monium chloride (10 mL), washed three times with aqueous sodium chloride, and dried over anhydrous sodium sulfate. Evaporation left a crude product which was purified by distillation at 1.5 mm with a 170 °C bath to give pure **3c**: 14.6 g (99%); IR (neat) 3540 (s), 2950 (s), 1125 (s), 1090 (m), 1070 (m), 925 (m) cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.1 (s, 6 H), 1.5 (s, 1 H), 1.6–2.2 (m, 13 H), 3.9 (s, 4 H); ^{13}C NMR ($CDCl_3$, ^1H decoupled) δ 111.2, 64.3 (2 C), 36.7, 36.5 (2 C), 35.8, 35.4, 34.3 (2 C), 33.9 (2 C), 27.3, 24.6 (2 C). Anal. Calcd for $C_{15}H_{24}O_3$: C, 71.39; H, 9.59. Found: C, 71.58; H, 9.69.

Dehydration of this product to 5-isopropenyladamantan-2-one ethylene ketal (**3d**) was accomplished by heating with 20 g of potassium hydrogen sulfate (2–3 equiv) under nitrogen in a 170 °C bath for 4 h. A brown solid resulted which was extracted three times with 100-mL of chloroform. After evaporation, IR showed the product to be a mixture of ketone and ketal (peak at 1720 cm^{-1}); reketalization with 200 mL of benzene, 6 mL of ethylene glycol, and 0.01 g of *p*-toluenesulfonic acid in a Dean–Stark apparatus for 5 h as above gave after the workup and distillation at 1.5 mm and 130 °C pure 3d: 13.1 g (96.8%); IR (neat) 2930 (s), 1650 (m), 1440 (m), 1375 (m), 1180 (m), 1120 (s), 1070 (m), 955 (m), 920 (m), 890 (m) cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.7 (t, J = 1 Hz, 3 H), 1.4–2.1 (m, 13 H), 3.9 (s, 4 H), 4.7 (q, J = 1 Hz, 2 H); ^{13}C NMR ($CDCl_3$, ^1H decoupled) δ 153.4, 111.2, 108.1, 64.3 (2 C), 40.6, 38.4 (2 C), 36.7 (3 C), 34.3 (2 C), 27.4, 18.8. Anal. Calcd for $C_{15}H_{22}O_2$: C, 76.88; H, 9.46. Found: C, 76.74; H, 9.43.

Cyclopropanation of this material was done in 3.0-g batches to give 5-(1-methylcyclopropyl)adamantan-2-one ethylene ketal (**3e**) as follows. A 50-mL ethereal solution of diazomethane[17] prepared from 5 g of *N*-methyl-*N*-nitrosoethylurea was added to 3.0 g (12.8 mmol) of the olefin in a 125-mL erlenmeyer flask with vigorous stirring at 0 °C. Palladium acetate (10 mg) was added in small portions over a period of 15 min. When gas evolution ceased, the mixture was filtered through a sintered-glass funnel, and the solvent was evaporated by flash evaporation; GC analysis showed that 30% conversion had occurred. The procedure was repeated four or five times until no further olefin was observable by GC. Fractional vacuum distillation of the residue yielded **3** as a colorless liquid: 2.41 g (9.7 mmol, 76%); bp 155 °C (1.5 mm); IR neat, 3010 (m), 2980 (s), 1440 (m), 1375 (m), 1125 (s), 1100 (m), 1070 (m), 1010 (m), 930 (m) cm^{-1}; mass spectrum, m/e 248.2; ^1H NMR ($CHCl_3$) δ 0.0 (t, J = 4 Hz, 2 H), 0.5 (t, J = 4 Hz, 2 H), 0.9 (s, 3 H), 1.3–2.1 (m, 13 H), 3.9 (s, 4 H); ^{13}C NMR ($CDCl_3$, ^1H decoupled) δ 111.4, 64.3 (2 C), 38.6, 36.7 (2 C), 36.4 (2 C), 34.5 (2 C), 32.2, 27.5, 22.3, 21.2, 8.9 (2 C). Anal. Calcd for $C_{16}H_{24}O_2$: C, 77.38; H, 9.74. Found: C, 77.23; H, 9.55.

Catalytic reduction of this cyclopropane derivative (2.4 g, 9.7 mmol) gave 5-*tert*-butyladamantan-2-one ethylene ketal (**3f**) as follows. A mixture with 500 mg of platinum(IV) oxide, 20 mL of glacial acetic acid, and 5 mL of acetic anhydride was subjected in a Parr apparatus to hydrogen at 60 °C and 60 psi for 36 h. The reaction mixture was filtered through a sintered-glass funnel, most of the solvent was removed by flash evaporation, 20 mL of water was added, and the mixture was extracted three times with 50 mL of methylene chloride. The organic extracts were combined, washed once with 10% sodium carbonate and three times with 100 mL of saturated sodium chloride solution, and dried over anhydrous sodium sulfate. The yellowish liquid obtained after evaporation of the solvent yielded 2.16 g (89%) of colorless liquid **3f** upon distillation at 165 °C (1.5 mm): ^1H NMR ($CDCl_3$) δ 0.9 (s, 4 H), 1.5–2.1 (m, 13 H), 3.9 (s, 4 H). This batch was not analyzed but was deprotected to 5-*tert*-butyladamantan-2-one **2f** by dissolution in 30 mL of methanol and 5 mL aqueous 1 M HCl and refluxing for 12 h. The resulting mixture was extracted three times with 100 mL of methylene chloride. The combined extracts were concentrated to 50 mL, washed once with 50 mL of 10% sodium carbonate and three times with 50 mL saturated sodium chloride solution, dried with anhydrous sodium sulfate, and flash evaporated to give a colorless liquid. Two successive sublimations at 90 °C (1.5 mm) gave white crystalline **2f**: 1.745 g (87%); mp 57–58 °C; IR ($CHCl_3$) 2980 (vs), 1720 (vs), 1475 (s), 1360 (s), 1280 (m), 1060 (s) cm^{-1}; mass spectrum, m/e 206; ^1H NMR ($CDCl_3$) δ 0.85 (s, 9 H), 1.5–2.2 (m, 11 H), 2.5 (br s, 2 H); ^{13}C NMR ($CDCl_3$), ^1H decoupled) δ 219.4, 46.6 (2 C), 38.9 (2 C) 38.6 (2 C), 36.6, 35.4, 34.4, 28.2, 26.0 (3 C). Anal. Calcd for $C_{14}H_{22}O$: C, 81.50; H, 10.75. Found: C, 81.56; H, 10.71.

Acknowledgment. We are indebted to Dr. P. Helquist for a generous gift of his new methylene transfer reagent, to Dr. P. Kropp for a preprint describing his photocyclopropanation, to Professor D. J. Raber for agreeing to simultaneous publication of his synthesis of the only *O*-positional isomer of the title compound, and to the National Science Foundation for financial support.

Registry No. **2a**, 20098-14-0; **2b**, 56674-88-5; **3b**, 84454-62-6; **3c**, 84454-63-7; **3d**, 84454-64-8; **3e**, 84454-65-9; **3f**, 84454-66-0; **2f**, 84454-67-1; adamantanone, 700-58-3.

(17) Arndt, F. "Organic Syntheses"; Wiley: New York, 1943; Collect. Vol. II, p 165.

1-*tert*-Butyl-2-adamantanone

Douglas J. Raber* and Christopher M. Janks

Department of Chemistry, University of South Florida, Tampa, Florida 33620

Received April 13, 1982

As part of an investigation of steric effects on the interaction of ketones with lanthanide shift reagents, we needed to synthesize a sample of 1-*tert*-butyl-2-adamantanone (**4a**). We investigated the sequence shown in Scheme I which was developed by Schleyer and coworkers[1] for the preparation of 1-methyl-2-adamantanone (**4b**). The success of this approach despite several potential pitfalls prompts us to report the details of the synthesis.

4-Protoadamantanone (**1**) was prepared by the method of Majerski and Hameršak,[2] but the reaction of **1** with *tert*-butylmagnesium bromide was unsuccessful.[3] Consequently, we turned to the lithium derivative for which reduction was expected to be less important.[4a] The reaction of **1** with *tert*-butyllithium afforded a material which appeared to be a mixture of the desired product (**2a**) together with unreacted **1**. The proton NMR spectrum of the crude product exhibited a peak corresponding to a *tert*-butyl group, but the ^{13}C NMR spectrum still showed a peak corresponding to the carbonyl carbon of **1**. This suggested that a substantial fraction of the protoadamantanone had not undergone the desired *addition* reaction with *tert*-butyllithium but had instead been converted to the lithium enolate in an acid–base reaction. Such enolization is also well-precedented in the reactions of organometallic reagents with hindered ketones.[4,5] Since some of the desired addition had occured, the crude product was again subjected to treatment with *tert*-butyllithium, and the process was repeated several more times (for a total of five cycles) until no further decrease in the peak corresponding to the carbonyl group of **1** was observed in the ^{13}C NMR spectrum.

(1) Lenoir, D.; Glaser, R.; Mison, P.; Schleyer, P. v. R. *J. Org. Chem.* **1971**, *36*, 1821.
(2) Majerski, Z.; Hameršak, Z. *Org. Synth.* **1980**, *59*, 147.
(3) A small quantity of 1-adamantanol (**3c**) was obtained from this attempt, and this suggested that *reduction* to **2c** (followed by rearrangement, Scheme I) had occurred. Such reductions during attempts to prepare hindered tertiary alcohols via Grignard reactions are well precedented.[4]
(4) (a) Huet, F.; Emptoz, G. *J. Organomet. Chem.* **1975**, *101*, 139. (b) Whitmore, F. C.; George, R. S. *J. Am. Chem. Soc.* **1942**, *64*, 1239. (c) Cowan, D. O.; Mosher, H. S. *J. Org. Chem.* **1964**, *29*, 37.
(5) (a) Bartlett, P. D.; Tidwell, T. T. *J. Am. Chem. Soc.* **1968**, *90*, 4421. (b) Bohler, J. C. *J. Org. Chem.* **1973**, *38*, 904.

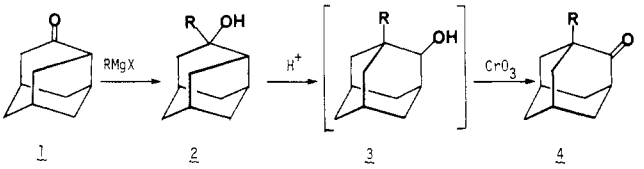
0022-3263/83/1948-1101$01.50/0

Table I. Eu(fod)$_3$-Induced Shifts of 1-*tert*-Butyl-2-adamantanone (4a)[a]

parameter	proton a	b	b'	c	c'	d	e	e'	*t*-Bu
chemical shift,[b] ppm	2.47	1.96	2.01	1.96	1.79	2.08	1.96	1.96	1.00
scaled exptl LIS,[c] ppm	13.89[d]	6.40	8.62	3.61	5.53	4.07	3.06	3.63	7.45
predicted LIS,[e] ppm	12.14[d]	6.61	8.73	3.33	5.86	3.93	3.11	3.68	7.36

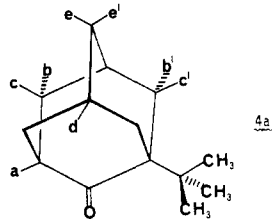
[a] See the Experimental Section for details. [b] $CDCl_3$ solution in the absence of shift reagent. [c] All shifts were scaled[7] by a factor of 0.94. [d] The hydrogen α to the carbonyl group was excluded from the analysis because of an undetermined contact shift contribution to the experimental shift. [e] For the complex with a C-O-Eu bond angle of 152° and a Eu-O-C-H_a dihedral angle of 0°, the agreement factor is 0.03.

Scheme I. Synthesis of 1-Alkyl-2-adamantanones from 4-Protoadamantanone



Rearrangement of the crude alcohol **2a** to the isomeric **3a** and subsequent oxidation to **4a** were carried out in a single step with CrO_3–H_2SO_4. Chromatography of the resulting product on alumina afforded fractions that were identified as 4-protoadamantanone (**1**) and 1-adamantanol as well as a crystalline material (mp 126–127 °C, after recrystallization from pentane) which was assigned structure **4a**, an assignment consistent with IR, proton NMR, and ^{13}C NMR data.

The proposed structure was confirmed by an analysis of the lanthanide-induced shifts (LIS) with Eu(fod)$_3$ according to our previously described methodology.[6] Experimental and predicted LIS were obtained for each of the nine types of hydrogen in **4a** (Table I), although the

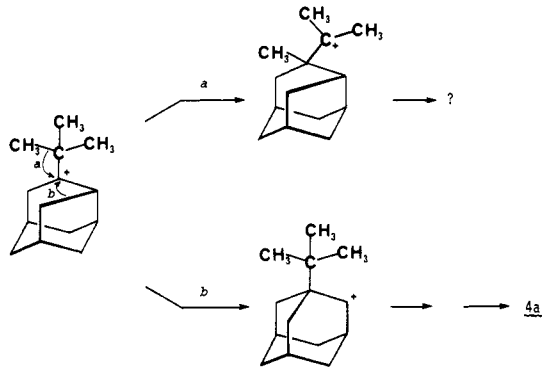


hydrogen α to the carbonyl group (i.e., H_a) was excluded from the analysis because of the unknown contribution from contact shift.[6] Optimum agreement between experimental and predicted values corresponds to a complex in which the carbon–oxygen–europium bond angle is 152°. The europium lies in the symmetry plane of **4a** and is bent away from the *tert*-butyl group in accord with earlier indications that such nonlinear distortions result from steric repulsions.[6] The agreement factor for this structure is 0.03, and this is within the range previously suggested[6-8] for acceptability of a proposed structure.

The successful synthesis of 1-*tert*-butyl-2-adamantanone by this procedure is somewhat surprising since no products corresponding to *methyl shifts* (Scheme IIa) were observed.

The preferential formation of **4a** might be the result of a stereoselective reaction of **1** with *tert*-butyllithium. Attack on **1** from the less hindered side would yield the stereoisomer of **2a** with the OH group anti to the carbon–carbon bond whose migration leads to **3a**. While the opposite stereoselectivity is observed in the hydride reduction of **1**, reaction of **1** with methylmagnesium iodide does afford the corresponding stereoisomer of **2b** as the major product.[9,10] Alternatively, the formation of **4a** from **2a** does not preclude *reversible* methyl shifts in the cationic intermediates. Such reversible methyl migrations have recently been observed by Fry[11] in adamantane derivatives. In the present case the relief of strain associated with the protoadamantane to adamantane rearrangement[10] would provide the necessary driving force to drive the equilibrium in the direction of the observed product.

Scheme II. Rearrangement of the 4-*tert*-Butyl-4-protoadamantyl Cation



Experimental Section

General Methods. NMR spectra were obtained with a JEOL FX90Q spectrometer, and infrared spectra were recorded with a Perkin-Elmer Model 700 spectrometer. A Varian Series 2400 chromatograph equipped with 5 ft × $^1/_8$ in. columns was used for GLC analysis. Melting points are uncorrected. Elemental analysis was carried out by M-H-W Laboratories.

Reaction of 4-Protoadamantanone with *tert*-Butyllithium. A three-necked, 250-mL, round-bottomed flask fitted with a dropping funnel, septum cap, and magnetic stirrer was charged with 50 mL of petroleum ether (bp 30–60 °C), and 15 mL (0.032 mol) of 2.1 M *tert*-butyllithium[12] in pentane was added with a syringe. The resulting solution was cooled with a dry ice–acetone bath, and a solution of 2.15 g (0.014 mol) of 4-protoadamantanone (**1**)[2] in 40 mL of petroleum ether was added dropwise over 30 min. After the addition was complete, the solution was allowed to warm to room temperature and was then quenched by the cautious addition of 20 mL of water. The mixture was acidified with 6 N HCl, and the petroleum ether was evaporated with a gentle stream of compressed air. The aqueous residue was extracted with two 60-mL portions of dichloromethane, and the combined

(6) Raber, D. J.; Janks, C. M.; Johnston, M. D., Jr.; Raber, N. K. *J. Am. Chem. Soc.* **1980**, *102*, 6591.
(7) Raber, D. J.; Janks, C. M.; Johnston, M. D., Jr.; Raber, N. K. *Org. Magn. Reson.* **1981**, *15*, 57.
(8) Raber, D. J.; Caines, G. H.; Johnston, M. D., Jr.; Raber, N. K. *J. Magn. Reson.* **1982**, *47*, 38.
(9) Lenoir, D.; Hall, R. E.; Schleyer, P. v. R. *J. Am. Chem. Soc.* **1974**, *96*, 2138.
(10) Lenoir, D.; Raber, D. J.; Schleyer, P. v. R. *J. Am. Chem. Soc.* **1974**, *96*, 2149.
(11) (a) Fry, J. L., personal communication. (b) Fry, J. L.; Saba, J. A. *Tetrahedron Lett.* **1982**, *23*, 1743.
(12) Commercially available from the Aldrich Chemical Co.

organic extracts were washed with two 50-mL portions of 1 N potassium bicarbonate and a 50-mL portion of saturated aqueous sodium chloride. The organic solution was dried over potassium carbonate, and evaporation of the solvent at reduced pressure yielded 2.0 g of material. The ^{13}C NMR spectrum showed peaks for both C=O (216 ppm) and C—OH (79 ppm), and this indicated only partial conversion to **2a**.

The reaction with *tert*-butyllithium was therefore repeated four additional times at which point no further decrease was observed in the intensity of the ^{13}C peak for the carbonyl group of 1. GLC analysis (10% Carbowax 20M, 175 °C, flow rate = 30 mL/min) suggested that unreacted starting material (1) and product (2) were present in a 30:70 ratio (with retention times of 7 and 9 min, respectively).

1-*tert*-Butyl-2-adamantanone. The crude alcohol (ca. 3 g) was dissolved in 75 mL of reagent grade acetone in a 300-mL flask, and 5 mL (40 mequiv) of Jones reagent[13] was added dropwise over 10 min with magnetic stirring. The reaction mixture was stirred at room temperature for 12 h, and the excess oxident was destroyed by adding 2-propanol until the red color had disappeared. The reaction mixture was poured onto 200 g of ice, and the aqueous mixture was extracted with three 50-mL portions of chloroform. The combined chloroform extracts were washed with two 50-mL portions of 1 N potassium bicarbonate and a single portion of saturated aqueous sodium chloride and were dried over sodium sulfate.

The solvent was evaporated at reduced pressure, and the residue was purified by chromatography on alumina. Elution with petroleum ether (bp 30–60 °C) afforded 0.27 g of 1-*tert*-butyl-2-adamantanone (**4a**) as a colorless solid (crude mp 114–115 °C), followed by fractions which appeared to be a mixture of the desired product and unreacted protoadamantanone (1). Subsequent elution with diethyl ether yielded material that was identified as 1-adamantanol on the basis of spectroscopic properties and GLC behavior. Kugelrohr distillation of **4a** (0.1 torr, 150 °C bath temperature) followed by several recrystallizations from petane provided material melting at 126–127 °C. Anal. Calcd for $C_{14}H_{22}O$: C, 81.50; H, 10.75. Found: C, 81.69; H, 10.86.

The proton NMR spectrum of **4a** ($CDCl_3$, Me_4Si) exhibits a sharp singlet at 1.0 ppm (9 H, *t*-Bu), a broad singlet at 2.5 ppm (1 H, H_a), and complex absorption between 1.1 and 2.2 ppm (12 H). See Table I for a complete analysis. The infrared spectrum shows strong absorptions at 1710 (C=O) and 2870–3040 cm^{-1} (CH). The ^{13}C NMR spectrum exhibits nine resonances in accord with the proposed structure ($CDCl_3$, Me_4Si): 215 (C=O), 54.0, 48.9, 39.3, 38.8, 36.1, 34.4, 28.2, 25.4 ppm.

Lanthanide induced shifts of 4a were obtained with Eu(fod)$_3$[12] in CCl_4 solution, and spectra were recorded with an EM-360 spectrometer. The incremental dilution method[6,14] was employed. Unique bound shifts were measured for each of the nine types of hydrogen in the molecule. LIS were independently predicted for the proposed structure with the pseudocontact equation[15,16] by using k = 976.6 and a carbon–europium bond length of 2.5 Å as described previously.[6,7] The optimum agreement between experiment and prediction was observed for a carbon–oxygen–europium bond angle of 152° with a scaling factor[7] of 0.94. The scaled experimental shifts are summarized in Table I together with the predicted values for each type of hydrogen.

Acknowledgement is made to the donors of the Petroleum Research Fund, administered by the American Chemical Society, for support of this research.

Registry No. 1, 27567-85-7; **2a**, 84580-03-0; **4a**, 84499-71-8; *tert*-butyllithium, 594-19-4.

(13) CrO_3–H_2SO_4–acetone reagent (8 N in CrO_3) was prepared according to: Kleinfelter, D. D.; Schleyer, P. v. R. "Organic Syntheses"; Wiley: New York, 1973; Collect. Vol. V, p 852.

(14) Shapiro, B. L.; Johnston, M. D., Jr. *J. Am. Chem. Soc.* **1972**, *94*, 8185.

(15) McConnell, H. M.; Robertson, R. E. *J. Chem. Phys.* **1958**, *29*, 1361.

(16) For recent reviews of lanthanide shift reagents see: (a) Hofer, O. *Top. Stereochem.* **1976**, *9*, 111–197. (b) Inagaki, F.; Miyazawa, T. *Prog. Nucl. Magn. Reson. Spectrosc.* **1981**, *14*, 67.

Anti Stereoselectivity in the Palladium(0)-Catalyzed Conversion of Propargylic Esters into Allenes by Phenylzinc Chloride

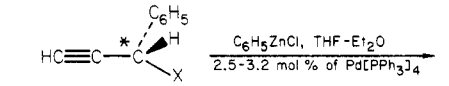
Cornelis J. Elsevier, Petra M. Stehouwer, Hans Westmijze, and Peter Vermeer*

Department of Organic Chemistry, State University at Utrecht, Croesestraat 79, 3522 AD Utrecht, The Netherlands

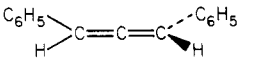
Received July 26, 1982

Recently we reported that the palladium(0)-catalyzed reaction of propargylic esters with organozinc compounds gives pure allenes.[1] The present paper concerns the stereochemistry of this synthetically useful reaction in both the steroid and the nonsteroid series.

In the nonsteroid series we studied the $Pd[PPh_3]_4$-promoted reaction of some esters derived from (*R*)-(–)-1-phenyl-2-propyn-1-ol with phenylzinc chloride and found that in all cases the induced 1,3-substitution proceeded with anti stereoselectivity to give the levorotatory allene (*R*)-**2**.[2]



(*R*)-**1a**, X = CH_3CO_2
b, X = CF_3CO_2
c, X = $CH_3S(O)O$



(1)

(*R*)-(–)-**2**

Comparison of the specific rotations, $[\alpha]^{20}_D$, measured for the produced allene **2** (see Experimental Section) with that reported for the optically pure allene, viz., –1137°,[3] showed that for all three conversions given in eq 1 the ratio of anti vs. syn 1,3-substitution was ca. 82/18. Apparently, the nature of the leaving group in ester **1** is not very important for the stereoselectivity of the reaction. From the literature it is known that phenylcopper also may be used to induce an anti 1,3-substitution in **1c**. The stereoselectivity in that case is better (ratio of anti vs. syn 1,3-substitution 88/12).[4]

In the steroid series three esters derived from mestranol (eq 2) were subjected to the reaction with phenylzinc chloride, again with $Pd[PPh_3]_4$ as the catalyst. In the steroid case the anti substitution product, compound **4**, can easily be distinguished from the epimeric syn substitution product, compound **5**, by ^1H NMR spectroscopy. The 13-Me signal for allene **4** is found as a sharp singlet at δ 1.07 and that for allene **5** at δ 0.95 (CCl_4, Me_4Si).[5] From the relative intensities of these peaks the product

(1) Ruitenberg, K.; Kleijn, H.; Elsevier, C. J.; Meijer, J.; Vermeer, P. *Tetrahedron Lett.* **1981**, *22*, 1451.

(2) In the case of 1,3-disubstituted allenes Lowe–Brewster rules can be used to correlate the sign of optical rotation with the absolute configuration of the allene: (a) Lowe, G. *Chem. Commun.* **1965**, 411. (b) Brewster, J. H. *Top. Stereochem.* **1967**, *2*, 33–39.

(3) Rossi, R.; Diversi, P. *Synthesis* **1973**, 25.

(4) Tadema, G.; Everhardus, R. H.; Westmijze, H.; Vermeer, P. *Tetrahedron Lett.* **1978**, 3935.

(5) The pure allene **4** ($[\alpha]^{20}_D$ –282.0° (in CH_2Cl_2)) has been obtained by reaction of **3b** or **3c** with phenylcopper; the pure allene **5** ($[\alpha]^{20}_D$ +296.4° (in CH_2Cl_2)) has been obtained by reaction of the 17-epimer of **3b** with phenylcopper: Westmijze, H. Thesis, State University of Utrecht, 1979. See for a recent report on organocopper-induced anti 1,3-substitution in ester **3b**: Elsevier, C. J.; Meijer, J.; Westmijze, H.; Vermeer, P.; van Dijck, L. A. *J. Chem. Soc., Chem. Commun.* **1982**, 84.

0022-3263/83/1948-1103$01.50/0