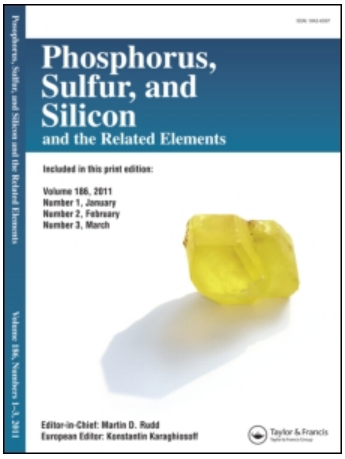

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Tertiary Phosphines Catalyzed Stereoselective Synthesis of *O*-Vinyl Ethers from Alkyl Acetylenecarboxylates and Alcohols

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Tertiary Phosphines Catalyzed Stereoselective Synthesis of *O*-Vinyl Ethers from Alkyl Acetylenecarboxylates and Alcohols

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Protonation of the highly reactive 1:1 intermediates, produced in the reaction between tertiary phosphines (triphenylphosphine and tributylphosphine) and alkyl acetylenecarboxylates, by alcohols (2,2,2-trichloroethanol, propargyl alcohol, and 4-(trifluoromethyl)-benzyl alcohol) leads to vinyltriphenylphosphonium salts, which undergo addition-elimination reaction to produce the corresponding O*-vinyl ethers. The NMR spectra (*$CDCl_3$ *as solvent) indicated that the compounds contained two stereoisomers for each* O*-vinyl ether. The relative populations of stereoisomers were determined from their* ^1H *NMR spectra.*

Keywords Acetylenic ester; alcohol; *O*-vinyl ether stereoisomers; tertiary phosphine

INTRODUCTION

Organophosphorus compounds have been extensively used in organic synthesis.[1–3] β -Additions of nucleophiles to the vinyl group of vinylic phosphonium salts leading to the formation of new alkylidenephosphoranes has attracted much attention as a very convenient and synthetically useful method in organic synthesis.[1–3] In the past, we

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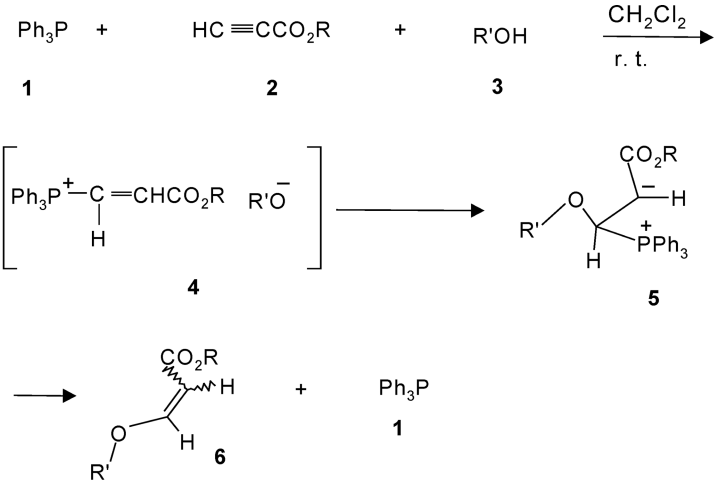
have established a convenient, one-pot method for preparing stabilized phosphorus ylides utilizing in situ generation of the phosphonium salts.[1] In this article, we report on the catalytic role of tertiary phosphines (triphenylphosphine (**1**) and tributylphosphine (**7**)) in the one-pot stereoselective synthesis of electron-poor *O*-vinyl ethers (**6**) from the reaction of alcohols (2,2,2-trichloroethanol, propargyl alcohol and 4-(trifluoromethyl)-benzyl alcohol) (**3**), and alkyl acetylenecarboxylates (**2**) in fairly good yields (Schemes 1 and 2).

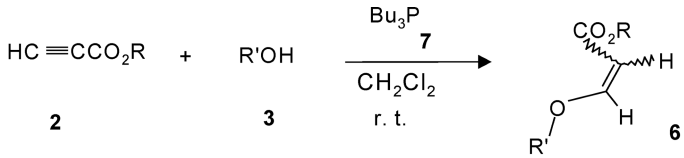


6a: R=Me, R'=CCl_3CH_2; %Z=0, %E=100; reaction time, 5 min; Yield, 65%.
6b: R=Et, R'=CCl_3CH_2; %Z=0, %E=100; reaction time, 5 min; Yield, 48%.
6c: R=Me, R'=$HCCCH_2$; %Z=31, %E=69; reaction time, 60 min; Yield, 45%.
6d: R=Et, R'=$HCCCH_2$; %Z=39, %E=61; reaction time, 60 min; Yield, 40%.
6e: R=Me, R'=*p*-$CF_3C_6H_4CH_2$; %Z=32, %E=68; reaction time, 5 days; Yield, 61%.
6f: R=Et, R'=*p*-$CF_3C_6H_4CH_2$; %Z=28, %E=72; reaction time, 5 days; Yield, 53%.

SCHEME 1

RESULTS AND DISCUSSION

Reactions are known in which an α-β, unsaturated carbonyl compound is produced from a phosphorane and a carbonyl compound such as an aldehyde or ketone.[4–10] Thus, compounds **6** may be regarded as the product of an addition-elimination reaction. Such addition-elimination products may result from an initial addition of tertiary phosphine (triphenylphosphine (**1**) and tributylphosphine (**7**)) to the acetylenic ester **2** and concomitant protonation of the 1:1 adduct, followed by attack of the anion of alcohol (2,2,2-trichloroethanol, propargyl alcohol and



6a: R=Me, R'=CCl_3CH_2; %Z=9, %E=91; reaction time, 30 min; Yield, 45%.
6b: R=Et, R'=CCl_3CH_2; %Z=35, %E=65; reaction time, 30 min; Yield, 55%.
6c: R=Me, R'=$HCCCH_2$; %Z=19, %E=81; reaction time, 60 min; Yield, 45%.
6d: R=Et, R'=$HCCCH_2$; %Z=22, %E=78; reaction time, 60 min; Yield, 39%.
6e: R=Me, R'=*p*-$CF_3C_6H_4CH_2$; %Z=29, %E=71; reaction time, 60 min; Yield, 58%.
6f: R=Et, R'=*p*-$CF_3C_6H_4CH_2$; %Z=34, %E=66; reaction time, 60 min; Yield, 55%.

SCHEME 2

4-(trifluoromethyl)-benzyl alcohol) **3** on the vinylphosphonium cation to form intermediate **5**. Elimination of tertiary phosphine **1** from intermediate **5** would lead to stereoselective formation of electron-poor *O*-vinyl ethers (**6**) in fairly good yields (Schemes 1 and 2). The reaction proceeds smoothly and cleanly under mild conditions and no side reactions were observed. The mechanism of the reaction has not been established experimentally. However, a possible explanation[11] is proposed in Scheme 1.

The NMR spectra indicated that solutions of compound **6a–f** ($CDCl_3$ as solvent) contain *E* isomer as a major product[11] that may be resulted from the relative stability of *E* isomer to *Z* isomer. The structures **6a–f** were deduced from their IR, ^1H and ^{13}C NMR spectra. The ^1H NMR spectra of compounds **6a–f** exhibited two peaks at $\delta = 4.98$–5.40 and $\delta = 6.60$–7.67 for the two olefinic protons.[11] The alkoxy groups and the alcoholic moieties give characteristic signals at appropriate chemical shifts (see Experimental section). Further evidence was obtained from the ^{13}C NMR spectra which displayed olefinic carbon resonances at about $\delta = 95.60$–99.70 and $\delta = 157.28$–162.26, and carbonyl carbons at about $\delta = 164.50$–167.76 (see Experimental section).[11]

Several methods have been reported in the literature for the synthesis of *O*-vinyl ethers. These protocols are routinely multi-step in nature.[12] The most general method involves usually under harsh reaction conditions.[12] Few reliable and operationally facile examples have been reported for the one step synthesis of *O*-vinyl ethers, especially from cyclic α-diketones and dialkyl acetylenedicarboxylates.[13,14] We believe the reported method offers a mild, simple, and efficient route for the preparation of electron-poor *O*-vinyl ether derivatives. Its ease of work up, high yields and fairly mild reaction conditions make it a useful addition to modern synthetic methodologies.

CONCLUSION

In summary, we have developed a convenient, one-pot method for the preparation of electron-poor *O*-vinyl ethers (**6**) from the reaction of alcohols (2,2,2-trichloroethanol, propargyl alcohol and 4-(trifluoromethyl)-benzyl alcohol) (**3**) and alkyl acetylenecarboxylates (**2**) in the presence of tertiary phosphines (triphenylphosphine and tributylphosphine) in fairly good yields (Scheme 1). Other aspects of this process are under investigation.

EXPERIMENTAL

Melting points were measured on an Electrothermal 9100 apparatus and are uncorrected. UV spectra were recorded on a Shimadzu UV-160 spectrophothometer. IR spectra were recorded on a Mattson 1000 FT-IR spectrometer. ^{1}H and ^{13}C NMR spectra were measured with a BRUKER Spectrospin spectrometer at 250, and 62.5 MHz, respectively.

General Procedure for the Preparation of O-vinyl Ethers (6a–f)

To a magnetically stirred solution of phosphine **1** (or **7**) (1 mmol) and alcohol **3** (1 mmol) in CH_2Cl_2 (3 ml) was added dropwise a mixture of **2** (1 mmol) in CH_2Cl_2 (4 ml) at $-10^{\circ}C$ over 15 min. The mixture was allowed to warm up to room temperature and stirred for 5 min. to 5 days (See Schemes 1 and 2). The solvent was removed under reduced pressure, and the viscous residue was purified by flash column chromatography (silica gel; petroleum ether-ethyl acetate). The solvent was removed under reduced pressure and the products were obtained.

Spectral Data for Methyl (E)-3-(2,2,2)-trichloroethaxy)-2-propenoate (6a *E*)

White crystals; m.p. 44–45°C; IR(KBr) (ν_{max}, cm^{-1}): 2946, 2854, 1704, 1650 and 1157. ^{1}H NMR($CDCl_3$) δ_H 3.73 (3 H, s, OCH_3); 4.45 (2 H, s, OCH_2); 5.43 and 7.60 (2 H, 2 d, $^{3}J_{HH} = 12.42$ Hz, CH=CH). ^{13}C NMR($CDCl_3$) δ: 51.40 (OCH_3); 82.29 (OCH_2); 94.60 (CCl_3); 99.39 (=CH); 160.29 (OCH=); 167.29 (C=O, ester).

Spectral Data for Methyl (Z)-3-(2,2,2)-trichloroethaxy)-2-propenoate (6a *Z*)

Yellow viscous oil; IR(CCl_4) (ν_{max}, cm^{-1}): 2946, 2854, 1704, 1650 and 1157. ^{1}H NMR($CDCl_3$) δ_H 3.72 (3 H, s, OCH_3); 4.55 (2 H, s, OCH_2);

5.00 and 6.61 (2 H, 2 d, $^3J_{HH} = 7.0$ Hz, CH=CH). ^{13}C NMR($CDCl_3$) δ: 51.13 (OCH_3); 85.16 (OCH_2); 95.35 (CCl_3); 98.30 (=CH); 157.28 (OCH=); 164.84 (C=O, ester).

Spectral Data for Ethyl (E)-3-(2,2,2)-trichloroethaxy)-2-propenoate (6b *E*)

White crystals; m.p. 75–79°C; IR(KBr) (ν_{max}, cm^{-1}): 2954, 2896, 1704, 1650, and 1157. ^{1}H NMR($CDCl_3$) δ_H 1.26 (3 H, t,$^3J_{HH} = 7.1$ Hz, CH_3); 4.16 (2 H, q,$^3J_{HH} = 7.1$ Hz, CH_2, Et); 4.43 (2 H, s, OCH_2); 5.40 and 7.58 (2 H, 2 d, $^3J_{HH} = 12.42$ Hz, CH=CH). ^{13}C NMR($CDCl_3$) δ: 14.30 (CH_3); 60.13 (CH_2, Et); 82.15 (OCH_2); 94.63 (CCl_3); 99.70 (=CH); 160.74 (OCH=); 166.80 (C=O, ester).

Spectral Data for Ethyl (Z)-3-(2,2,2)-trichloroethaxy)-2-propenoate (6b *Z*)

Colorless viscous oil; IR(CCl_4) (ν_{max}, cm^{-1}): 2945, 2869, 1712, 1643 and 1149. ^{1}H NMR($CDCl_3$) δ_H 1.24 (3 H, t,$^3J_{HH} = 7.1$ Hz, CH_3); 4.16 (2 H, q,$^3J_{HH} = 7.1$ Hz, CH_2, Et); 4.53 (2 H, s, OCH_2); 5.00 and 6.60 (2 H, 2 d, $^3J_{HH} = 7.0$ Hz, CH=CH). ^{13}C NMR($CDCl_3$) δ: 12.24 (CH_3); 59.89 (CH_2, Et); 85.13 (OCH_2); 95.38 (CCl_3); 98.76 (=CH); 157.02 (OCH–); 164.50 (C=O, ester).

Spectral Data for Methyl (E)-3-(2-propynyloxy)-2-propenoate (6c *E*)

Colorless viscous oil. UV(λ_{max}/nm, log ε, ethanol 95%); 227, 4.09. IR(CCl_4) (ν_{max}, cm^{-1}): 3285 (≡C–H, acetylene); 3000(C=C,alkene); 2150(C≡C, alkyne); 1660 (C=C,alkene); 1725 (C=O, ester); 1125 (C–O, ether).^{1}H NMR ($CDCl_3$) δ: 2.59(1H, t, $^4J_{HH} = 2.5$ Hz, ≡C–H); 3.67 (3H, s, OCH_3); 4.49 (2H, d,$^4J_{HH} = 2.5$ Hz, OCH_2); 5.31 and 7.53 (2H, 2d, $^3J_{HH} =$ 12.5 HZ, HC=CH). ^{13}C NMR ($CDCl_3$) δ: 51.21 (OCH_3); 58.27 (OCH_2); 76.96 and 77.08 (2C, C≡C); 98.05 and 160.57 (2C, C=C); 167.58 (C=O, ester).

Spectral Data for Methyl (Z)-3-(2-propynyloxy)-2-propenoate (6c *Z*)

Colorless viscous oil. UV(λ_{max}/nm, log ε, ethanol 95%); 227, 4.09. IR(CCl_4) (ν_{max}, cm^{-1}): 3285 (≡C–H, acetylene); 3000(C=C, alkene); 2150(C≡C, alkyne); 1660 (C=C,alkene); 1725 (C=O, ester); 1125 (C–O,

ether).^{1}H NMR ($CDCl_3$) δ: 2.59(1H, t, $^4J_{HH} = 2.5$ Hz, ≡C–H); 3.65 (3H, s, OCH_3); 4.63 (2H, d,$^4J_{HH} = 2.5$ Hz, OCH_2); 4.99 and 6.68 (2H, 2d, $^3J_{HH} =$ 7 Hz, HC=CH).^{13}C NMR ($CDCl_3$) δ: 51.06 (OCH_3); 61.11 (OCH_2); 76.96 and 77.08 (2C, C≡C); 97.84 and 159.47 (2C, C=C); 167.58 (C=O, ester).

Spectral Data for Ethyl (E)-3-(2-propynyloxy)-2-propenoate (6d *E*)

Colorless viscous oil. UV(λ_{max}/nm, log ε, ethanol 95%); 227, 4.58. IR(CCl_4) (ν_{max}, cm^{-1}): 3285 (≡C–H, acetylene); 3000(C=C,alkene); 2150(C≡C, alkyne); 1660 (C=C, alkene); 1725 (C=O, ester); 1125 (C–O, ether).^{1}H NMR ($CDCl_3$) δ: 1.25 (3H, t,$^3J_{HH} = 7.25$ Hz, CH_3); 2.58(1H, t, $^4J_{HH} = 2.5$ Hz, ≡C–H); 4.146 (2H, q, $^3J_{HH} = 7.25$ Hz, CH_2); 4.49 (2H, d,$^4J_{HH} =$2.5 Hz, OCH_2); 5.31 and 7.54 (2H, 2d, $^3J_{HH} = 12.5$ Hz, HC=CH).^{13}C NMR ($CDCl_3$) δ: 14.28 (CH_3);58.03(CH_2); 59.95 (OCH_2); 76.94 and 77.55(2C, C≡C); 98.41 and 160.41 (2C, C=C); 167.58 (C=O, ester).

Spectral Data for Ethyl (Z)-3-(2-propynyloxy)-2-propenoate (6d *Z*)

Colorless viscous oil. UV(λ_{max}/nm, log ε, ethanol 95%); 227, 4.58. IR(CCl_4) (ν_{max}, cm^{-1}): 3285 (≡C–H, acetylene); 3000(C=C,alkene); 2150(C≡C, alkyne); 1660 (C=C,alkene); 1725 (C=O, ester); 1125 (C–O, ether).^{1}H NMR ($CDCl_3$) δ: 1.25 (3H, t,$^3J_{HH} = 7.25$ Hz, CH_3); 2.58(1H, t, $^4J_{HH} = 2.5$ Hz, ≡C–H); 4.146 (2H, q, $^3J_{HH} = 7.25$ Hz, CH_2); 4.63 (2H, d,$^4J_{HH} = 2.5$ Hz, OCH_2); 4.98 and 6.64 (2H, 2d, $^3J_{HH} = 7$ Hz, HC=CH).^{13}C NMR ($CDCl_3$) δ: 14.27 (CH_3); 59.71(CH_2); 61.05 (OCH_2); 76.51 and 77.01(2C, C≡C); 98.17 and 156.41 (2C, C=C); 164.91 (C=O, ester).

Spectral Data for Methyl (E)-3-[4-(-trifluoromethyl)-benzyl]oxy-2-propenoate (6e *E*)

White crystals; UV(λ_{max}/nm, log ε, ethanol 95%); 228, 4.35. IR(KBr) (ν_{max}, cm^{-1}): 3085 and 2946 (C–H, aliphatic); 1712 (C=O, ester); 1627 (C=C, alkene); 1126 (C–O, ether).^{1}H NMR ($CDCl_3$) δ: 3.7 (3H, s, OCH_3); 4.95 (2H, 1s, OCH_2); 5.32 and 7.67 (2 H, 2 d,$^3J_{HH} = 12.5$ Hz, HC=CH); 7.45–7.64 (4 H, 2 d,$^3J_{HH} = 8.0$ Hz, arom).^{13}C NMR ($CDCl_3$) δ: 51.189 (OCH_3); 71.64 (OCH_2); 97.61 (=CH); 125.69 (CH, q,$^3J_{CF} = 3.7$ Hz); 126.18 (CF_3, q, $^1J_{CF} = 270$ Hz); 127.52 (CH, arom); 130.83 (C, q, $^2J_{CF} =$ 31 Hz, arom); 139.12 (C, arom); 161.61(OCH=); 167.76 (C=O, ester).

Spectral Data for Methyl (Z)-3-[4-(-trifluoromethyl)-benzyl]oxy-2-propenoate (6e *Z*)

Colorless viscous oil; UV(λ_{max}/nm, log ε, ethanol 95%); 228, 4.35. IR(CCl_4) (ν_{max}, cm^{-1}): 3085 and 2946 (C—H, aliphatic); 1712 (C=O, ester); 1627 (C=C, alkene); 1126 (C—O, ether).^{1}H NMR ($CDCl_3$) δ: 3.66 (3H, s, OCH_3); 4.93 (2H, 1s, OCH_2); 5.26 and 7.57 (2H, 2 d, HC=CH); 7.45—7.64 (4H, 2d,$^3J_{HH}$ = 8.0 Hz, arom).^{13}C NMR ($CDCl_3$) δ: 51.189 (OCH_3); 71.81 (OCH_2); 97.31 (=CH); 125.49 (CH, q,$^3J_{CF}$ = 3.7 Hz, arom); 126.18 (CF_3, q,$^1J_{CF}$ = 270 Hz); 128.06 (CH, arom); 130.83 (C, q,$^2J_{CF}$ = 31 Hz, arom); 139.248 (C, arom); 162.26 (OCH=); 166.99 (C=O, ester).

Spectral Data for Ethyl (E)-3-[4-(-trifluoromethyl)benzyl]-oxy-2-propenoate (6f *E*)

Colorless viscous oil; UV(λ_{max}/nm, log ε, ethanol 95%); 228, 4.41. IR(CCl_4) (ν_{max}, cm^{-1}): 3054 and 2985 (C—H, aliphatic); 1712 (C=O, ester); 1627 (C=C); 1133 (C—O, ether).^{1}H NMR ($CDCl_3$) δ: 1.26 (3H, t,$^3J_{HH}$ = 7.1 Hz, CH_3); 4.21 (2H, q,$^3J_{HH}$ = 7 Hz, CH_2); 4.95 (2H, 1s, OCH_2); 5.32 and 7.66 (2H, 2d,$^3J_{HH}$ = 12.75 Hz, HC =CH); 7.46–7.64 (4H, 2d,$^3J_{HH}$ = 8 Hz, arom).^{13}C NMR ($CDCl_3$) δ: 14.30 (CH_3); 59.94 (CH_2); 71.56 (OCH_2); 97.97 (=CH); 125.69 (CH, q, $^3J_{CF}$ = 3.7 Hz); 126.18 (CF_3, q, $^1J_{CF}$ = 270 Hz); 127.52 (CH, arom); 130.83 (C, q, $^2J_{CF}$ = 31 Hz, arom); 139.12 (C, arom); 161.44 (OCH=); 167.36 (C=O, ester).

Spectral Data for Ethyl (Z)-3-[4-(-trifluoromethyl)benzyl]-oxy-2-propenoate (6f *Z*)

Colorless viscous oil; UV(λ_{max}/nm, log ε, ethanol 95%); 228, 4.41. IR(CCl_4) (ν_{max}, cm^{-1}): 3054 and 2985 (C—H, aliphatic); 1712 (C=O, ester); 1627 (C=C); 1133 (C—O, ether).^{1}H NMR ($CDCl_3$) δ: 1.26 (3H, t,$^3J_{HH}$ = 7.1 Hz, CH_3); 4.21 (2H, q,$^3J_{HH}$ = 7 Hz, CH_2); 4.93 (2H, 1s, OCH_2); 5.26 and 7.57 (2H, 2d, HC=CH); 7.46–7.6 (4H, 2d,$^3J_{HH}$ = 8 Hz, arom).^{13}C NMR ($CDCl_3$) δ: 13.99 (CH_3); 59.94 (CH_2); 71.56 (OCH_2); 95.6 (=CH); 125.49 (CH, q,$^3J_{CF}$ = 3.7 Hz, arom); 126.18 (CF_3, q,$^1J_{CF}$ = 270 Hz); 128.06 (CH, arom); 130.83 (C, q,$^2J_{CF}$ = 31 Hz, arom); 139.248 (C, arom); 162.22 (OCH=); 166.99 (C=O, ester).

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