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A Highly Stereo- and Regioselective Synthesis of (E)-1,3-dienes and (E,E)-1,3,5-trienes[1]

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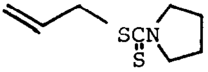
Summary: (E)-1,3-dodecadien-1-yl acetate, an insect sex pheromone of the red bollworm moth and (E,E)-1,3.5-undecatriene, a component of Dictyopteris and Galbanum were synthesized in a highly stereo- and regioselective manner from allyl and pentadienyl dithiocarbamates, respectively.

Insect sex pheromones continue to attract attention as synthetic targets because a stereoselective synthesis of their well-defined structures serves as a touchstone for a new methodology. In the previous papers, we have explored the utility of allyl and pentadienyl dithiocarbamates (1 and 2) for the highly stereoselective formation of the *trans* double bond.[2,3] In this communication, we wish to describe herein a new application of these reagents to the synthesis of (E)-1,3-dienes and (E,E)-1,3,5-trienes, in which we have developed a new, simple procedure for introducing a vinyl group.[4]

Among the natural products bearing a 1,3-diene unit is an insect sex pheromone of the red bollworm moth, Diparopsis castana Hmps, which does substantial damage to the cotton crop in southern Africa,[5] and the natural products having a 1,3,5-triene unit have been found in Hawaiian seaweed, Dictyopteris[6] and also in Galbanum,[7] which are reported to exhibit interesting olfactive properties.[8]



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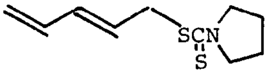

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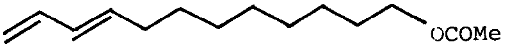
The former compound is (E)-1,3-dodecadien-1-yl acetate (3) and one of the latter compounds is (E,E)-1,3,5-undecatriene (4). Although a number of synthetic ap-



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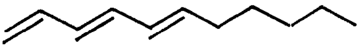

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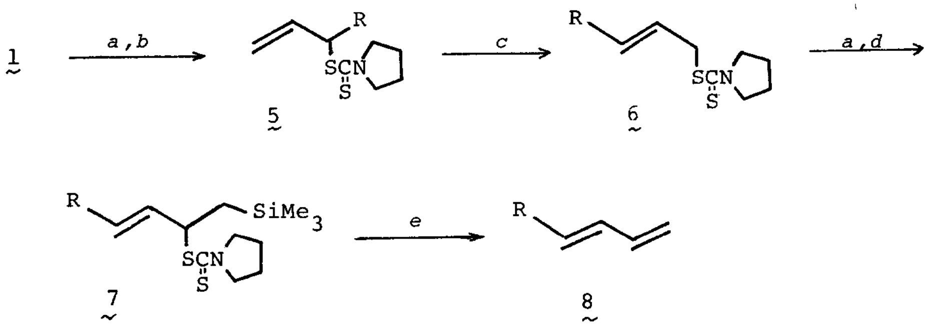
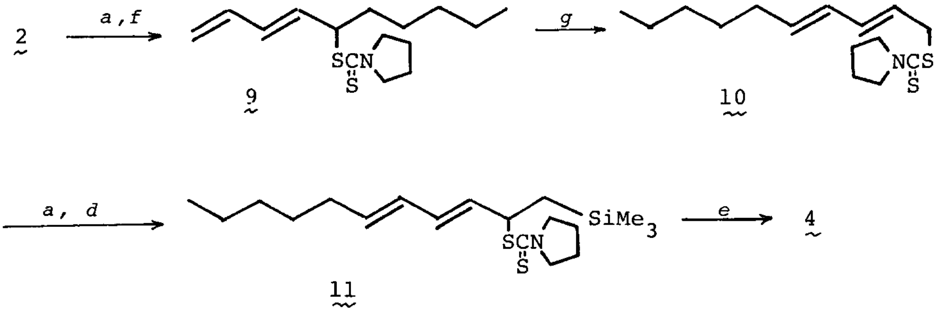
proaches to 3 and 4 has been reported,[9-11] our method constitutes a general, convenient, and highly stereo- and regioselective route to the products. The strategies are shown in Scheme I and II.

Scheme I



Scheme II

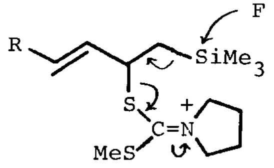


a: LDA in THF, -60°C, b: R-I, c: reflux in isooctane, d: Me_3SiCH_2I, *e:* $MeI/LiF/LiCO_3/DMF$, *f:* $n\text{-}C_5H_{11}I$, *g: reflux in toluene.*

The α-alkylation of 1 and 2 was easily performed according to the procedure described earlier [2,3,12] (combined yields of the α- and γ-isomers, based on the chromatographed material, 5a, R=PhCH$_2$CH$_2$, 99.4%, $\alpha:\gamma$ = 77.1:22.9; 5b, R=THPO-(CH$_2$)$_6$, 99.5%, $\alpha:\gamma$ = 93.6:6.4; 5c, R= THPO(CH$_2$)$_8$, 99.5%, $\alpha:\gamma$ = 85:15; 9, 95.0%, $\alpha:\gamma$ = 85.1:14.9).[13] The products were purified with column chromatography, using hexane:EtOAc(9:1) as the eluent, and then subjected to thermal rearrangement.[2,3] A most striking feature of this procedure is that the rearrangement gives rise to the *trans* products, free from a detectable amount of the *cis* isomers. The yields were almost quantitative. Products 6 and 10 can be again lithiated with LDA in THF at -60°C. Treatment of the lithium salts with Me$_3$SiCH$_2$I afforded

7 and **11** in excellent yields (**7a**, R=$PhCH_2CH_2$, 83.5%; **7b**, R=$THPO(CH_2)_6$, 85%; **7c**, R=$THPO(CH_2)_8$, 85%; **11**, 87.2%).

The conversion of **7** and **11** into diene **8** and triene **4** was realized by their treatment with a mixture of MeI, LiF, and Li_2CO_3 in DMF in the dark under argon at room temperature overnight. This oxidative desulfurization occurs regioselectively, leaving the existing double bond intact.[14] The reaction is considered to proceed through the intermediary of **12** via S-methylation of the thiocarbonyl function. The isolated yields were 82.1% for **8a** (R=Ph-CH_2CH_2), 94.0% for **8b** [R=$THPO(CH_2)_6$], and 93.4% for **8c** [R= $THPO(CH_2)_8$]. Triene **4** was purified by HPLC, using hexane:EtOAc(9:1) as the solvent. The yield was 56.4%. This rather low yield seems to be due to the unstable nature of this compound which is very sensitive to the air and light, and easily polymerizes.



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Diene **8c** was deprotected by treating with MeOH in the presence of a catalytic amount of pyridinium *p*-tosylate at room temperature overnight to furnish the corresponding alcohol in a quantitative yield.[15] The alcohol was acytylated with acetic anhydride in the presence of pyridine to give **3** in 95% yield.

All the spectral data of **3** and **4** were in complete agreement with the reported values.[10a,6a] Furthermore, 400 MHz ^1H NMR spectra permitted us to perform the first order analysis of the olefinic proton signals, which supports that the inner double bonds of **3** and **4** have all the *trans* geometry (15.1 Hz for **3**, and $J_{3,4}$ = 14.9 Hz and $J_{4,5}$ = 15.0 Hz for **4**). No signals corresponding to the *cis* isomers were detected both in the NMR and HPLC charts.[16,17]

General procedure for Oxidative Desulfurization of **7** and **11**. To a suspended mixture of MeI(3.0 eq.), LiF(or CsF, 3.0 eq.), Li_2CO_3(3.0 eq.) in DMF(large excess) was added the dithiocarbamate (**7** or **11**, 1.0 eq.). The solution was stirred at room temperature in the dark under argon overnight. The resulting yellow solids were removed by filtration, and washed with hexane. The combined organic layers were washed with Na_2SO_3 solution and water. and then dried over Na_2SO_4. The solvent was removed in *vacuo*, and residue was subjected to column and liquid chromatography.

In summary, the method described here consitutes the first stereoselective synthesis of (E,E)-1,3,5-undecatriene and one of the most effective preparation of (E)-1,3-dienes.

References and Notes

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3) T. Hayashi, I. Hori, and T. Oishi, *J. Am. Chem. Soc.*, **105**, in press (1983).

4) Recently, two methods for introducing a vinyl group have been reported; (a) M. Ochiai, S. Tada, K. Sumi, and E. Fujita, *J. Chem. Soc. Chem. Commun.*, 281 (1982); (b) M. Ochiai, S. Tada, K. Sumi, and E. Fujita, *Tetrahedron Lett.*, **23**, 2205 (1982).

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9) For a recent review see K. Mori, "The Total Synthesis of Natural Products", vol. 4, p 1 (Ed. by J. ApSimon), John Wiley & Sons, New York (1981).

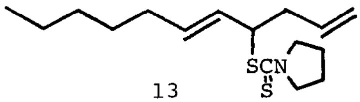
10) Recently, two stereoselective syntheses of **3** have been reported; (a) R. Rossi, A. Carpita, and G. Quirici, *Tetrahedron*, **37**, 2617 (1981); (b) R. Bloch and J. Abecassis, *Tetrahedron Lett.*, **23**, 3277 (1982).

11) For the synthesis of **4** see; (a) F. Naf, R. Decorzant, W. Thommen, B. Willhalm, and G. Ohloff, *Helv. Chim. Acta*, **58**, 1016 (1975); (b) M.P. Schneider and M. Bruch, The 4th International Congress on Organic Synthesis (IUPAC), August, (1982), Tokyo, Japan.

12) J.F. Biellmann and J.B. Ducey, *Org. React.*, **27**, 1 (1982).

13) α:γ refers to the isomeric ratio of the α-alkyl to the β-alkyl products.

14) In the previous paper, we reported the oxidative desulfurization of **13** gave a mixture of **4** and 2,4,6-undecatriene (1:1).[2c] It seems that the terminal double bond is easily internalized by heat and protic catalyst.



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15) Privat communication from M. Ochiai, Inst. Chem. Res. Kyoto Univ.

16) ^{1}H NMR spectrum of **3** (CDCl$_3$, 400 MHz) δ 1.34(12H, br), 2.05(3H, s), 2.07(2H, m), 4.05(2H, t), 4.95(1H, d, J=10.0 Hz), 5.08(1H, d, J=16.8 Hz), 5.70(1H, dt, J=15.1 Hz, 6.8 Hz), 6.04(1H, dd, J=15.1 Hz, 10.5 Hz), 6.31(1H, dt, J=16.8 Hz, 10.3 Hz, 10.1 Hz).

17) ^{1}H NMR spectrum of **4** (CDCl$_3$, 400 MHz) δ 0.88(3H, t), 1.27(6H, br), 2.09(2H, m), 5.04(1H, d, J=10.0 Hz), 5.17(1H, d, 16.6 Hz), 5.73(1H, quintet, J= 14.9 Hz, 7.1 Hz), 6.07(1H, dd, J=14.9 Hz, 10.0 Hz), 6.12(1H, dd, J=15.0 Hz, 10.0 Hz), 6.21(1H, dd, J=15.0 Hz, 10.0 Hz), 6.35(1H, dt, J=16.6 Hz, 10.0 Hz).

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