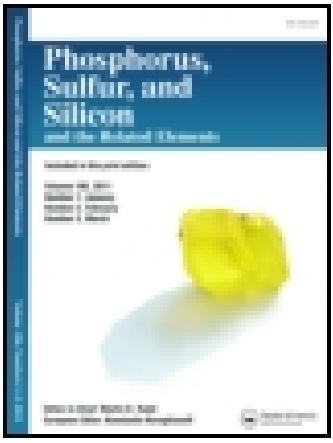

Phosphorus, Sulfur, and Silicon and the Related Elements

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An Unexpected Phosphine-Mediated Olefination of Salicylaldehydes with α-Methyl Allenoate

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An Unexpected Phosphine-Mediated Olefination of Salicylaldehydes with α-Methyl Allenoate

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An unexpected phosphine-mediated olefination of salicylaldehydes with α-methyl allenoate is described. Thus, under the mediation of PPh_3, six salicylaldehydes react with ethyl α-methyl butadienoate forming the corresponding (1E, 3E)-1-(2-hydroxyphenyl)-3-carboethoxy-1,3-pentadienes in fair to excellent yields. A plausible mechanism for this reaction is also discussed.

Keywords Ethyl 2,3-butadienoate; olefination; salicylaldehyde; triphenylphosphine

INTRODUCTION

In recent years, the nucleophilic catalysis by phosphine has attracted much attention within the chemistry community. Many new phosphine-catalyzed reactions with high synthetic potentials have been discovered.[1] A class of substrate commonly used in these reactions is allene, which generally is activated by electron-withdrawing groups and has proven to be increasingly important and versatile synthetic intermediate by renewed research efforts. The phosphine-catalyzed reactions of activated allenes mainly fall into four categories: isomerization,[2] α-addition,[3] γ-addition,[4] and cycloaddition,[5] in which the phosphine acts as a nucleophilic organocatalyst. In addition to its pronounced nucleophilicity, the tertiary phosphine also possesses a strong deoxygenating function, which is believed to be a primary driving force for the famous Wittig and Mitsunobu reactions.[6] Most recently,

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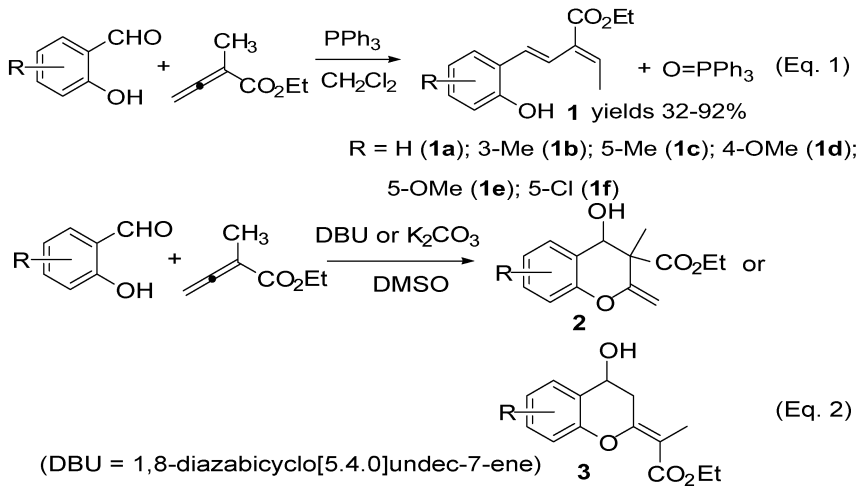


many novel phosphine-mediated heterocyclic constructions from the activated allenes have been reported, in which both nucleophilicity and deoxygenating ability of phosphine take effects.[1c,7] These new findings all further strengthen the versatility of phosphine in the organic synthesis.

In most cases of the phosphine-mediated reactions of allenes, the new bond formation in the product occurs at α- or/and γ-carbons of allenic esters. However, subtle structural changes, such as the replacement of hydrogen with methyl at α position in the allenoates, can significantly alter the reactivity trend. For example, under the catalysis of a nucleophilic phosphine, a series of α-alkyl substituted allenoates with N-tosyl imines undergo the [4 + 2] annulation, forming highly functionalized tetrahydropyridines in high yields,[8] rather than the usual [3 + 2] cycloaddition for α-unsubstituted analogous allenes under similar conditions.[5d,9] As part of our continuous efforts on the phosphine-mediated carbon-carbon bond forming reactions,[10] we are interested in the reaction of allenic esters with substituted salicylaldehydes, which possess both nucleophilic phenolic hydroxyl and electrophilic formyl. Herein, we report an unexpected triphenylphosphine-mediated olefination of salicylaldehyde with α-methyl allenoate.

RESULTS AND DISCUSSION

Under the participation of one equivalent of triphenylphosphine, a series of substituted salicylaldehydes readily reacted with ethyl α-methyl butadienoate, giving the corresponding (1*E*, 3*E*)-1-(2-hydroxyphenyl)-

3-carboethoxy-1,3-pentadienes **1** in fair to excellent yields [Eq. (1)]. Preliminary optimization on reaction conditions disclosed that the reaction run in the methylene chloride at low temperature (0°C) gave better result. It is surprising that the new double bond formation in the major product takes place at the α-methyl group, other than the olefinic α- and γ-carbons of the allenic ester. The structures of product **1** were identified by their microanalysis, ^{1}H, and ^{13}C NMR spectra. Their ^{1}H NMR data provide a diagnostic evidence for the *E*-configuration assignment to the double bond at C1: relatively greater coupling constants (ca. 16 Hz) between the olefinic protons at C1 and C2 were observed for products **1** except **1c**, whose olefinic proton signals severely overlap with the aromatic proton signals. In the ^{1}H NMR spectra of products **1**, a broad singlet peak in the range of 5.32–6.70 ppm also supports the assignment of the phenolic hydroxyl. For all products **1**, the ^{13}C NMR data clearly show there are 11 sp^{2}-hybridized carbons in a single molecule. Also, the X-ray crystallography analysis of product **1c** (CCDC 653761) provides unambiguous evidence for the structure determination (Figure 1).[11]

In contrast with the results obtained in this study, a cyclization reaction of salicylic aldehydes with α-methyl allenic ester catalyzed by either organic Lewis base or inorganic base was reported by Shi[12] [Eq. (2)]. The annulation reaction constitutes an efficient synthesis of 2*H*-1-chromene derivatives. Although the authors did not rule out the

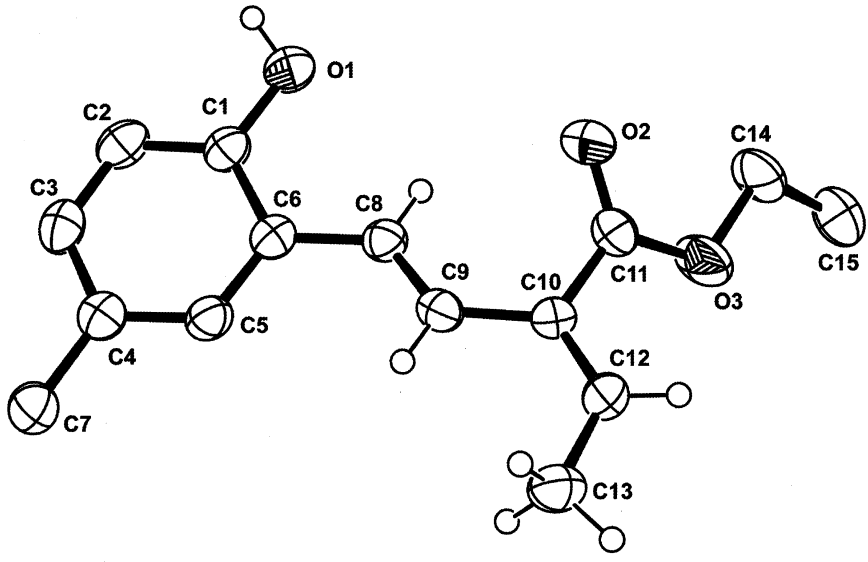
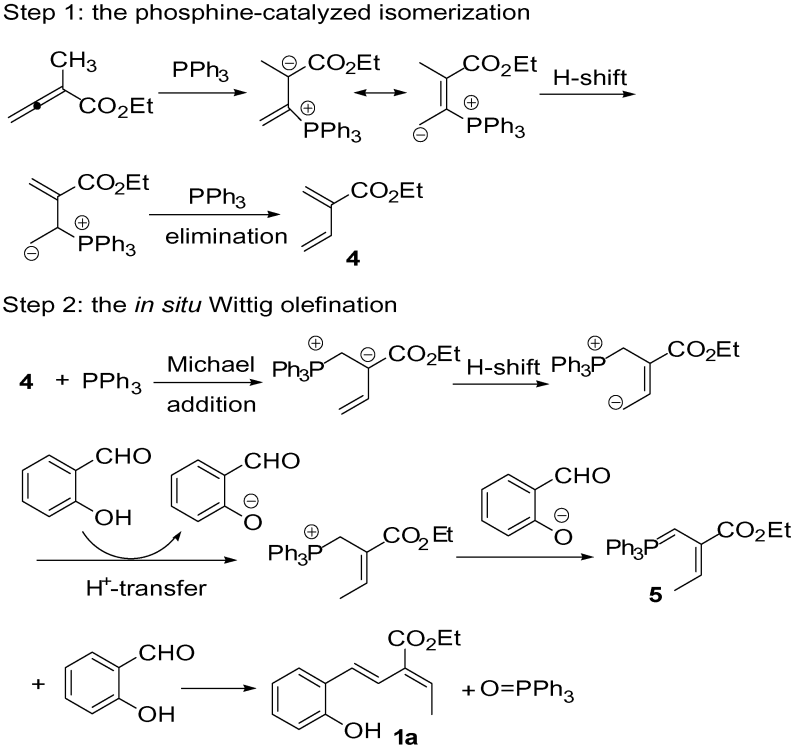


FIGURE 1 The X-ray structure of Compound **1c.**

possibility that the Lewis base acts as a nucleophilic catalyst in a plausible mechanism, it is believed that the basicity of the employed catalyst plays a critical role in the catalysis. It is well known that triphenylphosphine has a weaker basicity compared to trialkylphosphines or tertiary amines. This may be the reason for its ineffectiveness in the catalysis of the above cyclization reaction.[12a] However, triphenylphosphine still possesses a decent nucleophilicity due to the better polarization ability of phosphorus atom, and therefore is the most often used nucleophilic organocatalyst in recent years. Also, as the characteristics of tertiary phosphine, it has a good deoxygenating ability. Probably, both its nucleophilicity and strong affinity for oxygen play critical roles in the olefination of salicylic aldehydes in this study.

The exact mechanism for this phosphine-mediated olefination remains unclear. Based on experimental results in this study, a rationalized mechanism may be proposed, as shown in Scheme 1. The olefination of salicylic aldehyde with α-methyl allenoate presumably proceeds via two steps: the phosphine-catalyzed isomerization and the



SCHEME 1 A plausible mechanism.

olefination via *in situ* formed triphenylphosphonium ylide. It is well documented that the nucleophilic phosphine can catalyze the isomerization of electron-deficient alkynes or allenes into conjugated dienes[2]. Thus, the α-methyl allenoate is first isomerized into 1,3-diene **4** via the phosphine nucleophilic attack at the β-carbon of the allenoate, followed by hydrogen shift and elimination of the phosphine. Subsequently, the Michael addition of triphenylphosphine to the 1,3-diene **4**, followed by proton transfer, leads to the in situ formation of triphenylphosphonium ylide **5**, which then reacts with salicylic aldehyde forming a new double bond with *E*-configuration. The in situ formation of phosphonium ylide from electron-deficient alkene or alkyne has been reported since the early times,[13] which also has been developed as an effective way to the olefination of aldehydes via the Wittig reaction. In this study, all attempts to employ other aromatic aldehydes without phenolic hydroxyl instead of salicylic aldehydes failed in giving the similar products. This result clearly shows the phenolic hydroxyl plays a critical role in the olefination, possibly by the way of facilitating the proton transfer as shown in the above-proposed mechanism (Scheme 1).

In summary, a novel phosphine-mediated olefination between the salicylic aldehydes and α-methyl allenoate is described. To the best of our knowledge, it is the first example of its kind for the substrate allene. It also furnishes a convenient synthesis of highly functionalized 1,3-dienes. Triphenylphosphine acts as both nucleophilic organocatalyst and deoxygenating agent in the reaction.

EXPERIMENTAL

Unless otherwise noted, all reactions were carried out in the ambient atmosphere. Commercially available chemicals were used as received. Ethyl α-methyl butadienoate was prepared as described in the literature.[14]

Nuclear magnetic resonances (^{1}H, ^{13}C) were recorded on Bruker 300 MHz and Variant 400 MHz NMR spectrometers using TMS as internal standard (^{1}H, ^{13}C), and $CDCl_3$ as solvent. Elemental analyses were performed on a Yanaco CHN Corder MT-3 automatic analyzer. ESI mass spectra were recorded with ThermoFinnigan LCQ Advantage LC-MS. X-ray crystal diffraction data were collected on a Nonius Kappa CCD diffractometer with Mo Kα radiation ($\lambda = 0.7107$ Å).

Phosphine-Mediated Olefination of Salicylaldehydes with α-Methyl Allenoate (General Procedure)

To a magnetically stirred mixture of triphenylphosphine (0.26 g, 1.0 mmol) and salicylic aldehyde (1.0 mmol) in dichloromethane (2 mL) was

dropwise added a solution of ethyl 2-methyl-2,3-butadienoate (0.15 g, 1.2 mmol) in dichloromethane (1 mL) at 0°C over 10 min. The reaction was then allowed to warm to room temperature and stirred for 12–24 h until the aldehyde was consumed (TLC monitoring). After the removal of solvent and column chromatography on silica gel (200–300 mesh) eluted with a mixture of petroleum ether and ethyl acetate (20:1, V/V), a pure product **1** was obtained in 32–92% isolated yield (based on the substrate aldehyde).

1a (R = H)

Reaction time 24 h; solidified on standing as a white solid, m.p. 42–44°C; yield 92%; ^{1}H NMR: δ 7.46 (m, 1H), 7.28 (d, J = 16.4 Hz, 1H), 7.10 (m, 1H), 6.92 (d, J = 16.4 Hz, 1H), 6.91-6.84 (m, 3H), 6.70 (br s, 1H), 4.28 (q, J = 7.2 Hz, 2H), 2.00 (d, J = 7.2 Hz, 3H), 1.32 (t, J = 7.2 Hz, 3H); ^{13}C NMR: δ 167.9, 153.6, 138.2, 131.4, 128.7, 128.4, 126.8, 124.8, 121.5, 120.5, 116.0, 60.9, 14.8, 14.1 ppm; microanalysis calculated for $C_{14}H_{16}O_3$ (MW: 232.1): C 72.39, H 6.94; Found: C 72.30, H 7.11; ESI-MS (positive mode): m/z 233.3 $[M + H]^+$.

1b (R = 3-Me)

Reaction time 24 h; solidified on standing as a white solid, m.p. 75–77°C; yield 60%; ^{1}H NMR: δ 7.30 (m, 1H), 7.25 (d, J = 16.2 Hz, 1H), 7.15 (m, 1H), 6.90–6.81 (m, 3H), 5.32 (br s, 1H), 4.25 (q, J = 7.2 Hz, 2H), 2.26 (s, 3H), 1.93 (d, J = 7.2 Hz, 3H), 1.32 (t, J = 7.2 Hz, 3H); ^{13}C NMR: δ 167.3, 151.5, 138.2, 131.3, 130.2, 128.2, 124.9, 124.5, 123.9, 122.6, 120.4, 60.7, 15.9, 14.7, 14.2 ppm; microanalysis calculated for $C_{15}H_{18}O_3$: C 73.15, H 7.37; Found: C 73.11, H 7.54.

1c (R = 5-Me)

Reaction time 12 h; yield 70%; ^{1}H NMR: δ 7.24 (m, 2H), 6.92–6.84 (m, 3H), 6.71 (m, 1H), 5.98 (br s, 1H), 4.26 (q, J = 7.2 Hz, 2H), 2.26 (s, 3H), 2.00 (d, J = 7.2 Hz, 3H), 1.32 (t, J = 7.2 Hz, 3H); ^{13}C NMR: δ 164.9, 151.3, 138.0, 131.5, 129.8, 129.4, 128.3, 127.3, 124.4, 121.6, 115.9, 60.8, 20.5, 14.8, 14.2 ppm; microanalysis calculated for $C_{15}H_{18}O_3$ (MW: 246.3): C 73.15, H 7.37; Found: C 73.17, H 7.42; ESI-MS (positive mode): m/z 246.4 $[M]^+$; slow evaporation of its solution in a mixture of petroleum ether/ethyl acetate (10:1, V/V) afforded colorless crystals suitable for X-ray diffraction, m.p. 84–85°C.

1d (R = 4-OMe)

Reaction time 24 h; solidified on standing as a white solid, m.p. 39–42°C; yield 79%; ^{1}H NMR: δ 7.29 (d, J = 8.4 Hz, 1H), 7.18 (d, J = 16.5 Hz, 1H), 6.80 (q, J = 7.5 Hz, 1H), 6.78 (d, J = 16.5 Hz, 1H), 6.46 (dd, J =

8.4, 2.1 Hz, 1H), 6.42 (d, J = 2.1 Hz, 1H), 4.26 (q, J = 6.9 Hz, 2H), 3.74 (s, 3H), 1.98 (d, J = 7.5 Hz, 3H), 1.33 (t, J = 6.9 Hz, 3H); ^{13}C NMR: δ 167.9, 160.3, 154.7, 137.1, 131.6, 128.0, 127.8, 119.6, 117.9, 106.7, 101.8, 60.8, 55.2, 14.7, 14.2 ppm; microanalysis calculated for $C_{15}H_{18}O_4$: C 68.68, H 6.92; Found: C 68.87, H 7.02.

1e (R = 5-OMe)

Reaction time 24 h; yellowish viscous oil; yield 32%; ^{1}H NMR: δ 7.22 (d, J = 16.8 Hz, 1H), 6.98 (s, 1H), 6.88-6.65 (m, 4H), 6.34 (br s, 1H), 4.25 (q, J = 7.2 Hz, 2H), 3.76 (s, 3H), 1.97 (d, J = 7.2 Hz, 3H), 1.31 (t, J = 7.2 Hz, 3H); ^{13}C NMR: δ 167.8, 153.5, 147.9, 138.4, 131.4, 128.4, 125.5, 121.7, 116.9, 114.6, 111.6, 60.9, 55.8, 14.8, 14.2 ppm; microanalysis calculated for $C_{15}H_{18}O_4$: C 68.68, H 6.92; Found: C 69.01, H 6.93.

1f (R = 5-Cl)

Reaction time 24 h; yellowish semi-solid; yield 67%; ^{1}H NMR: δ 7.36 (s, 1H), 7.18 (d, J = 16.4 Hz, 1H), 7.00-6.75 (m, 4H), 6.13 (br s, 1H), 4.24 (q, J = 7.2 Hz, 2H), 1.97 (d, J = 7.2 Hz, 3H), 1.32 (t, J = 7.2 Hz, 3H); ^{13}C NMR: δ 167.7, 152.6, 138.9, 131.2, 128.3, 127.4, 126.4, 126.2, 125.1, 122.3, 117.5, 60.9, 14.8, 14.2 ppm; microanalysis calculated for $C_{14}H_{15}ClO_3$: C 63.04, H 5.67; Found: C 62.98, H 5.77.

REFERENCES

[1] (a) X. Lu, C. Zhang, and Z. Xu, *Acc. Chem. Res.*, **34,** 535 (2001); (b) J. L. Methot and W. R. Roush, *Adv. Synth. Catal.*, **346,** 1035 (2004); (c) V. Nair, R. S. Menon, A. R. Sreekanth, N. Abhilash, and A. T. Biju, *Acc. Chem. Res.*, **39,** 520 (2006).

[2] (a) B. M. Trost and U. Kazmaier, *J. Am. Chem. Soc.*, **114,** 7933 (1992); (b) C. Guo, and X. Lu, *J. Chem. Soc., Chem. Commun.*, 394 (1993); (c) C. Guo and X. Lu, *J. Chem. Soc., Perkin Trans. 1*, 1921 (1993).

[3] B. M. Trost and G. R. Dake, *J. Am. Chem. Soc.*, **119,** 7595 (1997).

[4] (a) B. M. Trost and C.-J. Li, *J. Am. Chem. Soc.*, **116,** 3167 (1994); (b) B. M. Trost and C.-J. Li, *J. Am. Chem. Soc.*, **116,** 10819 (1994); (c) C. Zhang and X. Lu, *Synlett*, 645 (1995); (d) B. M. Trost and G. R. Dake, *J. Org. Chem.*, **62,** 5670 (1997).

[5] (a) C. Zhang and X. Lu, *J. Org. Chem.*, **60,** 2906 (1995); (b) Z. Xu and X. Lu, *Tetrahedron Lett.*, **38,** 3461 (1997); (c) G. Zhu, Z. Chen, Q. Jiang, D. Xiao, P. Cao, and X. Zhang, *J. Am. Chem. Soc.*, **119,** 3836 (1997); (d) Z. Xu and X. Lu, *J. Org. Chem.*, **63,** 5031 (1998); (e) Z. Xu and X. Lu, *Tetrahedron Lett.*, **40,** 549 (1999); (f) J. E. Wilson and G. C. Fu, *Angew. Chem. Int. Ed.*, **45,** 1426 (2006); (g) L. Jean and A. Marinetti, *Tetrahedron Lett.*, **47,** 2141 (2006), and references cited therein.

[6] (a) L. D. Quin, A Guide to Organophosphorus Chemistry (Wiley, New York, 2000); (b) D. H. Valentine, and J. H. Hillhouse, *Synthesis*, 317 (2003).

[7] V. Nair, A. T. Biju, K. Mohanan, and E. Suresh, *Org. Lett.*, **8,** 2213 (2006).

[8] (a) X.-F. Zhu, J. Lan, and O. Kwon, *J. Am. Chem. Soc.*, **125,** 4716 (2003); (b) R. P. Wurz and G. C. Fu, *J. Am. Chem. Soc.*, **127,** 12234 (2005); (c) Y. S. Tran and O. Kwon, *Org. Lett.*, **7,** 4289 (2005).

[9] X.-F. Zhu, C. E. Henry, and O. Kwon, *Tetrahedron*, **61,** 6276 (2005).

[10] (a) Z. He, X. Tang, Y. Chen, and Z. He, *Adv. Synth. Catal.*, **348,** 413 (2006); (b) X. Tang, B. Zhang, R. Gao, and Z. He, *Adv. Synth. Catal.*, **349,** (2007).

[11] Selected crystal data for Compound **1c** (CCDC 653761): $C_{15}H_{18}O_3$, $M = 246.29$, orthorhombic, space group $P2_12_12_1$, $a = 8.371(16)$, $b = 10.106(19)$, $c = 17.26(3)$ Å, $\alpha = 90^\circ$, $\beta = 90^\circ$, $\gamma = 90^\circ$, $F(000) = 528$, $Z = 4$, $D_c = 1.120$ g cm^{-3}, $U = 1460(5)$ Å^3, $T = 113(2)$ K, λ(Mo-Kα) = 0.7107 Å, 10488 reflections collected in the range of $2.36 \leq \theta \leq 25.01^\circ$, $R_{int} = 0.0907$. The structure was solved by different methods and refinement, based on F^2, was by full-matrix least-squares to $R1 = 0.0754$, $wR2 = 0.1759$. The supplementary crystallographic data for this compound can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif

[12] (a) G.-L. Zhao, Y.-L. Shi, and M. Shi, *Org. Lett.*, **7,** 4527 (2005); (b) M. Shi, L.-Z. Dai, Y.-L. Shi, and G.-L. Zhao, *Adv. Synth. Catal.*, **348,** 967 (2006).

[13] (a) R. Oda, T. Kawabata and S. Tanimoto, *Tetrahedron Lett.*, **5,** 1653 (1964); (b) S. W. McCombie and C. A. Luchaco, *Tetrahedron Lett.*, **38,** 5775 (1997); (c) R. A. Aitken, P. Lightfoot, and N. J. Wilson, *Eur. J. Org. Chem.*, 35 (2001); (d) R. Hekmatshoar, S. Souri, and F. Faridbod, *Phosphorus Sulfur Silicon Relat. Elem.*, **178,** 1457 (2003).

[14] R. W. Lang and H.-J. Hansen, *Org. Synth.*, **22,** 202 (1984).