mixture was extracted with two 10-mL portions of pentane which were combined, washed with water, dilute $NaHCO_3$, dilute hydrochloric acid, and water, and dried over Na_2SO_4. Concentration gave an oil which was purified by PTLC (13:1 dichloromethane–ethyl acetate). Bulb-to-bulb distillation (160 °C, 0.75 mm) afforded 118 mg (92%) of **25b** as an oil: IR (neat) 3080, 2983, 2962, 2930, 1732, 1707, 1640, 1450, 1362, 1230, 1040, 910 cm^{-1}; ^1H NMR (CCl_4, 100 MHz) δ 1.2–1.6 (rı, 2 H, homoallylic CH_2), 1.72 (s, 3 H, vinyl CH_3), 1.99 (s, 3 H, $OCOCH_3$), 2.08 (s, 3 H, CH_3CO), 1.9–2.6 (m, 6 H, allylic CH_2), 4.00 (t, 2 H, CH_2O, J = 7 Hz), 4.84–5.08 (m, 2 H, C=CH_2), 5.10 (t, 1 H, C-5 vinyl H, J = 7 Hz) 5.4–5.9 (m, 1 H, vinyl H).

(±)-(*Z*)-3-Methyl-6-isopropenyl-3,9-decadien-1-ol Acetate (14). A solution of methylenetriphenylphosphorane was prepared by treating 160 mg (0.45 mmol) of methyltriphenylphosphonium bromide in 2 mL of THF with 0.28 mL (0.42 mmol) of 1.50 N *n*-BuLi in hexane at 0 °C followed by stirring for 10 min at 0 °C and then for 15 min at 25 °C. This solution was added dropwise over 2 min by cannula to a stirred solution containing 88 mg (0.35 mmol) of **25b** in 2.5 mL of THF under argon. The mixture was stirred for 0.5 h, and the solvent was removed in vacuo at 25 °C. The residue was treated with 5 mL of water and twice extracted with 5-mL portions of diethyl ether which were combined and then washed with water and dried over Na_2SO_4. The oil obtained after removal of the solvent by distillation was treated with 290 μL (3.1 mmol) of Ac_2O and 125 μL (1.6 mmol) of pyridine and allowed to stand for 0.5 h at 25 °C. Water (250 μL) was added dropwise to the mixture over several minutes followed by treatment with 7 mL of water and extraction with two 10-mL portions of pentane. The combined extracts were successively washed with small portions of aqueous $NaHCO_3$, dilute hydrochloric acid, water, and brine. The residue obtained upon removal of the solvent was chromatographed (PTLC, dichloromethane), giving 17 mg of recovered **25b** and 47 mg (57% based on recovered starting material) of pure (±)-14: IR (neat) 3080, 2970, 2930, 2860, 1734, 1640, 1450, 1362, 1230, 1036, 905, 885 cm^{-1} (the spectrum was nearly identical to that of an authentic sample[17] of a 1:1 moisture of *E* and *Z* isomers); ^1H NMR (CS_2, 200 MHz) δ 1.29–1.45 (m, 2 H, homoallylic CH_2), 1.568, 1.575 (dd, 3 H, isopropenyl CH_3, J = 0.8 Hz), 1.665 (m, 3 H, vinyl CH_3), 1.8–2.1 (m, 4 H, allylic CH_2), 1.901 (s, 3 H, $COCH_3$), 2.247 (t, 2 H, CH_2COCO, J = 7.3 Hz), 3.929 (t, 2 H, CH_2O, J = 7.3 Hz), 4.61–4.98 (m, 4 H, C=CH_2), 5.106 (br t, 1 H, C-4 vinyl H), 5.58–5.79 (m, 1 H, C-9 vinyl H). This spectrum corresponds closely to the reported[8b] 300-MHz spectrum of natural (–)-**12**. ^{13}C NMR ($CDCl_3$) δ 18.5 (isopropenyl CH_3), 21.0 (acetate CH_3), 23.6 (3-CH_3), 31.3, 31.6, 32.0, 32.0 (C-5,6,7,8), 47.1 (C-2), 62.7 (C-1), 111.6 (isopropenyl CH_2=C), 114.2 (C-9), 126.4 (C-4), 131.1 (C-3), 138.9 (C-10), 147.1 (isopropenyl CH_2=C), 171.0 (C=O).

Upon GLC analysis (6 ft × 0.25 in. column, 10% UCW-98), racemic **14** was found to have the same retention time as the more mobile of the two isomers present in the authentic mixture of isomers. Approximately 2% of the *E* isomer was found to be present in our sample.

Acknowledgment. We thank Ms. Lynne Goswami for preliminary experiments and the National Science Foundation for support of this work. We also thank the Boeing Co. for assistance in the purchase of the Nicolet NT-200 spectrometer.

Registry No. 2a, 83199-83-1; (*E*)-**2b**, 83199-84-2; (*E*)-**2c**, 83207-71-0; **6a**, 83199-86-4; **6b**, 83199-87-5; **6c**, 83199-88-6; **6d**, 83199-89-7; **6e**, 83199-90-0; **6f**, 83199-91-1; **6g**, 83199-92-2; **6h**, 83199-93-3; **7**, 35000-38-5; **8b**, 83199-85-3; **11**, 83199-82-0; **13a**, 6137-08-2; **13b**, 49827-45-4; **13c**, 83199-94-4; **13d**, 2550-26-7; **13e**, 83199-95-5; **13f**, 83199-96-6; **13g**, 83199-97-7; **13h**, 83199-98-8; **13** (R_1 = R_2 = R_4 = H; R_3 = Pr), 110-43-0; (±)-(*Z*)-**14**, 66348-55-8; (*Z*)-**18**, 39149-98-9; (*Z*)-**19**, 83199-99-9; (*Z*)-**21**, 83200-00-4; (*Z*)-**22**, 83200-01-5; **23** (R = THP), 83200-02-6; (±)-(*Z*)-**24a**, 83200-03-7; (±)-(*Z*)-**24b**, 83200-04-8; (±)-(*Z*)-**25a**, 83200-05-9; (±)-(*Z*)-**25b**, 83200-06-0; (2-*tert*-butoxy-2-oxoethyl)triphenylphosphonium chloride, 35000-37-4; triphenylphosphine, 603-35-0; *tert*-butyl chloroacetate, 107-59-5; 3-chloropropanoyl chloride, 625-36-5; (*E*)-crotonyl chloride, 625-35-4; (*E*)-cinnamoyl chloride, 17082-09-6; hexanoyl chloride, 142-61-0; 2-lithio-1,3-dithiane, 36049-90-8; hydrocinnamoyl chloride, 645-45-4; methylenetriphenylphosphorane, 3487-44-3; geranyl chloride, 5389-87-7; geranyl bromide, 6138-90-5; (*Z*)-1-chloro-3,7-dimethyl-2,6-octadiene, 20536-36-1; (*Z*)-1-bromo-3,7-dimethyl-2,6-octadiene, 25996-10-5.

Versatile Route to Substituted Ketones through Charge-Directed Conjugate Addition Reactions

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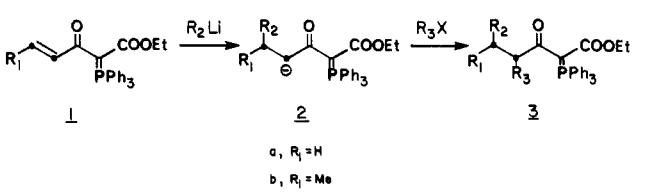
Received July 17, 1981

Charge-directed conjugate addition reactions have been applied to the preparation of highly substituted ketones. Acylphosphoranes resulting from conjugate addition–alkylation reactions are reduced by Al–Hg to β-keto esters, which, upon alkylation and hydrolysis, give ketones in high yields. An application of this methodology to the synthesis of **9**, the defense substance of *L. longipes*, is described.

We have previously described the highly efficient charge-directed conjugate addition reactions of a variety of nucleophiles to unsaturated acyl derivatives of (carboethoxymethylene)triphenylphosphorane **1**.[1] These additions give anionic adducts, **2**, that are readily alkylated by ordinary alkyl halides (Scheme I). The elaborated acyl ylide **3** may then be converted to an ester by heating with an alcohol in the presence of an acid.[1a] In the preceding paper[2] we demonstrated the utility of the *tert*-butyl esters

Scheme I

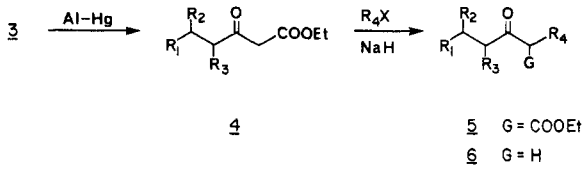


of such ylides in the preparation of methyl ketones through a sequence of manipulations involving decarbalkoxylation of these esters and subsequent hydrolyses of (acylmethylene)triphenylphosphoranes. Ylide manipulations which would lead to more highly substituted ketones would

(1) (a) Cooke, M. P., Jr.; Goswami, R. *J. Am. Chem. Soc.* **1977**, *99*, 642. (b) Cooke, M. P., Jr. *Tetrahedron Lett.* **1979**, 2199.
(2) Cooke, M. P., Jr.; Burman, D. L. *J. Org. Chem.*, preceeding paper in this issue.

0022-3263/82/1947-4963$01.25/0

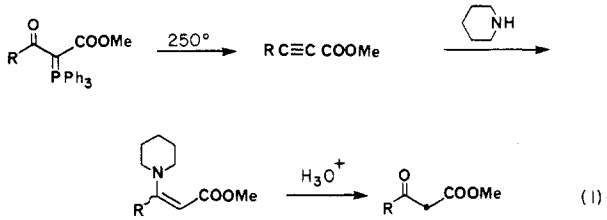
Scheme II



further enhance the utility of our conjugate addition–alkylation methodology. In this paper we describe the facile reduction of (acylcarbethoxymethylene)triphenylphosphoranes to β-keto esters **4** with Al–Hg, thereby allowing execution of the overall transformation shown in Scheme II. Using these transformations, one may obtain highly substituted ketones **6** from the conjugate addition–alkylation reactions of unsaturated ylide **1**.

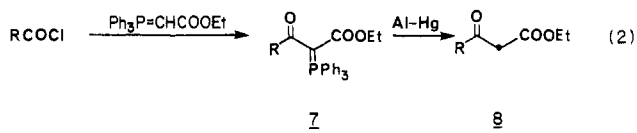
Discussion and Results

Bestmann has previously reported the procedure for the conversion of (acylcarbalkoxymethylene)phosphoranes to β-keto esters shown in eq 1.[3] In addition to requiring



(1)

several operations, the pyrolytic conversion required in the first step makes this process of limited utility. We have investigated the reductive removal of triphenylphosphine from ylides such as **3** as a means of directly transforming these derivatives to β-keto esters, which may then be used for the preparation of substituted ketones as shown in Scheme II. Reductions of diacylsulfuranes[4a] and certain (acylalkylidene)phosphoranes[4b] with Zn–HOAc have been reported, but this method gave poor results with our (acylcarbethoxymethylene)phosphoranes.[5] We have found, however, that the desired reductive removal of triphenylphosphine may readily be accomplished with Al–Hg.[6] Reductions may be conducted in THF, at 15–25 °C, by stirring solutions of the ylide with excess Al–Hg, with periodic additions of small amounts of water and either HCl or trifluoroacetic acid (TFA). Examples of typical reductions of model ylides **7** are shown in Table I. These ylides, prepared by treating the corresponding acid chloride with (carbethoxymethylene)triphenylphosphorane (eq 2), gave corresponding β-keto esters **8** in

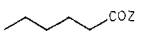
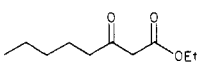
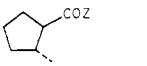
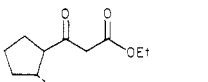
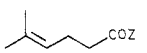
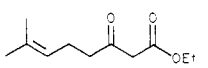
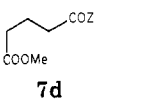
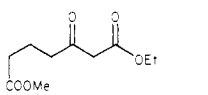
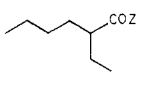
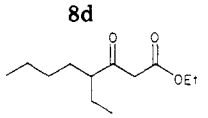


(2)

high yields.

The reductive removal of triphenylphosphine does not occur in the absence of water or with the use of more weakly acidic acetic acid as the proton donor. These reductions presumably occur through the phosphonium salts formed by protonation of the weakly basic ylide carbon in **3**. By gradually adding the required acid, mild reaction conditions are maintained, and no damage results to either the product β-keto esters or to the olefin and ester functionality found in **7c** and **7d** (entries 3 and 4).

Table I. Reduction of Acyl Ylides with Al–Hg[a]

entry	ylide 7	product 8[b]	% yield[c]
1	 **7a**	 **8a**	90[d]
2	 **7b**	 **8b**	94
3	 **7c**	 **8c**	81
4	 **7d**	 **8d**	81
5	 **7e**	 **8e**	93

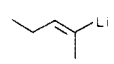
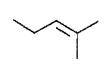
[a] Reductions were typically conducted on 1.0 mmol of ylide in wet THF at 15–25 °C with excess Al–Hg and the periodic addition of either TFA or HCl. [b] Purified by preparative layer chromatography and bulb-to-bulb distillation. [c] Isolated yields. [d] Identified by comparison with an authentic sample.

The monoalkylation of resulting β-keto esters proceeds smoothly under the conditions developed by Stotter and Hill[7] where alkyl iodides or benzylic and allylic bromides are used to alkylate the sodium salts of the β-keto esters in THF at 25 °C. The monoalkylated β-keto esters are in most cases readily freed of small amounts of dialkylated and unalkylated byproducts by preparative thick-layer chromatography (PTLC). Only in alkylations using methyl iodide is a notable increase in dialkylation observed (approximately 10%) along with an attending increased difficulty in the removal of structurally similar byproducts by chromatography. Decarbethoxylations of substituted β-keto esters are readily affected with $Ba(OH)_2$ by using a modification of the method of Johnson.[8] Higher yields were obtained by shortening hydrolysis times to 2 h. It is also noteworthy that nearly all of the product ketone is present prior to the acidification of the reaction mixtures, suggesting that decarbethoxylation does not, for the most part, proceed via the β-keto carboxylic acid salt.

The application of the charge-directed conjugate addition approach to the preparation of substituted ketones, through the reactions outlined in Schemes I and II, is illustrated in Table II. The reaction sequence shown in entry **2** is typical, where **1** (R_1 = H), in THF, gave after treatment with PhLi and EtI substituted ylide **3b** in 90% yield. The reduction of **3b** with Al–Hg in wet THF in the presence of TFA gave the corresponding β-keto ester **4b** (77%) which, upon alkylation in THF with NaH and 1.05 equiv of *n*-BuI at 25 °C for 24 h gave **5b** in 91% yield after

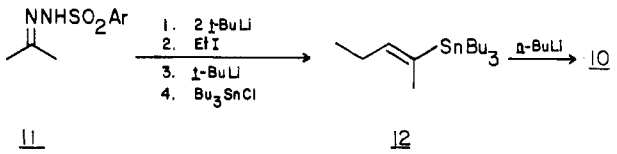
(3) Bestmann, H. J.; Geismann, C. *Justus Liebigs Ann. Chem.* **1977**, 282.
(4) (a) Yamato, M. *J. Chem. Soc., Chem. Commun.* **1975**, 289. (b) Bestman, H. J.; Arnason, B. *Chem. Ber.* **1962**, *95*, 1513.
(5) For the electrolysis and hydrolysis of phosphonium ylides see: Bestmann, H. J.; Zimmermann, R. In "Carbon–Carbon Bond Formation"; Augustin, R. L., Ed.; Marcel Dekker: New York, 1979; Vol. 1, Chapter 3.
(6) Corey, E. J.; Chaykovsky, M. *J. Am. Chem. Soc.* **1964**, *86*, 1639.
(7) Stotter, P. L.; Hill, K. A. *Tetrahedron Lett.* **1972**, 4067.
(8) Brady, S. F.; Ilton, M. A.; Johnson, W. S. *J. Am. Chem. Soc.* **1968**, *90*, 2882.

Table II. Ketones from Unsaturated Acylphosphoranes (Scheme I and II)

entry	R_1 for 1	R_2Li	R_3X	R_4X	series	3-6 R_1	3-6 R_2	3-6 R_3	3-6 R_4	% yield[a] 3	4	5	6
1	H	BuLi	MeI	BnBr	a	H	Bu	Me	Bn	95	92	72	93
2	Me	PhLi	EtI	BuI	b	Me	Ph	Et	Bu	90[b]	77	91	95
3	H		MeI	MeI	c	H		Me	Me	71	84	85	91

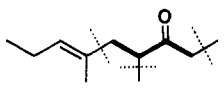
[a] Isolated yields. [b] Obtained as a mixture of diastereoisomers. The major isomer (mp 128-130 °C) could be separated by chromatography or crystallization and was used for subsequent reactions.

Scheme III

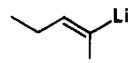


purification by chromatography. Hydrolysis with $Ba(OH)_2$ gave a 95% yield of pure **6b**.

The final entry in Table II illustrates the synthetic utility of this sequence in a stereoselective synthesis of 4,6-dimethyl-(*E*)-6-nonen-3-one (**9**), the defense substance



9



10

of *L. longipes*.[9] By recognition of the structural unit central to our methodology (heavy lines), it can be seen that construction of **9** requires the addition of lithium reagent **10** to ylide **1a**, alkylation of the resulting ylide anion with methyl iodide, and conversion of the ylide moiety to the desired ethyl ketone unit present in **9** through Al–Hg reduction, methylation, and decarbethoxylation of the resulting β-keto ester. The required nucleophile, (*Z*)-(2-penten-2-yl)lithium (**10**), was prepared as shown in Scheme III by using modifications of the method of Chamberlin and Bond.[10] The trisylhydrazone of acetone, **11**, in THF was treated with 2.2 equiv of *t*-BuLi[11] at −78 °C, and the resulting dianion was C-alkylated with EtI over 3.5 h. The use of *sec*-BuLi and shorter reaction times resulted in incomplete alkylation. Treatment with additional *t*-BuLi at −78 °C followed by warming the new dianion to 0 °C gave, after vigorous nitrogen evolution, a complex mixture containing **10**. The conversion of **10** to vinylstannane **12** was accomplished by treating the mixture with Bu_3SnCl at −78 °C. Attempted stannation at 0 °C led to complex mixtures. The need for the use of a low reaction temperature for successful stannations of this type has been previously noted.[12] Vinylstannane **12**, obtained in 56% yield, was purified by distillation and reconverted to the desired lithium reagent **10** by transmetalation with a deficiency of *n*-BuLi in THF.[13] The conjugate addition of **10** to **1a** and the alkylation of the resulting ylide anion with methyl iodide gave **3c** in 71% yield. Reduction of **3c** with Al–Hg (84%), alkylation of the corresponding β-keto ester **4c** with NaH and CH_3I (85%), and $Ba(OH)_2$ hydrolysis (91%) gave the racemic defense substance **9**, whose NMR, IR, and mass spectra closely correspond to those previously reported for both the natural and synthetic substances.[8]

In summary, unsaturated acyl ylide **1** provides a useful synthon ($R_1C^+HC^-H_2COC^-H_2$) for the preparation of highly substituted ketones through the transformations shown in Schemes I and II. Work is in progress on other ylide transformations which will further increase the utility of the conjugate addition–alkylation reactions of unsaturated acyl ylides.

Experimental Section

General Methods. Infrared spectra were recorded as films (neat) or as solutions ($CHCl_3$, 0.1 mm) with a Beckman AccuLab 1 spectrometer. ^1H NMR spectra were recorded at 60 MHz by using a Varian EM-360 spectrometer, at 100 MHz by using a JEOL MH-100 spectrometer, or at 200 MHz with a Nicolet NT-200 spectrometer. Chemical shifts are reported in parts per million (δ) relative to internal tetramethylsilane. Analytical thin-layer chromatography (TLC) was performed with Merck silica gel 60 F-254 plates. Preparative thick-layer chromatography (PTLC) was performed on 20 × 20 cm plates coated with a 1–2-mm layer of Merck silica gel 60 PF-254. Baker 60–200-mesh silica gel powder was used for column chromatography. Bulb-to-bulb distillations of the Kugelrohr type were conducted at the air oven temperatures and pressures cited. Melting points are uncorrected. Analyses were performed by Galbraith Laboratories, Inc.

Alkyllithium reagents (*n*-BuLi in hexane and PhLi in benzene–diethyl ether) were obtained from Aldrich Chemical Co. and titrated[14] prior to use. All reactions involving air-sensitive materials were conducted under an argon atmosphere. Extracts were routinely dried over Na_2SO_4. Tetrahydrofuran (THF) was distilled from sodium benzophenone ketyl prior to use.

Ethyl 3-Oxo-2-(triphenylphosphoranylidene)octanoate (7a). A solution containing 6.96 g (20 mmol) of (carbethoxymethylene)triphenylphosphorane[15] in 50 mL of dry benzene was cooled to 6 °C and was treated with stirring over 2 min with a solution containing 1.40 mL (10 mmol) of hexanoyl chloride in 8 mL of benzene. The mixture was stirred at 25 °C for 15 min, treated with 50 mL of diethyl ether to aid in the precipitation of the hydrochloride salt of (carbethoxymethylene)triphenylphosphorane, and filtered. Concentration of the filtrate gave an oil which crystallized from ethyl acetate–hexane, giving 3.41 g (76%) of **7a** after several crops: mp 72–73 °C; IR ($CHCl_3$) 3000, 2960, 2940, 1640, 1550, 1435, 1370, 1290, 1100, 1087 cm^{-1}; ^1H NMR (CCl_4, 60 MHz) δ 0.68 (t, 3 H, OCH_2CH_3), 0.90 (t, 3 H, CH_3), 1.05–1.95 (br, 6 H, CH_2), 2.78 (t, 2 H, CH_2CO), 3.93 (q, 2 H, OCH_2), 7.1–8.0 (m, 15 H, Ph). Anal. Calcd for $C_{28}H_{31}O_3P$: C, 75.32; H, 7.00. Found: C, 75.27; H, 7.07.

In like manner, the following ylides were prepared.

7b: 66%; mp 183–185 °C (95% EtOH); IR ($CHCl_3$) 3000, 2950, 1645, 1540, 1432, 1385, 1310, 1285, 1100, 1087 cm^{-1}; ^1H NMR

(9) Isolation and synthesis: Jones, T. H.; Conner, W. E.; Kluge, A. F.; Eisner, T.; Meinwald, J. *Experientia* **1976**, *32*, 1234. A less stereoselective synthesis has also been reported: Vig, O. P.; Sharma, S. D.; Kumar, S. D.; Handa, V. K. *Indian J. Chem., Sect. A* **1978**, *16B*, 114.

(10) Chamberlin, A. R.; Bond, F. T. *Synthesis* **1979**, 44.

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(13) A deficiency of *n*-BuLi is required to ensure the presence of only the desired lithium reagent **10**. The presence of any remaining BuLi leads to a butyl adduct which could not be separated from **3c** by TLC but whose presence is evidenced by a peak at δ 1.27 in the NMR spectrum of the reaction product.

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($CDCl_3$, 60 MHz) δ 0.67 (t, 3 H, OCH_2CH_3, J = 7.5 Hz), 1.00 (d, 3 H, CH_3, J = 6 Hz), 1.40–2.60 (br, 8 H, CH_2 and CH), 3.80 (q, 2 H, OCH_2CH_3), 7.4–8.1 (m, 15 H, Ph). Anal. Calcd for $C_{29}H_{31}O_3P$: C, 75.96; H, 681. Found: C, 76.20; H, 7.10.

7c: mp 92.5–93.5 °C (EtOAc–hexane); IR ($CHCl_3$) 3000, 1650, 1550, 1435, 1370, 1300, 1100, 1085 cm^{-1}; ^1H NMR (CCl_4, 60 MHz) δ 0.67 (t, 3 H, OCH_2CH_3), 1.57, 1.65 (s, 6 H, vinyl CH_3), 2.27 (t, 2 H, CH_2CH=), 2.6–3.0 (m, 2 H, CH_2CO), 3.68 (q, 2 H, OCH_2), 5.21 (t, 1 H, C=CH), 7.4–8.0 (m, 15 H, Ph). Anal. Calcd for $C_{29}H_{31}O_3P$: C, 75.96; H, 6.81. Found: C, 76.17; H, 7.00.

7d: 75%; mp 96–97 °C; IR ($CHCl_3$) 3000, 1722, 1650, 1550, 1433, 1300, 1100, 1088 cm^{-1}; ^1H NMR (CCl_4, 60 MHz) ^1H NMR (CCl_4, 60 MHz) δ 0.67 (t, 3 H, OCH_2CH_3, J = 7 Hz), 1.75–2.44 (m, 4 H, CH_2), 2.90 (t, 2 H, CH_2COC=P, J = 7 Hz), 3.63 (s, 3 H, OCH_3), 3.73 (t, 2 H, OCH_2), 7.4–8.0 (m, 15 H, Ph). Anal. Calcd for $C_{28}H_{29}O_5P$: C, 70.58; H, 6.13. Found: C, 70.76; H, 6.20.

7e: 90%; mp 116.5–118.5 °C; IR ($CHCl_3$) 3000, 2960, 2930, 1650, 1540, 1432, 1300, 1100, 1082 cm^{-1}; ^1H NMR ($CDCl_3$, 100 MHz) δ 0.70 (t, 3 H, OCH_2CH_3, J = 8 Hz), 0.88 (t, 6 H, CH_2CH_3, J = 8 Hz), 1.0–2.0 (m, 8 H, CH_2), 3.8–4.1 (br, 1 H, CHCO), 3.92 (q, 2 H, OCH_2), 7.6–8.2 (m, 15 H, Ph). Anal. Calcd for $C_{30}H_{35}O_3P$: C, 75.93; H, 7.43. Found: C, 75.97; H, 7.53.

Reduction of 7 with Al–Hg.[6] Typical Procedure. Ethyl 4-Ethyl-3-oxooctanoate (8e). A 25-mL flask was charged with aluminum chips (5 mm × 5 mm) cut from 360 mg (13.3 mmol) of aluminum foil. A 2% solution of $HgCl_2$ (15 mL) was added, and the mixture was stirred by hand for 1 min whereupon the aqueous phase was removed by an aspirated pipet. The chips were washed successively with five 20-mL portions of absolute EtOH, five 15-mL portions of anhydrous diethyl ether, and five 15-mL portions of dry THF. After decantation of the last portion of THF, 20 mL of fresh THF and 474 mg (1.0 mmol) of **7e** were added. The stirred mixture was then treated with 190 μL of TFA and 400 μL of water. After the mixture was stirred for 40 min, an additional 95 μL of TFA and 260 μL of water were added. Stirring was continued for 40 min after which time 400 μL of water was added followed by 15 min of additional stirring. The solution phase was separated from the remaining aluminum chips which were washed with an additional small portion of THF. The combined solutions were concentrated in vacuo (≤20 °C), and the residue was treated with 15 mL of water. The mixture was made acidic by the addition of 4 N HCl, saturated with NaCl, and extracted with five 20-mL portions of pentane. (The more polar keto diester **8d** was extracted with 1:1 pentane–diethyl ether.) Concentration of the extracts gave an oil which, upon purification by PTLC (silica gel, CH_2Cl_2, R_f 0.4), provided pure **8e**. Bulb-to-bulb distillation (160 °C, 4 mm) gave 200 mg (93%) of **8e** as an oil: IR (neat) 2970, 2940, 1742, 1710, 1230 cm^{-1}; ^1H NMR (CCl_4, 60 MHz, an approximately 4:1 mixture of keto–enol forms) δ 0.67–1.10 (m, 6 H, CH_2CH_3), 1.27 (t, 3 H, OCH_2CH_3), 1.1–2.2 (br, 8 H, CH_2), 2.2–2.7 (br, 1 H, CHCO), 4.10 (q, 2 H, OCH_2), 4.80 (s, CH=COH proton of enol form), 12.0 (s, CH=COH proton of enol form). Anal. Calcd for $C_{12}H_{22}O_3$: C, 67.26; H, 10.35. Found: C, 67.07; H, 10.47.

In a similar manner the following new β-keto esters cited in Table I were prepared.

8b: IR (neat) 2962, 1742, 1708, 1313, 1235, 1150 cm^{-1}; ^1H NMR (CCl_4, 60 MHz) δ 1.05 (d, 3 H, CH_3, J = 6 Hz), 1.30 (t, 3 H, OCH_2CH_3, J = 7 Hz), 1.5–2.2 (br, 7 H, ring CH_2, CH), 2.2–2.8 (br, 1 H, CHCO), 3.43 (s, 2 H, CH_2CO), 4.27 (q, 4 H, OCH_2), 5.07 (s, enolic CH=C). Anal. Calcd for $C_{11}H_{18}O_3$: C, 66.64; H, 9.15. Found: C, 66.69; H, 9.06.

8c: IR (neat) 2975, 2925, 1742, 1712, 1311, 1235 cm^{-1}; ^1H NMR (CCl_4, 100 MHz) δ 1.27 (t, 3 H, OCH_2CH_3, J = 7.5 Hz), 1.60 (s, 3 H, $C=CCH_3$), 1.66 (s, 3 H, $C=CCH_3$), 2.0–2.6 (m, 4 H, $COCH_2CH_2$), 3.26 (s, 2 H, CH_2CO), 4.14 (q, 2 H, OCH_2), 4.85 (s, enolic CH=C), 5.00 (br t, 1 H, CH=C). Anal. Calcd for $C_{11}H_{18}O_3$: C, 66.64; H, 9.15. Found: C, 66.42; H, 9.26.

8d: IR (neat) 3000, 2970, 1732, 1710, 1370, 1320, 1255, 1177 cm^{-1}; ^1H NMR (CCl_4, 100 MHz) δ 1.28 (t, 3 H, OCH_2CH_3, J = 7.5 Hz), 1.60–2.05 (m, 2 H, CH_2), 2.29 (t, 2 H, CH_2COO, J = 7 Hz), 2.48 (t, 2 H, CH_2CO, J = 7 Hz), 3.30 (s, 2 H, CH_2CO), 3.60 (s, 3 H, OCH_3), 4.10 (q, 2 H, OCH_2), 4.87 (s, enolic CH=C). Anal. Calcd for $C_{10}H_{16}O_5$: C, 55.55; H, 7.46. Found: C, 55.25; H, 7.51.

Ethyl 3-Oxo-2-(triphenylphosphoranylidene)-4-pentenoate (1a). A solution containing 69.6 g (0.2 mol) of (carbethoxymethylene)triphenylphosphorane[15] in 400 mL of dry benzene was cooled to 5 °C and with stirring treated with a solution of 9.5 mL (0.1 mol) of 3-chloropropanoyl chloride in 80 mL of benzene. After 10 min the mixture was stirred at 20 °C for an additional 15 min, diluted with 400 mL of diethyl ether, and filtered to remove the phosphonium salt. The oil obtained after solvent removal crystallized from EtOAc–hexane, giving 35 g of ethyl 5-chloro-3-oxo-2-(triphenylphosphoranylidene)pentanoate. This material was dissolved in 300 mL of MeOH and treated with 200 mL of MeOH in which 4.6 g (0.2 mol) of sodium had previously been dissolved. The mixture was stirred at 25 °C, and the dehydrochlorination was followed by TLC (silica gel, 3:1 CH_2Cl_2–EtOAc). After the consumption of the chloride was complete, the solvent was quickly removed under reduced pressure. The solution temperature was allowed to remain below 20 °C during the evaporation. The residue was treated with water and extracted with two portions of CH_2Cl_2. The oil obtained after concentration of the dried extracts was dissolved in a small volume of CH_2Cl_2 and passed through a short column of silica gel to remove nonmobile, colored material. Concentration of the eluent gave an oil which crystallized from EtOH–hexane, giving 22.5 g (70%) of **1a**. The yield may be raised to 85% by reworking the crystallization filtrate. An analytical sample was prepared by PTLC and recrystallization: mp 111 °C; IR ($CHCl_3$) 3000, 1655, 1645, 1630, 1525, 1440, 1410, 1368, 1325, 1280, 1105, 1090 cm^{-1}; ^1H NMR ($CDCl_3$, 100 MHz) δ 0.70 (t, 3 H, OCH_2CH_3, J = 7.2 Hz), 3.92 (q, 2 H, OCH_2), 5.64 (dq, 1 H, $H_AH_BC=CH_XCO$, J_{AX} = 10.5 Hz, $J_{AB} \approx J_{PH}$ = 2.6 Hz), 6.32 (dd, 1 H, $H_AH_BC=CH_XCO$, J_{BX} = 17.5 Hz), 7.4–8.1 (m, 16 H, Ph and CH_XCO).

Anal. Calcd for $C_{25}H_{23}O_3P$: C, 74.61; H, 5.76. Found: C, 74.61; H, 5.73.

Ethyl 3-Oxo-2-(triphenylphosphoranylidene)-4-hexenoate (1b). A solution of 480 μL (5.0 mmol) of crotonoyl chloride in 5 mL of benzene was added to a stirred solution of 3.48 g (10.0 mmol) of (carbethoxylmethylene)triphenylphosphorane in 20 mL of benzene cooled to 10 °C. The mixture was warmed to 20 °C, stirred for 15 min, diluted with diethyl ether (25 mL), and filtered, and the filtrate was concentrated in vacuo. Crystallization of the residue from ethyl acetate gave 1.49 g (86%) of **1b**: mp 146 °C (lit.[16] mp 146–147 °C); IR ($CHCl_3$) 3000, 1645, 1520, 1435, 1370, 1290, 1270, 1100, 1087 cm^{-1}; ^1H NMR ($CDCl_3$, 100 Mz) δ 0.68 (t, 3 H, OCH_2CH_3, J = 8 Hz), 1.90 (dd, 3 H, CH_3CH=C, J = 7.0, 1.3 Hz), 3.91 (q, 2 H, OCH_2), 6.93 (dq, 1 H, $CH_2CH_A=CH_B$, J_{AB} = 15.5 Hz, $J_{H_ACH_3}$ = 6.7 Hz), 7.6–8.1 (m, 16 H, Ph and CH_BCO).

Ethyl 4-Methyl-3-oxo-2-(triphenylphosphoranylidene)-nonanoate (3a). A solution containing 322 mg (0.80 mmol) of **1a** in 6 mL of THF was cooled to −78 °C and treated, while being stirred, with 0.57 mL (0.89 mmol) of 1.57 N *n*-BuLi solution. The dark yellow solution was stirred for 10 min at −78 °C and then 5 min at 0 °C. Methyl iodide (150 μL, 2.4 mmol) was added, and the mixture was stirred at 20 °C until the color was discharged (5 min). Solvent was removed in vacuo and PTLC of the residue (10:1 CH_2Cl_2–EtOAc) gave 360 mg (95%) of **3a** as an oil which solidified. Recrystallization from EtOAc–hexane gave crystalline **3a**: mp 101–103 °C; IR ($CHCl_3$) 3000, 3060, 3030, 1650, 1350, 1433, 1295, 1100, 1082 cm^{-1}; ^1H NMR (CCl_4, 100 MHz) δ 0.66 (t, 3 H, OCH_2CH_3, J = 8 Hz), 0.88 (t, 3 H, CH_3CH_2, J = 8 Hz), 1.00 (d, 3 H, CH_3CH, J = 8 Hz), 1.05–1.80 (br, 8 H, CH_2), 3.5–4.0 (br, 1 H, CHCO), 3.68 (q, 2 H, OCH_2), 7.0–8.0 (m, 15 H, Ph). Anal. Calcd for $C_{30}H_{35}O_3P$: C, 75.93; H, 7.43. Found: C, 75.71; H, 7.46.

By use of a similar procedure, treatment of **1b** (1.0 mmol) with PhLi (1.1 equiv; 3 min at −78 °C, 8 min at 0 °C) and EtI (1.85 equiv, 25 °C, 8 h) gave after PTLC (13:1 CH_2Cl_2–EtOAc) **3b**: 90% yield; mp 128–130 °C (from EtOAc–hexane, major diastereoisomer); IR ($CHCl_3$) 3000, 2700, 1650, 1440, 1380, 1300, 1100, 1090 cm^{-1}; ^1H NMR (CCl_4, 60 MHz, mixture of diastereoisomers) δ 0.67 (br t, 3 H, OCH_2CH_3), 1.03 (br d, 3 H, CH_3CH), 0.9–1.6 (br, 5 H, CH_3CH_2), 2.4–2.9 (br, 1 H, $CHCH_3$), 3.58 (q, 2 H, OCH_2), 3.4–4.4 (br, 1 H, CHCO), 7.00 (s, 5 H, Ph), 7.2–7.8 (m, 15 H, PhP). Anal. Calcd for $C_{34}H_{35}O_3P$: C, 78.14; H, 6.75. Found: C, 78.30; H, 6.87.

Ethyl 4-Methyl-3-oxononanoate (4a). By use of the procedure cited above for the preparation of **8e**, the reduction of 474 mg (1.0 mmol) of **3a** with Al–Hg gave, after bulb-to-bulb distil-

(16) Gough, S. T. D.; Trippett, S. *J. Chem. Soc.* **1962**, 2333.

lation (160 °C, 20 mm), 197 mg (92%) of **4a**: IR (neat) 2960, 2930, 1740, 1706, 1227 cm^{-1}; ^1H NMR (CCl_4, 100 MHz) δ 0.90 (t, 3 H, CH_3CH_2) 1.04, 1.06 (2 d, 3 H, CH_3CH of keto and enol form), 1.2–1.68 (m, 11 H, OCH_2CH_3 and CH_2), 2.10, 2.60 (2 m, 1 H, CHCO of enol and keto form, respectively), 2.38 (s, 1 H, CH_2CO), 4.20, 4.22 (2 q, 2 H, OCH_2, keto and enol form), 4.94 (s, CH=C of enol). Anal. Calcd for $C_{12}H_{22}O_3$: C, 67.26; H, 10.35. Found: C, 67.12; H, 10.38.

Ethyl 4-Ethyl-3-oxo-5-phenylhexanoate (4b). By use of the procedure cited above, 522 mg (1.0 mmol) of **3b** upon reduction with Al–Hg gave, after bulb-to-bulb distillation, 202 mg (77%) of **4b**: IR (neat) 2980, 1740, 1707, 1230, 1150, 1030 cm^{-1}; ^1H NMR (CCl_4, 100 MHz, mixture of diastereoisomers) δ 0.6–1.0 (2 t, 3 H, CH_3CH_2), 1.1–1.5 (m, 11 H, CH_3CH, CH_3CH_2 and OCH_2CH_3), 2.7–3.1 (m, 2 H, CHCHCO), 3.32 (s, 2 H, $COCH_2$), 4.14, 4.16 (2 q, 2 H, OCH_2), 5.06 (s, CH=C of enolic form), 7.26 (m, 5 H, Ph). Anal. Calcd for $C_{16}H_{22}O_3$: C, 73.25; H, 8.45. Found: C, 73.15; H, 8.58.

Ethyl 2-Benzyl-4-methyl-3-oxononanoate (5a). A stirred mixture containing 90 mg (2.05 mmol) of 55% NaH in 5 mL of THF was treated dropwise with a solution of 430 mg (2.0 mmol) of **4a** in 2 mL of THF. After being stirred at 25 °C for 0.5 h, the homogeneous mixture was treated with 250 μL (2.12 mmol) of benzyl bromide and stirred for 22 h at 25 °C. The mixtures was concentrated in vacuo and treated with water. The mixture was made acidic with 4 N HCl and extracted twice with 20-mL portions of CH_2Cl_2. Concentration of the dried extracts, PTLC (CH_2Cl_2), and bulb-to-bulb distillation (160 °C, 0.5 mm) gave 219 mg (72%) of **5a** as an oil: IR (neat) 2940, 1740, 1710, 1250, 1200, 1160 cm^{-1}; ^1H NMR (CCl_4, 100 MHz) δ 0.84 (t, 3 H, CH_3CH_2), 1.02 (d, 3 H, CH_3CH, J = 7 Hz), 1.22 (t, 3 H, OCH_2CH_3, J = 7 Hz), 1.0–1.4 (br, 8 H, CH_2), 2.54 (m, 1 H, CHCO), 3.12 (d, 2 H, CH_2Ph), 3.80 (m, 1 H, CHCOO), 4.16 (q, 2 H, OCH_2), 7.24 (s, 5 H, Ph). Anal. Calcd for $C_{19}H_{28}O_3$: C, 74.96; H, 9.27. Found: C, 75.11; H, 9.46.

Ethyl 2-Butyl-4-ethyl-3-oxo-5-phenylhexanoate (5b). By use of the procedure described above, 524 mg (2.0 mmol) of **4b** was alkylated with *n*-BuI (2.1 mmol, 58 °C, 48 h), giving, after PTLC, 580 mg (91%) of **5b** as an oil. An analytical sample was obtained by bulb-to-bulb distillation (160 °C, 1 mm): IR (neat) 2960, 2940, 2880, 1740, 1708, 1450, 1180 cm^{-1}; ^1H NMR (CCl_4, 100 MHz) δ 0.68 (t, 3 H, CH_3CH_2CH), 0.94 (t, 3 H, CH_3CH_2), 1.0–2.0 (m, 11 H, CH_2 and CH_3CHPh), 1.30 (t, 3 H, CH_3CH_2O, J = 7 Hz), 2.8–3.5 (m, 3 H, CH), 4.24 (q, 2 H, OCH_2), 7.26 (br s, 5 H, Ph). Anal. Calcd for $C_{20}H_{30}O_3$: C, 75.43; H, 9.50. Found: C, 75.41; H, 9.59.

4-Methyl-1-phenylnonan-3-one (6a). A mixture containing 304 mg (1.0 mmol) of **5a**, 630 mg (2 mmol) of $Ba(OH)\cdot 8H_2O$, 1 mL of EtOH, and 2 mL of water was heated at reflux with stirring under an argon atmosphere for 2 h. After cooling, the mixture was diluted with 10 mL of water and overlaid with 10 mL of pentane, and with stirring 4 N HCl was added until the precipitate dissolved. The aqueous phase was extracted twice again with pentane. Concentration of the combined extracts gave an oil which, upon bulb-to-bulb distillation (175 °C, 2 mm), gave 215 mg (93%) of **6a**. An analytical sample was obtained by PTLC (CH_2Cl_2) and bulb-to-bulb distillation: IR (neat) 2960, 2930, 1703, 1450 cm^{-1}; ^1H NMR (CCl_4, 100 MHz) δ 0.88 (t, 3 H, CH_3CH_2), 2.00 (d, 3 H, CH_3CH, J = 7 Hz), 1.08–1.80 (br, 8 H, CH_2), 2.40 (m, 1 H, CHCO), 2.56–3.00 (m, 4 H, CH_2CH_2CO), 7.20 (s, 5 H, Ph). Anal. Calcd for $C_{16}H_{24}O$: C, 82.70; H, 10.41. Found: C, 82.52; H, 10.57.

3-Ethyl-2-phenylnonan-4-one (6b). In a manner similar to that described above for the decarbethoxylation of **5a**, 318 mg (1.0 mmol) of **5b** gave 234 mg (95%) of **6b** after bulb-to-bulb distillation (160 °C, 5 mm). An analytical sample was obtained by PTLC (CH_2Cl_2) and redistillation: IR (neat) 2960, 2940, 1708, 1450 cm^{-1}; ^1H NMR (CCl_4 100 MHz) δ 0.68, (t, 3 H, CH_3CH_2CH), 0.92 (t, 3 H, $CH_3CH_2CH_2$), 1.14 (d, 3 H, CH_3CH, J = 7 Hz), 1.0–1.8 (br, 8 H, CH_2), 2.36 (t, 2 H, CH_2CO, J = 8 Hz), 2.60 (m, 1 H, CHCO), 2.92 (m, 1 H, CHPh), 7.28 (m, 5 H, Ph). Anal. Calcd for $C_{17}H_{26}O$: C, 82.87; H, 10.64. Found: C, 82.69; H, 10.47.

(*E*)-(2-Penten-2-yl)tributylstannane (12). A solution containing 10.14 g (30 mmol) of acetone 2,4,6-triisopropylbenzenesulfonylhydrazone[17] in 80 mL of dry THF was cooled to −78 °C and treated, while being stirred, with 66 mL (66 mmol) of 1.0 N *t*-BuLi in pentane over 10 min. The mixture was stirred for an additional 20 min, and 3.6 mL (44 mmol) of EtI was slowly added. The solution was stirred at −78 °C for 3.5 h and then treated with 42 mL of *t*-BuLi. After being stirred for 0.5 h, the mixture was stirred in an ice–water bath for 5 min beyond the point of cessation of N_2 evolution (approximately 10 min total), and the orange slurry was recooled immediately to 78 °C. A solution of Bu_3SnCl in 45 mL of hexane was added to the stirred mixture, and after 10 min at −78 °C, the cooling bath was removed, and the mixture was allowed to warm to 20 °C where stirring was continued for 0.5 h. The solvent was removed under reduced pressure, and the residue was treated with water and extracted twice with pentane. The combined extracts were washed successively with two portions of water, 1 N NaOH, water, and brine. The dried extract was filtered through Celite and concentrated. The residue gave upon distillation 6.06 g (56%) of **12**: bp 124 °C (1.5 mm); IR (neat) 2960, 2925, 1610, 1460, 1070, 960 cm^{-1}; ^1H NMR (CCl_4, 100 MHz) δ 0.90 (m, 12 H, CH_3), 1.42 (m, 18 H, CH_2), 1.82 (s, 3 H, C=CCH_3), 2.10 (m, 2 H, CH_2C=C), 5.50 (br t, 1 H, C=CH). Anal. Calcd for $C_{17}H_{36}Sn$: C, 56.85; H, 10.10. Found: C, 56.58; H, 10.01.

Ethyl 4,6-Dimethyl-3-oxo-2-(triphenylphosphoranylidene)-(*E*)-6-nonenoate (3c). A solution of (*Z*)-2-penten-2-yllithium (**10**) was prepared by cooling a solution of 1.145 g (3.19 mmol) of **12** in 6 mL of THF to −78 °C and adding 2.0 mL (3.0 mmol) of a 1.5 N *n*-BuLi solution. The mixture was stirred for 12 min at −5–0 °C and immediately recooled to −78 °C. This solution was added by cannula to a stirred solution containing 1.21 g (3.0 mmol) of **1a** in 15 mL of THF at −78 °C. The mixture was stirred for 10 min at −78 °C and then for 10 min at 0 °C whereupon 380 μL (6.0 mmol) of MeI was added. The mixture was stirred overnight at 20 °C and then concentrated in vacuo. The residue was dissolved in a small amount of CH_2Cl_2 and chromatographed on a 35-cm column of silica gel (CH_2Cl_2 followed by 10:1 CH_2Cl_2–EtOAc), giving 1.04 g (71%) of **3c** as a viscous oil: IR ($CHCl_3$) 2990, 1650, 1550, 1485, 1440, 1380, 1300, 1105, 1090 cm^{-1}; ^1H NMR ($CDCl_3$, 200 MHz) δ 0.65 (t, 3 H, OCH_2CH_3, J = 7.2 Hz), 0.92 (t, 3 H, CH_3CH_2, J = 7.4 Hz), 0.99 (d, 3 H, CH_3CH, J = 6.8 Hz), 1.63 (s, 3 H, C=CCH_3), 1.85 (dd, 1 H, CH_2CH, J_{AB} = 13 Hz, J_{AX} = 8.2 Hz), 1.99 (m, 2 H, CH_2CH=C, J_{AB} = 13.2 Hz, J_{AX} = 8.2 Hz), 2.42 (dd, 1 H, CH_2CH, J_{BX} = 6.2 Hz), 3.71 (q, 2 H, OCH_2), 4.08 (m, 1 H, CHCO), 5.13 (t, 1 H, C=CH, J = 7.0 Hz), 7.32–7.72 (m, 15 H, Ph).

Ethyl 4,6-Dimethyl-3-oxo-(*E*)-6-nonenoate (4c). The typical procedure previously described for the preparation of **8e** was followed with the exception that the temperature of the reaction mixture was kept at 10 °C during the reduction. The reduction of 650 mg (1.34 mmol) of **3c** with Al–Hg gave, after PTLC (CH_2Cl_2) and bulb-to-bulb distillation (140 °C, 1 mm), 254 mg (84%) of **4c**: IR (neat) 2970, 1743, 1707, 1645, 1625, 1307, 1232, 1150, 1030 cm^{-1}; ^1H NMR (CCl_4, 100 MHz) δ 0.92, 0.94 (2 t, 3 H, CH_3CH_2, keto and enol form, J = 8 Hz), 1.07, 1.10 (2 d, 3 H, CH_3CH, keto and enol form, J = 6 Hz), 1.32 (t, 3 H, OCH_2CH_3, J = 8 Hz), 1.64 (s, 3 H, C=CCH_3), 1.8–2.6 (m, 4 H, allylic CH_2), 2.84 (m, 1 H, CHCO), 3.38 (s, 2 H, $COCH_2$, keto form), 4.23 (q, 2 H, OCH_2), 4.96 (s, CH=C—O, enol form), 5.22 (br t, 1 H, C=CH), 10.06 (s, OH, enol form). Anal. Calcd for $C_{13}H_{22}O_3$: C, 68.99; H, 9.80. Found: C, 69.00; H, 9.58.

Ethyl 2,4,6-Trimethyl-3-oxo-(*E*)-6-nonenoate (5c). To 50 mg (1.2 mmol) of 57% NaH in 5 mL of THF was added with stirring 250 mg (1.1 mmol) of **4c**. The mixture was stirred until homogeneous (15 min), cooled to 5 °C, and treated with 70 μL (1.1 mmol) of MeI. After 4 h at 5 °C, an additional 20 μL (0.32 mmol) of MeI was added, and the mixture was allowed to warm to 25 °C over 2 h. TLC (silica gel, CH_2Cl_2) indicated the presence of diastereomeric **5c** (R_f 0.32, 0.29), a small amount unalkylated **4c** (R_f 0.24), and a small amount (5–10%) of 2,2-dimethylated material (R_f = 0.39). The solvent was removed under reduced pressure, and the residue was treated with water, whereupon the mixture was acidified with 4 N HCl and extracted with CH_2Cl_2. Concentration of the dried extracts, followed by careful PTLC (CH_2Cl_2) and bulb-to-bulb distillation (150 °C, 2 mm), gave 235 mg (87%) of **5c** as an oil: IR (neat) 2970, 1740, 1708, 1450, 1190

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cm^{-1}; ^{1}H NMR (CCl_4, 100 MHz, mixture of diastereomers) δ 0.96 (t, 3 H, CH_3CH_2, J = 7 Hz), 1.03 (d, 3 H, CH_3CHCH_2, J = 7 Hz), 1.16-1.40 (m, 6 H, CH_3CHCOO and OCH_2CH_3), 1.60, 1.65 (2 s, 3 H, C=CCH_3), 1.7-2.6 (m, 4 H, CH_2), 2.90 (m, 1 H, CHCO), 3.50 (m, 1 H, CHCOO), 4.20 (q, 2 H, OCH_2), 5.18 (br t, 1 H, C=CH). Anal. Calcd for $C_{14}H_{24}O_3$: C, 69.96; H, 10.07. Found: C, 69.86; H, 10.18.

4,6-Dimethyl-(*E*)-6-nonen-3-one (6c). A mixture of 150 mg (0.62 mmol) of **5c**, 400 mg (1.27 mmol) of $Ba(OH)\cdot 8H_2O$, 0.7 mL of EtOH, and 1.4 mL of water was stirred under argon in a 100 °C oil bath for 2 h. The cooled mixture was overlaid with pentane, diluted with 8 mL of water, and treated with 4 N HCl until the white precipitate dissolved. The aqueous layer was extracted with four additional portions of pentane. The concentrated extracts gave upon bulb-to-bulb distillation (150 °C, 40 mm) 95 mg (91%) of **6c**. Spectra were obtained by using material which was further purified by PTLC (CH_2Cl_2) and redistillation: IR (neat) 2960, 2930, 1707, 1460, 1450, 1375 cm^{-1} (lit.[9] 1710 cm^{-1}); ^{1}H NMR ($CDCl_3$, 200 MHz) δ 0.92 (t, 3 H, CH_3CH_2, J = 7.5 Hz), 1.02 (d, 3 H, CH_3CHCO, J = 6.8 Hz), 1.03 (t, 3 H, CH_3CH_2CO, J = 7.3 Hz), 1.59 (s, 3 H, C=CCH_3), 1.93 (m, 1 H, CH_2CHCO), 1.98 (m, 2 H, CH_2CH=C), 2.32 (dd, 1 H, CH_2CHCO, J = 13.5, 7.0 Hz), 2.44 (q, 2 H, CH_2CO, J = 7.3 Hz), 2.71 (m, 1 H, CHCO), 5.13 (qt, 1 H, C=CH, J = 7.1, 1.2 Hz); mass spectrum (70 eV), m/e (relative intensity) 168 (35), 139 (33), 111 (35), 86 (88), 83 (45), 69 (100), 57 (75), 55 (50), 41 (45); these spectra are in accord with those previously reported;[9] ^{13}C NMR ($CDCl_3$, 22.62 MHz) δ 7.7, 14.2, 15.7, 16.2, 21.2, 34.5, 43.4, 44.4, 129.2, 131.5, 214.9.

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Registry No. **1a**, 62251-79-0; **1b**, 62251-80-3; (±)-**3a**, 83269-60-7; (±)-**3b** (isomer 1), 83269-61-8; (±)-**3b** (isomer 2), 83269-83-4; (±)-(*E*)-**3c**, 83269-62-9; (±)-**4a**, 83269-63-0; (±)-**4b** (isomer 1), 83269-64-1; (±)-**4b** (isomer 2), 83269-84-5; (±)-(*E*)-**4c**, 83269-65-2; **5a**, 83269-66-3; **5b**, 83269-67-4; (±)-(*E*)-**5c** (isomer 1), 83269-68-5; (±)-(*E*)-**5c** (isomer 2), 83269-85-6; (±)-**6a**, 83269-69-6; **6b**, 83269-70-9; **7a**, 83269-72-1; (±)-*trans*-**7b**, 83269-73-2; **7c**, 83269-74-3; **7d**, 83269-75-4; (±)-**7e**, 83269-76-5; **8a**, 10488-95-6; (±)-*trans*-**8b**, 83269-77-6; **8c**, 5248-18-0; **8d**, 83269-78-7; (±)-**8e**, 83269-79-8; (±)-(*E*)-**9**, 83269-71-0; (*Z*)-**10**, 83269-80-1; **11**, 61835-96-9; (*E*)-**12**, 83269-81-2; BnBr, 100-39-0; BuI, 542-69-8; MeI, 74-88-4; Ph_3P=CHCOOEt, 1099-45-2; BuLi, 109-72-8; PhLi, 591-51-5; EtI, 75-03-6; Bu_3SnCl, 1461-22-9; 3-chloropropanoyl chloride, 625-36-5; crotonoyl chloride, 10487-71-5; ethyl 5-chloro-3-oxo-2-(triphenylphosphoranylidene)pentanoate, 83269-82-3; hexanoyl chloride, 142-61-0.

Synthesis of Nonachloro-4-phenoxyphenol

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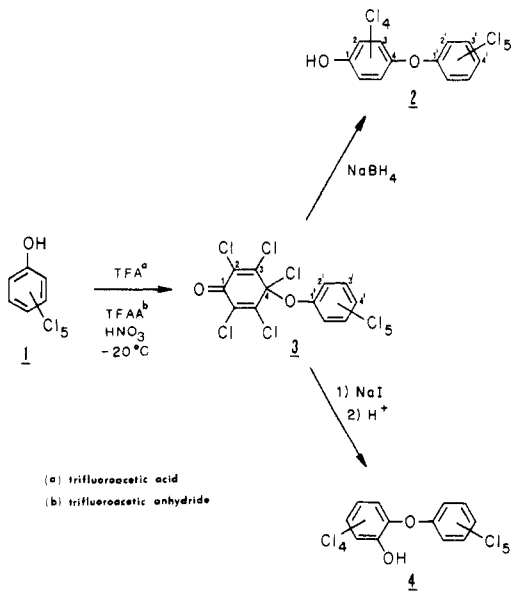
Reduction of 2,3,4,5,6-pentachloro-4-(pentachlorophenoxy)-2,5-cyclohexadienone (**3**) yields nonachloro-4-phenoxyphenol (**2**) and nonachloro-2-phenoxyphenol (**4**) in varying amounts, depending on the nature of the reaction scheme. Mechanistic pathways for the formation of **2** and **4** from **3** are suggested. The structure of **3** was confirmed by X-ray crystallography. The carbon-13 NMR spectrum of **2** is described.

Analysis of technical pentachlorophenol (**1**) indicates the presence of numerous chlorinated byproducts that arise in the manufacturing process.[2] The potential health hazards from exposure to these chemicals are of some concern. It has been shown, for example, that nonachloro-4-phenoxyphenol (**2**), a contaminant of **1**,[3] has a hemolytic potency at least a hundred times greater than that of **1**.[4] The need to evaluate other toxicological properties of this compound is apparent. Therefore, a convenient procedure for preparing this compound is needed. We report here our methods for synthesizing and purifying **2**.

Results and Discussion

Synthesis of **2** was accomplished by reduction of 2,3,4,5,6-pentachloro-4-(pentachlorophenoxy)-2,5-cyclohexadienone (**3**), prepared from **1**.[5] In addition to the desired product **2**, the 2-hydroxy isomer (**4**) was obtained in varying yield, depending on the nature of the reduction used (Scheme I). When sodium borohydride was used to reduce **3**, isomers **2** and **4** were formed in a ratio of 2:1. In contrast, when sodium iodide in methanol and chloroform was used to reduce **3**, the ratio of **2** to **4** was 1:20.[5] Reduction of **3** in a neutral methanolic solution with sodium iodide has been reported to produce **2**.[6] However, a

Scheme I



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