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THE REACTION OF CHALCONE WITH PHOSPHONATES

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Abstract—Chalcone reacts with the anions of triethyl phosphonoacetate (I) and diethyl benzylphosphonate (IV)—depending on the operating conditions—either in a Michael or a Wittig–Horner reaction.

VERY little is known on the Wittig–Horner reaction of α,β-unsaturated ketones. Freeman[1] has outlined the possible routes in the reaction of such α,β-unsaturated ketones with Wittig reagents proper.

In his studies, he observed a Michael-type reaction only between triphenylphosphinemethylene and benzylidene-acetomesitylene; he also reported that the latter did not react with triethyl phosphonoacetate.

Pudovik *et al.*[2,3] have described the 1,4-addition of triethyl phosphonoacetate and diethyl 2-oxopropylphosphonate to benzalacetone, 3-penten-2-one and similar simple unsaturated ketones in the presence of sodium ethoxide.

We have studied the question whether the phosphonate anion

$$[R{\cdot}CH{\cdot}P(=O)(OEt)_2]^-$$

will undergo preferably the Wittig–Horner or the Michael reaction. Fiszer and Michalski[4] have reported that the reaction of chalcone with triethyl phosphonoacetate (I) in the form of its potassio- or sodio-enolate (prepared with the metals) in benzene gives two compounds, formulated as II and III, the mono- and di-Michael adducts of I to chalcone; the yields were 35 and 37% respectively. The m.ps of the two compounds were given as 240–241° and 261–262°, respectively.

Our observations on the above systems, mostly carried out under somewhat different conditions, do not agree with the results of the Polish authors. When chalcone was condensed with I or with diethyl benzylphosphonate (IV) in the presence of *sodium hydride* and in *diglyme* as solvent, only the Wittig–Horner reaction took place, leading to the ethyl ester of the known 2,4-diphenylbutadiene-1-carboxylic acid (V) and 1,2,4-triphenylbutadiene (VI), respectively. When *sodium ethoxide* in *benzene* was used as catalyst, triethyl phosphonoacetate (I) reacted with two molecules of chalcone in a double Michael reaction, and the expected product (III) cyclised spontaneously to diethyl 1-benzoyl-5-carbethoxy-2,4,6-triphenylcyclohex-1-ene-5-carboxylate (VII). Equally, diethyl benzylphosphonate (IV) gave with chalcone the double Michael product VIII, no subsequent cyclisation taking place. However, part of the chalcone was dimerized to the known 1,2-dibenzoyl-3,4-diphenylcyclobutane (IX).

The *mono*-Michael adduct (X) was obtained when chalcone was condensed with IV in the presence of *sodamide* in *ether*. The analogous product II, m.p. 52–54° was formed

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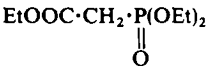
* This study forms part of the Ph.D. thesis of A. Solomonovici, to be submitted to the Hebrew University of Jerusalem.

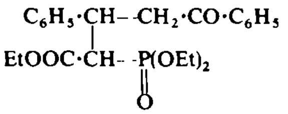
under these conditions also from chalcone and triethyl phosphonoacetate (I), although part of the starting materials was recovered unchanged. When we treated chalcone with triethyl phosphonoacetate in *benzene* and in the presence of *metallic sodium*, about half of the ketone was recovered unchanged and half was converted into the ester V. The latter was hydrolysed to the acid of m.p. 142–144°. Diethyl benzylphosphonate gave under the same conditions a very small amount of the di-adduct VIII.

The structures of the new products were assigned on the basis of the combustion analysis and the spectral data. It is noteworthy that the electronic spectrum of compound VII shows an absorption which is not much different from that of a saturated phenyl ketone. This may be due to the high degree of substitution in this compound. Obviously, compound VII contains the substituents of the double bond in *cis*-conformation.



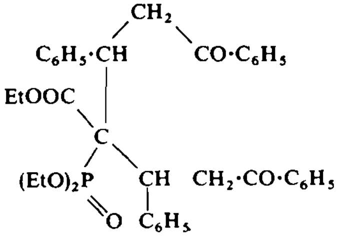
$$\mathrm{EtOOC\cdot CH_2\cdot \underset{\underset{O}{\|}}{P}(OEt)_2}$$

I

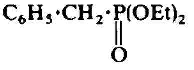


$$\begin{array}{l}\mathrm{C_6H_5\cdot CH-CH_2\cdot CO\cdot C_6H_5}\\ \qquad\quad |\\ \mathrm{EtOOC\cdot CH-\underset{\underset{O}{\|}}{P}(OEt)_2}\end{array}$$

II



III



$$\mathrm{C_6H_5\cdot CH_2\cdot \underset{\underset{O}{\|}}{P}(OEt)_2}$$

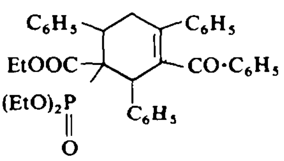
IV

$\mathrm{C_6H_5\cdot CH{=}CH\cdot C(C_6H_5){=}CH\cdot COOEt}$

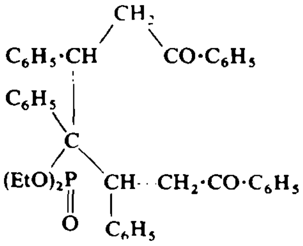
V

$\mathrm{C_6H_5\cdot CH{=}CH\cdot C(C_6H_5){=}CH\cdot C_6H_5}$

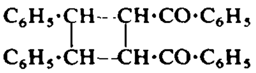
VI



VII

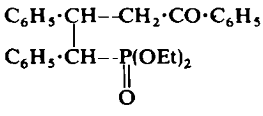


VIII



$$\begin{array}{l}\mathrm{C_6H_5\cdot CH-CH\cdot CO\cdot C_6H_5}\\ \qquad\quad |\qquad\ \ |\\ \mathrm{C_6H_5\cdot CH-CH\cdot CO\cdot C_6H_5}\end{array}$$

IX



$$\begin{array}{l}\mathrm{C_6H_5\cdot CH-CH_2\cdot CO\cdot C_6H_5}\\ \qquad\quad |\\ \mathrm{C_6H_5\cdot CH-\underset{\underset{O}{\|}}{P}(OEt)_2}\end{array}$$

X

EXPERIMENTAL

Ethyl 2,4-diphenylbutadiene-1-carboxylate (V). The solns of 4·48 g of I in 5 ml diglyme and of 4·16 g chalcone in 25 ml of the same solvent were added successively, at room temp and with stirring, to 0·96 g NaH (50%) in 25 ml diglyme. The mixture was heated at 70–80° for 4 hr, poured into 200 ml water and thoroughly extracted with ether. The product boiled at 156–164° (0·6 mm) (lit:[5] 237° (10 mm)); yield, 2·9 g (52%); $\nu_{\mathrm{max}}^{\mathrm{chlf}}$ 1700, 1660, 1605, 1500, 1450, 1170, 750 cm^{-1}. (Found: C, 81·8; H, 6·8. Calcd. for $C_{19}H_{18}O_2$; C, 82·0; H, 6·5).

2,4-*Diphenylbutadiene*-1-*carboxylic acid*. A mixture of 1 g of V in 10 ml ethanol and 0·7 g NaOH in 7 ml water was refluxed for 7 hr. The work-up gave 0·45 g of the free acid (50%), after recrystallisation from cyclohexane; m.p. 142°–144° (lit.[5]: 145°); $\nu_{\mathrm{max}}^{\mathrm{KBr}}$ 1700, 1600, 1500, 1460, 1170, 762 cm^{-1}. (Found: C, 81·6; H, 5·6. Calcd. for $C_{17}H_{14}O_2$: C, 81·6; H, 5·6%).

1,2,4-*Triphenylbutadiene* (VI). In the manner described above, IV was condensed with chalcone, sodium hydride in diglyme serving as catalyst. The crude product was distilled *in vacuo* (b.p. 132–138° (1·2 mm); yield, 0·7 g (50%)) and solidified immediately. From cyclohexane colourless leaflets of m.p. 114–116° (lit.[6]: 110°); $\lambda_{\mathrm{max}}^{\mathrm{EtOH}}$ 297 mμ (log ε 4·65). (Found: C, 93·2; H, 6·6. Calcd. for $C_{22}H_{18}$: C, 93·6; H, 6·4%).

Diethyl 1-*benzoyl*-5-*carbethoxy*-2,4,6-*triphenylcyclohex*-1-*ene*-5-*phosphonate* (VII). Sodium (1 g) was dissolved in 20 ml EtOH and the soln diluted with 35 ml benzene. Then 8·9 g of I and a soln of 8·32 g chalcone in 35 ml benzene were added successively. The mixture was heated at 60° for 11 hr and poured into 250 ml water, whereupon a yellowish solid precipitated. This was filtered and recrystallized from EtOAc, m.p. 207–209°; yield, 2·9 g (24%). A further crop (0·3 g; 2·5%) was obtained by evaporation of the organic layer and recrystallization of the residue from EtOAc; $\lambda_{\mathrm{max}}^{\mathrm{EtOH}}$ 247 mμ (log ε 4·17); $\nu_{\mathrm{max}}^{\mathrm{KBr}}$ 1718, 1680, 1600, 1440, 1250, 1160, 1035, 980, 700 cm^{-1}. (Found: C, 73·3; H, 6·1; P, 5·2; OEt, 21·4. Calcd. for $C_{38}H_{39}O_6P$: C, 73·3; H, 6·3; P, 5·0; OEt, 21·7%).

2,4-*Dinitrophenylhydrazone*, from MeOH orange crystals of m.p. 221–222°. $\nu_{\mathrm{max}}^{\mathrm{KBr}}$ 1680, 1600, 1540, 1250, 1030, 970, 700 cm^{-1}; $\lambda_{\mathrm{max}}^{\mathrm{EtOH}}$ 336 mμ (log ε 4·02). (Found: C, 66·0; H, 5·0; N, 6·9; P, 3·9. Calcd. for $C_{44}H_{43}O_9N_4P$: C, 65·8; H, 5·4; N, 7·0; P, 3·9%).

From the mother liquor of VII, about half of the originally employed chalcone was recovered and identified as 2,4-dinitrophenylhydrazone.

Triethyl 4-benzoyl-3-phenyl-2-phosphonobutyrate (II). The solns of 2·24 g of I in 5 ml ether and 1·04 g chalcone in 10 ml of the same solvent were added successively at room temp to a suspension of 0·4 g sodamide in 20 ml ether. After 16 hr, the mixture was poured into 150 ml water and the solid which precipitated, filtered and recrystallized from hexane, m.p. 52–54°; yield, 0·94 g (42%); $\lambda_{\mathrm{max}}^{\mathrm{EtOH}}$ 243 mμ (log ε 4·11); $\nu_{\mathrm{max}}^{\mathrm{BKr}}$ 1720, 1690, 1600, 1260, 1160, 1030, 975 cm^{-1}. (Found: C, 63·8; H, 6·7; P, 6·9; OEt, 31·2; mol. wt., 432 (mass spectrum). Calcd. for $C_{23}H_{29}O_6P$: C, 63·9; H, 6·7; P, 7·2; OEt, 31·3; mol. wt., 432).

Diethyl 3-*benzoyl*-1,2-*diphenylpropyl*-1-*phosphonate* (X). The solns of 2·28 g of IV in 5 ml ether and of 1·04 g chalcone in 10 ml ether were added successively at room temp to a suspension of 0·6 g sodamide in 30 ml of the same solvent. After 15 hrs, the yellow soln, from which an oily product had separated, was treated with 150 ml water and the ethereal layer worked up as usual. The solid residue was recrystallized from cyclohexane and melted at 128–129°; yield, 0·5 g (24%); $\lambda_{\mathrm{max}}^{\mathrm{EtOH}}$ 243 mμ (log ε 3·85); $\nu_{\mathrm{max}}^{\mathrm{KBr}}$ 1665, 1590, 1440, 1245, 1065, 1032, 970 cm^{-1}. (Found: C, 71·9; H, 6·8; P, 6·8; OEt, 20·6. Calcd. for $C_{26}H_{29}O_4P$: C, 71·6; H, 6·7; P, 7·1; OEt, 20·6%).

When the reaction was carried out with an 1:1 ratio of the two reactants, the yield was somewhat lower.

The *DNP of X* was recrystallized from MeOH and melted at 207–209°; $\lambda_{\mathrm{max}}^{\mathrm{EtOH}}$ 370 mμ (10 g ε 4·40); $\nu_{\mathrm{max}}^{\mathrm{KBr}}$ 1620, 1595, 1520, 1245, 1035, 910, 710 cm^{-1}. (Found: C, 62·6; H, 5·6; N, 9·2; P, 5·1; OEt, 14·3. Calcd. for $C_{32}H_{33}O_7N_4P$: C, 62·3; H, 5·4; N, 9·1; P, 5·0; OEt, 14·6%).

1,2-*Dibenzoyl*-3,4-*diphenylcyclobutane* (IX) *and diethyl* 1,5-*dibenzoyl*-2,3,4-*triphenylpentyl*-3-*phosphonate* (VIII). A soln of NaOEt, prepared from 1 g Na and 20 ml EtOH, was diluted with 30 ml benzene, and 9·12 g of IV and a soln of 8·32 g chalcone in 35 ml benzene were added successively at room temp. After 11 h at 60°, the mixture was treated with 200 ml water and worked up as usual. The resulting brown-red oil was treated with benzene; thus, a *solid product* was obtained which was recrystallized from benzene and melted at 249–250°; yield, 1·3 g (8%). It was phosphorus-free and proved to be 1^c, 2^t-dibenzoyl-3^c, 4^t-diphenylcyclobutane ("neotruxin diphenyl diketone") for which the literature[7] gives a m.p. of 250°; $\lambda_{\mathrm{max}}^{\mathrm{EtOH}}$ 250 mμ (log ε 4·01); $\nu_{\mathrm{max}}^{\mathrm{KBr}}$ 1660, 1600, 1495, 1450, 1225, 1070, 980, 705 cm^{-1}. (Found: C, 86·2; H, 6·1. Calcd. for $C_{30}H_{24}O_2$: C, 86·5; H, 5·8%).

The *benzene mother liquor* was concentrated, giving some unchanged chalcone, and then evaporated and the residue distilled *in vacuo*. After a head fraction of diethyl benzylphosphonate (b.p. 93–102° (0·2 mm);

yield, 1·5 g, (17%), the product VIII boiled at 188–208° (0·1 mm); yield, 0·25 g (1%); λ_{max}^{EtOH} 245 mμ (log ε 4·28); 306 mμ (log ε 4·18); ν_{max}^{chlf} 1665, 1605, 1580, 1500, 1450, 1250, 1060, 1030, 970 cm^{-1}. (Found: C, 77·0; H, 7·0; P, 4·7; OEt, 13·5. Calcd. for $C_{41}H_{41}O_5P$: C, 76·4; H, 6·4; P, 4·8; OEt, 14·0%).

REFERENCES

[1] J. P. Freeman, *J. Org. Chem.* **31**, 538 (1966), where also an extensive literature survey is given

[2] A. N. Pudovik and N. M. Lebedeva, *Zh. Obshchei Khim.* **22**, 2128 (1952); *Chem. Abstr.* **48**, 564 (1954)

[3] A. N. Pudovik and N. M. Lebedeva, *Dokl. Akad. Nauk* **90**, 799 (1953); *Chem. Abstr.* **50**, 2429 (1956)

[4] B. Fiszer and J. Michalski, *Roczniki Chem.* **28**, 185 (1954); **34**, 1461 (1960); *Chem. Abstr.* **49**, 9493 (1955) **55**, 15331 (1961)

[5] J. Bloom and C. K. Ingold, *J. Chem. Soc.* 2765 (1931)

[6] F. Bergmann and E. Bergmann, *J. Am. Chem. Soc.* **62**, 1699 (1940)

[7] R. Stoermer, H. Starck and H. E. Anker, *Ber. Dtsch. Chem. Ges.* **70**, 483 (1937)