3025, 2995, 1606, 1574, 968 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 1.12 (s, 9 H), 3.81 (s, 3 H), 6.12 (d, J = 16.2 Hz, 1 H), 6.25 (d, J = 16.2 Hz, 1 H), 6.84 (d, J = 8.8 Hz, 2 H), 7.29 (d, J = 8.8 Hz, 2 H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 29.7, 33.2, 55.2, 113.9, 123.9, 127.0, 130.9, 139.8, 158.6; MS m/z (relative intensity) 190 (M^+, 34), 175 (100), 160 (13), 121 (14), 91 (12); exact mass calcd for $C_{13}H_{18}O$ 190.1357, found 190.1349.

(*E*)-3,3-Dimethyl-1-(4-methylphenyl)-1-butene (2d). Via the general procedure, the reaction of **1d** (236 mg, 1.0 mmol), MeMgI (2.0 mL of a 2 M solution in ether, 4 mmol), and $NiCl_2(dppe)$ (26.3 mg, 0.05 mmol) gave **2d** (150 mg, 86%): IR 3020, 2956, 1511, 967 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 1.12 (s, 9 H), 2.33 (s, 3 H), 6.21 (d, J = 16.1 Hz, 1 H), 6.28 (d, J = 16.1 Hz, 1 H), 7.10 (d, J = 8.0 Hz, 2 H), 7.26 (d, J = 8.0 Hz, 2 H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 21.1, 29.6, 33.2, 124.4, 125.9, 129.1, 135.3, 136.3, 140.9; MS m/z (relative intensity) 174 (M^+, 42), 159 (100), 105 (19); exact mass calcd for $C_{13}H_{18}$ 174.1408, found 174.1392.

(*E*)-1,3-Diphenyl-3-methyl-1-butene (2e). Via the general procedure, the reaction of **1e** (284 mg, 1.0 mmol), MeMgI (2.0 mL of a 2 M solution in ether, 4 mmol), and $NiCl_2(dppe)$ (26.3 mg,

(7) Wenkert, E.; Ferreira, T. W. *Organometallics* **1982**, *1*, 1670.

(8) Seyferth, D.; Singh, G. *J. Am. Chem. Soc.* **1965**, *87*, 4156.

0.05 mmol) gave **2e**[9] (173 mg, 78%): ^{1}H NMR (200 MHz, $CDCl_3$) δ 1.55 (s, 6 H), 6.45 (s, 2 H), 7.19–7.45 (m, 10 H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 28.7, 40.8, 125.8, 125.9, 126.2, 126.7, 127.0, 128.2, 128.5, 137.7, 140.2, 148.7.

(1*E*,3*E*)-5,5-Dimethyl-1-phenyl-1,3-hexadiene (2f), (4*E*)-6-Phenyl-2-methyl-2,4-heptadiene (8), and (1*E*)-3,5-Dimethyl-1-phenyl-1,4-hexadiene (9). Via the general procedure, the reaction of **1f** (124 mg, 0.5 mmol), MeMgI (1.0 mL of a 2 M solution in ether, 2 mmol), and $NiCl_2$(dppe) (13.2 mg, 0.025 mmol) gave a mixture of **2f**, **8**, and **9** (74 mg, 80%, **2f**:**8**:**9** = 71:16:13). After chromatographic separation, **2f** and **8** were obtained. Compound **8** was extremely unstable in pure form. Attempts to separate **9** from **2f** were unsuccessful. **2f**:[10] ^{1}H NMR (200 MHz, $CDCl_3$) δ 1.07 (s, 9 H), 5.85 (d, J = 15.4 Hz, 1 H), 6.14 (dd, J = 15.4, 9.9 Hz, 1 H), 6.46 (d, J = 15.7 Hz, 1 H), 6.75 (dd, J = 15.7, 9.9 Hz, 1 H), 7.17–7.39 (m, 5 H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 29.6, 33.4, 125.4, 126.1, 127.0, 128.5, 129.9, 130.2, 137.7, 146.8. **8**: ^{1}H NMR (200 MHz, $CDCl_3$) δ 1.37 (d, J = 7.0 Hz, 3 H), 1.73 (s, 3 H), 1.74 (s, 3 H), 3.50 (m, 1 H), 5.70 (dd, J = 15.1, 7.0 Hz, 1 H), 5.79 (d, J = 10.6 Hz, 1 H), 6.25 (dd, J = 15.1, 10.6 Hz, 1 H), 7.16–7.32 (m, 5 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 18.3, 21.5, 25.9, 42.5, 124.9, 125.3, 126.0, 127.2, 128.4, 133.9, 136.2. **9**: ^{1}H NMR (200 MHz, $CDCl_3$) δ 1.12 (d, J = 6.9 Hz, 3 H), 1.66 (s, 3 H), 1.71 (s, 3 H), 3.20 (m, 1 H), 5.04 (d, J = 8.8 Hz, 1 H), 6.15 (dd, J = 16.1, 6.4 Hz, 1 H), 6.31 (d, J = 16.1 Hz, 1 H), 7.17–7.39 (m, 5 H).

(*E*)-1-Cyclohexyl-3,3-dimethyl-1-butene (2g), (1*E*)-1-Cyclohexyl-3-methyl-1,3-butadiene (10), and [(2-Methyl-1-propenyl)methylene]cyclohexane (11). Via the general procedure, the reaction of **1g** (228 mg, 1.0 mmol), MeMgI (2.0 mL of a 2 M solution in ether, 4 mmol), and $NiCl_2$(dppe) (26.3 mg, 0.05 mmol) gave a mixture of **2g**, **10**, and **11** (145 mg, 89%, **2g**:**10**:**11** = 77:9:14). After chromatographic separation, a mixture of **2g** and **11** was obtained as an oil. Attempts to separate **10** from **2g** were unsuccesful. **2g**: IR 2957, 2929, 2851, 1449, 976 cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ 0.96 (s, 9 H), 0.92–1.35 (m, 5 H), 1.57–1.72 (m, 5 H), 1.85 (m, 1 H), 5.23 (dd, J = 15.7, 6.3 Hz, 1 H), 5.37 (d, J = 15.7 Hz, 1 H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 26.2, 26.3, 29.9, 32.5, 33.5, 40.7, 130.8, 138.9; MS m/z (relative intensity) 166 (M^+, 18), 151 (23), 110 (72), 95 (37), 83 (56), 69 (100); exact mass calcd for $C_{12}H_{22}$ 166.1721, found 166.1713. **10**:[10] ^{1}H NMR (200 MHz, $CDCl_3$) δ 0.92–1.35 (m, 5 H), 157–1.91 (m, 6 H), 1.81 (s, 3 H), 4.85 (s, 2 H), 5.58 (dd, J = 15.8, 7.0 Hz, 1 H), 6.10 (d, J = 15.8, 1 H). **11**: IR 3050, 2921, 1630, 1610, 1460 cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ 1.54 (m, 6 H), 1.73 (s, 3 H), 1.77 (s, 3 H), 2.14 (bs, 2 H), 2.25 (bs, 2 H), 5.91 (d, J = 11.3 Hz, 1 H), 6.02 (d, J = 11.3 Hz, 1 H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 18.0, 26.3, 26.9, 27.8, 28.7, 29.0, 37.6, 118.0, 120.4, 132.6, 140.6.

Camphene (14). Via the general procedure, the reaction of **13** (198 mg, 1.0 mmol) with MeMgI (2.0 mL of a 2 M solution in ether, 4 mmol) in the presence of $NiCl_2$(dppe) (26.3 mg, 0.05 mmol) gave **14** (112 mg, 82%), which exhibited physical properties identical to those of the authentic sample.

(*E*)-4-Phenyl-1,3-pentadiene (5) and (*E*)-2-Phenyl-4-methyl-2-pentene (6). Via the general procedure, the reaction of **4** (118 mg, 0.5 mmol), MeMgI (1.0 mL of a 2 M solution in ether, 2 mmol), and $NiCl_2$(dppe) (13.2 mg, 0.025 mmol) gave a mixture of **5** and **6** (52 mg, 72%, **5**:**6** = 93.7). After chromatographic separation, a mixture of **5** and **6** was obtained as an oil. **5**:[11] ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.18 (s, 3 H), 5.20 (d, J = 10.3 Hz, 1 H), 5.33 (d, J = 17.4 Hz, 1 H), 6.47 (d, J = 11.0 Hz, 1 H), 6.77 (ddd, J = 17.4, 11.0, 10.3 Hz, 1 H), 7.23–7.48 (m, 5 H); ^{13}C HMR (75 MHz, $CDCl_3$) δ 16.0, 117.6, 125.7, 127.1, 127.7, 128.2, 133.5, 136.7, 143.0. **6**:[12] ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.05 (d, J = 6.6 Hz, 6 H), 2.05 (s, 3 H), 2.70 (m, 1 H), 5.61 (d, J = 9.1 Hz, 1 H), 7.23–7.48 (m, 5 H).

Acknowledgment. This work has been supported by the National Science Council of the Republic of China.

(9) Zimmerman, H. E.; Steinmetz, M. G.; Kreil, C. L. *J. Am. Chem. Soc.* **1978**, *100*, 4147.
(10) Tamura, R.; Saegusa, K.; Kakihana, M.; Oda, D. *J. Org. Chem.* **1988**, *53*, 2723.
(11) Reich, H. J.; Wollowitz, S. *J. Am. Chem. Soc.* **1982**, *104*, 7051.
(12) Zioudrou, C.; Moustakali-Mavridis, I.; Chrysochou, P.; Karabatsos, G. J. *Tetrahedron* **1978**, *34*, 3181.

Registry No. **1a**, 107389-59-3; **1b**, 142039-23-4; **1c**, 142039-24-5; **1d**, 142039-25-6; **1e**, 142039-26-7; **1f**, 142039-27-8; **1g**, 142039-28-9; **2a**, 3846-66-0; **2b**, 142039-29-0; **2c**, 79958-53-5; **2d**, 142039-30-3; **2e**, 56763-59-8; **2f**, 114444-87-0; **2g**, 109660-16-4; **4**, 142039-31-4; **5**, 55177-38-3; **6**, 70303-26-3; **8**, 142039-32-5; **9**, 142039-33-6; **10**, 88001-23-4; **11**, 62412-27-5; **13**, 142039-34-7; **14**, 79-92-5; $NiCl_2$(dppe), 14647-23-5.

Supplementary Material Available: ^{13}C NMR spectra of **2b–d,g**, **8**, and **11** (6 pages). This material is contained in many libraries on microfiche, immediately follows this article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.

Experimental and Theoretical Study of the Orientation in Lithiation of Dithieno[2,3-*b*:3′,2′-*d*]pyridine

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Received December 30, 1991

Several papers have recently been published on the regioselectivity in electrophilic substitution reactions of dithienopyridine ring systems[1,2] with angular annelation. These publications have hitherto been focused on the experimental and theoretical investigation of nitration.[1,2] The present study was undertaken in order to gain insight into the regioselectivity in the lithiation of dithieno[2,3-*b*:3′,2′-*d*]pyridine. A comparison of the regioselectivity of this ring system with the mechanistically different electrophilic substitution reactions is especially interesting, because nitration (bromination) and lithiation might lead to different regioselectivity.

Experimental Results. Lithium diisopropylamide (LDA) in ether or THF was used as reagent in the lithiation reactions. In the second step dimethylformamide, dimethyl disulfide, or bromine were added as scavengers, resulting in the corresponding formyl (**1A**) methylthio (**2A**) and bromo (**3**) derivatives (Figure 1).

In the case of addition of DMF a minor product (~5%) could also be isolated. This product was identified as 7-(hydroxymethyl)dithienopyridine (**1B**). Its formation might be due to a Cannizarro reaction of the formyl derivative in the basic medium of the reaction. However, the corresponding carboxylic acid derivative could not be isolated.

The substitution reactions were followed by GLC, and the reaction mixtures were also analyzed by NMR. Only products substituted in the 7-position could be detected. Besides this, the reaction mixture contained only unreacted starting material. Its recovery is the consequence of noncomplete lithiation and/or consecutive substitution reactions. By treating the dithienopyridine with a large (5-fold) excess of LDA followed by addition of dimethyl disulfide, the final reaction mixture consisted of 85% of the 7-substituted derivative (**2A**) and 15% of 2,7-bis(methylthio)dithieno[2,3-*b*:3′,2′-*d*]pyridine (**2B**).

The determination of the substitution position was achieved using 1D ^{1}H NMR, ^{13}C NMR, and 2D COSY and HETCOR techniques. The ^{1}H NMR spectra of the isolated products show long-range coupling between H^5 and

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0022-3263/92/1957-4552$03.00/0