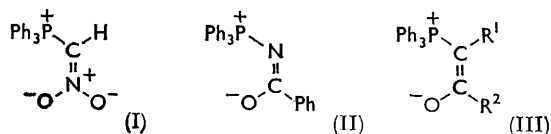


448. A New Synthesis of Acetylenes. Part I.

By S. T. D. GOUGH and S. TRIPPETT.

Pyrolysis of β -ketoalkylidene-triphenylphosphoranes gives triphenylphosphine oxide and a disubstituted acetylene, provided the acetylenic link is conjugated with an aromatic nucleus or with an ester or nitrile group. The pyrolysis, in the presence of a base, of β -ketoalkylphosphonates and of β -ketoalkylphosphine oxides has been investigated.

WE previously found¹ that treatment of nitromethyltriphenylphosphonium bromide with aqueous alkali gave triphenylphosphine oxide and fulminate ion, probably through the intermediate phosphorane (I). Staudinger and Hauser² had shown that benzoyl-iminotriphenylphosphorane (II) at 220° gave triphenylphosphine oxide and benzonitrile. Reasoning by analogy with these reactions, we pyrolysed a series of β -ketoalkylidene-triphenylphosphoranes (III) in the hope of obtaining acetylenes. The phosphoranes (III; R¹ = H, R² = H, Me, Ph, OEt) gave no acetylenes, but the phosphorane (III; R¹ = R² = Ph) at 300° gave almost quantitative yields of triphenylphosphine oxide and diphenylacetylene.¹



The pyrolysis of β -ketoalkylidene-triphenylphosphoranes (III) has now been further investigated and has been shown to constitute a general synthesis of acetylenes provided (a) that neither R¹ nor R² is hydrogen, and (b) that R¹ or R² is a phenyl or carbonyl group or the equivalent. In this way phenylalkylacetylenes were obtained from the phosphoranes (III; R¹ and R² = Ph or Alkyl), $\alpha\beta$ -acetylenic esters from the phosphoranes (III; R¹ = CO₂Et), and $\alpha\beta$ -acetylenic nitriles from the phosphoranes (III; R¹ = CN). The yields of acetylenes varied from 55% to 95%, and the crude products, particularly the simple $\alpha\beta$ -acetylenic esters and nitriles, were remarkably pure as shown by their infrared spectra. Pyrolysis of the phosphoranes (III; R¹ = CO₂Et, R² = [CH:CH]_n·CH₃) gave the crude esters CH₃·[CH:CH]_n·C:C·CO₂Et (*n* = 1 or 2), but the phosphoranes (III; R¹ = Me, R² = CH:CHPh; R¹ = CO₂Et, R² = OEt) gave no acetylenes. When R¹ and R² were both alkyl groups, the products contained only a few percent of the desired acetylenes, as shown by gas-liquid chromatography, and had strong allenic absorption

¹ Trippett and Walker, *J.*, 1959, 3874.

² Staudinger and Hauser, *Helv. Chim. Acta*, 1921, 4, 861.

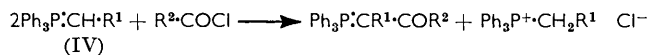
in the infrared region. It may be that the acetylenes were formed but largely isomerised under the reaction conditions.

Suitable β -ketoalkylidetriphenylphosphoranes (III) may be prepared as follows:

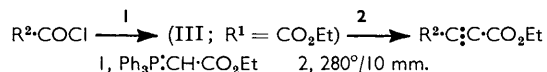
(1) From certain α -halogeno-carbonyl compounds by quaternisation with triphenylphosphine and treatment of the resulting phosphonium salts with aqueous alkali. In this way α -bromobenzyl methyl ketone gave the phosphorane (III; $R^1 = \text{Ph}$, $R^2 = \text{Me}$). Further investigation (see Part II) has shown that this is not a general method.

(2) From β -keto-esters by the action of dichlorotriphenylphosphorane in the presence of triethylamine.³

(3) From Wittig reagents by the action of acid halides^{4,5} or thioesters.⁶ We have



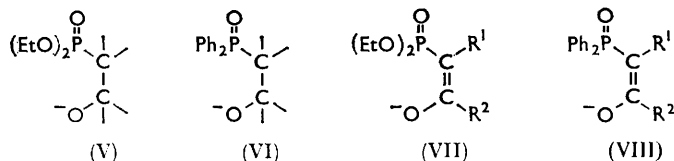
extended this reaction to the stable ester and nitrile phosphoranes (IV; $R^1 = \text{CO}_2\text{Et}$ or CN). The sequence of reactions:



constitutes the most convenient preparation of the acetylenic acid $\text{R}\cdot\text{C}:\text{C}\cdot\text{CO}_2\text{H}$ starting from the acid $\text{R}\cdot\text{CO}_2\text{H}$ and probably also, by successive reductions, of the ethylenic acid $\text{R}\cdot\text{CH}:\text{CH}\cdot\text{CO}_2\text{H}$ and the saturated acid $\text{R}\cdot\text{CH}_2\cdot\text{CH}_2\cdot\text{CO}_2\text{H}$.

We have not succeeded in preparing the phosphoranes (III; $R^1 = \text{COR}$) which on pyrolysis might be expected to give acetylenic ketones. The Horner method (2 above) failed in our hands when applied to β -diketones, the only isolable products being unchanged diketone and triphenylphosphine oxide. Aromatic acid chlorides with the stable phosphoranes (IV; $R^1 = \text{COR}$, $R = \text{H}$, Me , or Ph) gave *O*-acylated phosphonium salts, $\text{Ph}_3\text{P}^+\text{CH}:\text{CR}\cdot\text{O}\cdot\text{COAr} \text{Cl}^-$; these phosphoranes also undergo *O*-alkylation.⁷ When aliphatic acid chlorides were used, the sole isolable products were the phosphonium salts corresponding to the original phosphoranes, *i.e.*, $\text{Ph}_3\text{P}^+\text{CH}_2\cdot\text{COR} \text{Cl}^-$; the fate of the aliphatic acyl residue is unknown.

Horner and his co-workers⁸ have established olefin syntheses analogous to the Wittig reaction employing phosphonates and phosphine oxides. These involve eliminations from intermediate anions (V) and (VI). We have investigated possible acetylenic syntheses analogous to these Horner reactions, *i.e.*, employing eliminations from the intermediate anions (VII) and (VIII).



Diethyl α -ethoxycarbonylphenacylphosphonate was prepared by the action of benzoyl chloride on the magnesium salt of diethyl ethoxycarbonylmethylphosphonate.⁹ It is soluble in aqueous sodium carbonate, presumably with the formation of the anion (VII; $R^1 = \text{CO}_2\text{Et}$, $R^2 = \text{Ph}$), but, despite this, pyrolysis in the presence of a number of bases

³ Horner and Oediger, *Chem. Ber.*, 1958, **91**, 4371.

⁴ Trippett and Walker, *J.*, 1961, 1266.

⁵ Bestmann, *Tetrahedron Letters*, 1960, No. 4, 7.

⁶ Bestmann, *Tetrahedron Letters*, 1961, 455.

⁷ Ramirez and Dershowitz, *J. Org. Chem.*, 1957, **22**, 41.

⁸ Horner, Hoffmann, and Wippel, *Chem. Ber.*, 1958, **91**, 61; Horner, Hoffmann, Wippel, and Klahre, *Chem. Ber.*, 1959, **92**, 2499.

⁹ Kreutzkamp, *Chem. Ber.*, 1955, **88**, 195.

gave only very small amounts of the desired acetylenic ester. The major products were usually triethyl phosphite and ethyl benzoate.

More success attended the pyrolysis of a suitable phosphine oxide in the presence of a base. Benzylidiphenylphosphine oxide, prepared by the action of benzyl bromide on methyl diphenylphosphinite, was metallated with butyl-lithium and then treated with benzoyl chloride to give diphenyl- α -phenylphenacylphosphine oxide. Pyrolysis of this in the presence of sodium ethoxide gave 30%, and in the presence of potassium t-butoxide 64%, of diphenylacetylene, together with the salt of diphenylphosphinic acid. 1-Phenylpropyne (34%) was obtained similarly from α -acetylbenzylidiphenylphosphine oxide in the presence of potassium t-butoxide. Extension of this particular acetylenic synthesis is in hand.

EXPERIMENTAL

Experiments involving oxygen-sensitive phosphines or phosphoranes were carried out under oxygen-free nitrogen. Light petroleum refers to that fraction having b. p. 60–80°. Ultraviolet spectra were determined for ethanol solutions.

α -Acetylbenzylidenetriphenylphosphorane.—A solution of triphenylphosphine (49.2 g.) and α -bromobenzyl methyl ketone (20 g.) in benzene (250 ml.) was refluxed overnight. The resulting solid was filtered off, rubbed with acetone (2 \times 30 ml.), and crystallised from chloroform-light petroleum, to give the phosphonium salt (12 g.), m. p. 251°. This was dissolved in ethanol (80 ml.) and made alkaline to phenolphthalein with dilute sodium hydroxide, to give α -acetylbenzylidenetriphenylphosphorane (8.2 g.), m. p. 171° (from aqueous ethanol) (lit.,⁴ m. p. 167°).

Triphenyl-1-propionylbutylidenephosphorane.—To a stirred suspension of n-butyltriphenylphosphonium bromide (20 g.) in ether (300 ml.) was added ethereal 1.4*N*-butyl-lithium (33.5 ml.). After 1 hr., the resulting solution was added slowly to a stirred solution of propionyl chloride (4.6 g.) in ether (100 ml.). The suspension was then extracted with 2*N*-hydrochloric acid (2 \times 200 ml.), and the extracts were made alkaline to phenolphthalein at 0° and extracted with benzene (3 \times 150 ml.). Evaporation of the benzene gave an oil (8.9 g.) which crystallised from hexane, to give the *phosphorane* (4.1 g.), m. p. 114°, λ_{\max} 6.68 μ (Found: C, 80.2; H, 7.2. C₂₅H₂₇OP requires C, 80.2; H, 7.05%).

1-Ethoxycarbonyl-2-oxopentylidenetriphenylphosphorane.—Butyryl chloride (3.1 g.) in benzene (10 ml.) was added slowly to a stirred solution of ethoxycarbonylmethylenetriphenylphosphorane (10 g.) in benzene (100 ml.), and the resulting solution set aside at room temperature overnight. The precipitate of ethoxycarbonylmethyltriphenylphosphonium chloride (4.8 g.; m. p. 90–91°) was filtered off and the filtrate evaporated. Crystallisation of the residue from aqueous ethanol gave 1-ethoxycarbonyl-2-oxopentylidenetriphenylphosphorane (4.0 g.), m. p. 130–131°, λ_{\max} 6.0, 6.45 μ (Found: C, 74.25; H, 6.35. C₂₆H₂₇O₃P requires C, 74.6; H, 6.5%).

In a similar way, crotonoyl chloride gave 1-ethoxycarbonyl-2-oxopent-3-enylidenetriphenylphosphorane (57%), m. p. (from aqueous ethanol) 146–147°, λ_{\max} 6.07, 6.57 μ (Found: C, 75.0; H, 5.9. C₂₆H₂₅O₃P requires C, 75.0; H, 6.0%), and sorboyl chloride gave 1-ethoxycarbonyl-2-oxohepta-3,5-dienylidenetriphenylphosphorane (74%), m. p. (from aqueous ethanol) 158–159°, λ_{\max} 6.05, 6.6 μ (Found: C, 75.7; H, 6.1. C₂₈H₂₇O₃P requires C, 76.0; H, 6.1%).

α -Cyanophenacylidenetriphenylphosphorane.—Benzoyl chloride (4.5 g.) in benzene (10 ml.) was added slowly to a stirred solution of cyanomethylenetriphenylphosphorane (9.3 g.) in benzene (300 ml.), and the mixture set aside at room temperature overnight. The precipitate of cyanomethyltriphenylphosphonium chloride (4.1 g.; m. p. 278°) was filtered off and the filtrate evaporated. Crystallisation of the residue from aqueous ethanol gave α -cyanophenacylidenetriphenylphosphorane (3.65 g.), m. p. 208°, λ_{\max} 4.55, 6.45 μ (Found: C, 79.55; H, 5.0. C₂₇H₂₀NOP requires C, 80.0; H, 4.95%).

In a similar way, butyryl chloride gave 1-cyano-2-oxopentylidenetriphenylphosphorane (81%), m. p. (from ethyl acetate-light petroleum) 177°, λ_{\max} 4.57, 6.3 μ (Found: C, 77.6; H, 5.8. C₂₄H₂₂NOP requires C, 77.6; H, 5.9%).

α -Ethoxycarbonylphenacylidenetriphenylphosphorane.—A solution of chlorine (7.1 g.) in carbon tetrachloride (150 ml.) was added dropwise to a solution of triphenylphosphine (26.2 g.) in benzene (200 ml.) at 0°, followed after 10 min. by triethylamine (30.3 g.) and then by ethyl benzoylacetate (20 g.). The mixture was refluxed for 1 hr., cooled, and extracted with water

(500 ml.). The benzene layer was dried and evaporated, and the residue crystallised from ethyl acetate to give the *phosphorane* (77%), m. p. 142—143°, λ_{\max} . 6.03, 6.55 μ (Found: C, 76.7; H, 5.5. $C_{25}H_{25}O_3P$ requires C, 77.0; H, 5.5%).

A similar reaction with dimethylphenylphosphine gave *α -ethoxycarbonylphenacylidene-dimethylphenylphosphorane* (60%), m. p. (from ethyl acetate-light petroleum) 108—109°, λ_{\max} . 6.1, 6.55 μ (Found: C, 69.4; H, 6.4. $C_{19}H_{21}O_3P$ requires C, 69.5; H, 6.4%).

Pyrolysis of 1-Ethoxycarbonyl-2-oxopentylidene-triphenylphosphorane.—The phosphorane (3.32 g.) was heated for 1 hr. at 280°/10 mm. in a 50-ml. Claisen flask immersed in a Wood's-metal bath, the distillate being collected in a receiver cooled in liquid nitrogen. Redistillation gave ethyl hex-2-ynoate (0.87 g.), b. p. 93°/24 mm. (lit.,¹⁰ b. p. 93—94°/24 mm.), λ_{\max} . 4.42, 5.85 μ (Found: C, 68.85; H, 8.5. Calc. for $C_8H_{12}O_2$: C, 68.6; H, 8.6%).

The following phosphoranes were pyrolysed under the same conditions:

α -Acetylbenzylidene-triphenylphosphorane gave methylphenylacetylene (58%), b. p. 75°/15 mm. (lit.,¹¹ b. p. 74—75°/14 mm.), λ_{\max} . 237, 249 m μ (ϵ 19,200), 4.39, 4.44 μ . The same acetylene (55%) was obtained from *α -methylphenacylidene-triphenylphosphorane*.

1-Ethoxycarbonyl-2-oxopent-3-enylidene-triphenylphosphorane gave impure ethyl hex-4-en-2-ynoate (87%), b. p. 86°/13 mm., λ_{\max} . 253 m μ (ϵ 10,700), 4.47, 5.85 μ . Ethyl 6-hydroxyhept-4-en-2-ynoate¹² has λ_{\max} . 248 m μ (ϵ 14,000).

1-Ethoxycarbonyl-2-oxohepta-3,5-dienylidene-triphenylphosphorane gave impure ethyl octa-4,6-dien-2-ynoate (21%), λ_{\max} . 293 m μ (ϵ 20,400), 4.5, 5.87 μ .

α -Cyanophenacylidene-triphenylphosphorane gave phenylpropionitrile (84%), m. p. 38.5—39° (lit.,¹³ m. p. 38—40°), λ_{\max} . 4.37, 4.46, 4.6 μ .

α -Cyano-2-oxopentylidene-triphenylphosphorane gave *hex-2-ynonitrile* (60%), b. p. 34—36°/11 mm., λ_{\max} . 4.3, 3.9 μ (Found: C, 76.8; H, 7.3. C_6H_7N requires C, 77.4; H, 7.5%).

α -Ethoxycarbonylacetylidene-triphenylphosphorane gave ethyl tetrolate (91%), b. p. 165°, having an infrared spectrum identical with that of an authentic specimen. The amide had m. p. 148—149° (lit.,¹⁴ m. p. 147—148°).

α -Ethoxycarbonylphenacylidene-triphenylphosphorane gave ethyl phenylpropiolate (91%), b. p. 149°/15 mm., λ_{\max} . 4.45, 4.5, 5.86 μ . The amide had m. p. (from water) 99—100° (lit.,¹⁵ m. p. 99—100°). The same acetylenic ester (17%) was obtained by pyrolysis of *α -ethoxycarbonylphenacylidenedimethylphenylphosphorane*.

Diethyl α -ethoxycarbonylphenacylphosphonate.—Carbon tetrachloride (0.5 ml.) and one-half of a mixture of ethanol (24 ml.) and diethyl ethoxycarbonylmethylphosphonate (38.2 g.) were added to magnesium (4.1 g.), and the stirred suspension warmed till reaction started; then the other half of the ethanol solution was slowly added. After 1 hr., ether (75 ml.) was added, the mixture refluxed for 2 hr., and benzoyl chloride (28 g.) in ether (25 ml.) then added. The final mixture was refluxed for 1 hr. and set aside at room temperature overnight. It was then cooled to 0°, 25% sulphuric acid (80 g.) was added, and the resulting solution extracted with ether. Distillation of the extract gave *diethyl α -ethoxycarbonylphenacylphosphonate* (56%), b. p. 170—172°/0.3 mm., λ_{\max} . 5.75, 5.93 μ (Found: C, 54.9; H, 6.6. $C_{15}H_{21}O_6P$ requires C, 54.9; H, 6.4%).

A mixture of the above phosphonate (19.1 g.) and anhydrous sodium carbonate (10 g.) was heated at 280°/10 mm. for 2 hr., the distillate being collected in a receiver cooled with liquid nitrogen. Redistillation gave triethyl phosphite (5.5 g.), b. p. 94—96°/13 mm., and a fraction (0.2 g.), b. p. 140°/13 mm., identified as ethyl phenylpropiolate by its infrared spectrum. Similar pyrolyses in the presence of sodium ethoxide, potassium t-butoxide, and sodium hydride gave equally small acetylenic fractions.

Benzylidiphenylphosphine Oxide.—A solution of benzyl bromide (20 g.) and methyl diphenylphosphinite (25.2 g.) in benzene (250 ml.) was refluxed for 2 hr. and then evaporated. Crystallisation of the residue from aqueous ethanol gave *benzylidiphenylphosphine oxide* (71%), m. p. and mixed m. p. 194—195°.

Diphenyl- α -phenylphenacylphosphine Oxide.—Ethereal 1.18N-butyl-lithium (35 ml.) was

¹⁰ Moureu and Delange, *Compt. rend.*, 1903, **136**, 552.

¹¹ Nef, *Annalen*, 1900, **310**, 333.

¹² Haynes and Jones, *J.*, 1946, 503.

¹³ Claisen, *Ber.*, 1903, **36**, 3671.

¹⁴ Feist, *Annalen*, 1906, **345**, 110.

¹⁵ Stockhausen and Gattermann, *Ber.*, 1892, **25**, 3537.

added to a stirred suspension of benzyldiphenylphosphine oxide (12 g.) in ether (250 ml.), followed after 1 hr. by benzoyl chloride (5.75 g.) in ether (15 ml.). The mixture was refluxed for 1 hr. and then evaporated. The residue was shaken with chloroform (400 ml.) and water (200 ml.), the chloroform layer evaporated, and the residue crystallised from aqueous ethanol to give *diphenyl- α -phenylphenacylphosphine oxide* (86%), m. p. 235—236°, λ_{max} 5.97 μ (Found: C, 78.0; H, 5.2. $\text{C}_{26}\text{H}_{21}\text{O}_2\text{P}$ requires C, 78.8; H, 5.3%).

A mixture of this phosphine oxide (9.4 g.) and potassium t-butoxide (3.5 g.) was heated for 1 hr. at 280—300°/0.3 mm. The distillate crystallised from aqueous ethanol to give diphenylacetylene (64%), m. p. and mixed m. p. 58.5—59°.

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