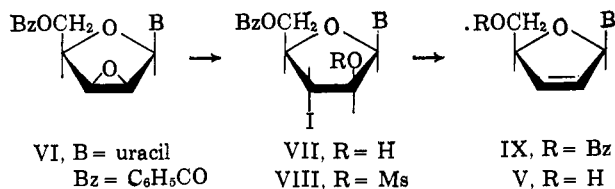


The identity of V was established by independent synthesis which utilized 1-(5'-*O*-benzoyl-2',3'-epoxy- β -D-lyxosyl)uracil (VI)⁷ as starting material and a method described recently for the introduction of a 2,3-double bond into a hexose.⁸ Scission of the epoxide ring in VI with sodium iodide in acetone containing 1 equiv. of acetic acid gave a single isolable iodohydrin (55% yield), m.p. 198–200° dec., $[\alpha]^{25D} +41^\circ$ (*c* 1.0, acetone) $\lambda_{\max}^{\text{EtOH}}$ (m μ) 261, 229 (ϵ 8710, 19,640), $\lambda_{\min}^{\text{EtOH}}$ (m μ) 248, 214 (ϵ 7330, 16,730), to which the structure 1-(5'-*O*-benzoyl-3'-deoxy-3'-iodo- β -D-arabinosyl)uracil (VII) has been tentatively assigned.⁹ The latter was converted to a 2'-*O*-mesylate (VIII, 50% yield), m.p. 114–116°, $[\alpha]^{20D} +41^\circ$ (*c* 0.8, acetone), $\lambda_{\max}^{\text{EtOH}}$ (m μ) 260, 232 (ϵ 10,100, 14,300), $\lambda_{\min}^{\text{EtOH}}$ (m μ) 249 (ϵ 8760), and treated with sodium iodide in acetone. Reaction occurred at 0° with elimination of iodine and the methanesulfonyloxy group to give 1-(5'-*O*-benzoyl-2',3'-dideoxy-2'-ene- β -D-glycero-pentofuranosyl)uracil (IX) in 70% yield, m.p. 139–140°, $[\alpha]^{25D} -107^\circ$ (*c* 0.5, acetone), $\lambda_{\max}^{\text{EtOH}}$ (m μ) 261, 230 (ϵ 9330, 14,320), $\lambda_{\min}^{\text{EtOH}}$ (m μ) 246, 217 (ϵ 7300, 12,005). Saponification of the benzoate ester in IX gave a solid which proved to be identical in every respect with V.

Studies are currently in progress to expand the scope of elimination reactions as applied to anhydro nucleosides. The results will be described in detail in the near future.



Acknowledgment.—This work was supported in part by research grants CA-02903 and CY-5943 from the National Cancer Institute, Public Health Service, and in part by an institutional grant from the United Foundation of Greater Detroit allocated through the Michigan Cancer Foundation.

(7) J. F. Codington, R. Fecher, and J. J. Fox, *J. Org. Chem.*, **27**, 163 (1962).

(8) N. F. Taylor and G. M. Riggs, *J. Chem. Soc.*, 5600 (1963).

(9) This assignment is in accord with the normal course of opening of sugar- or nucleoside-2,3-epoxides which occurs predominantly at C-3 [see C. D. Anderson, L. Goodman, and B. R. Baker, *J. Am. Chem. Soc.*, **81**, 898 (1959)]. However, it is to be noted that either of the two possible *trans* iodohydrins should lead to the introduction of a 2',3'-double bond in this alternate synthesis of V.

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Photolysis of Thiobenzophenone in the Presence of Olefins: A Novel Reaction

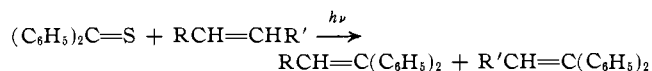
Sir:

A study of the light-catalyzed reactions of thiobenzophenone in alcoholic solvents was reported recently.¹

(1) G. Oster, L. Citarel, and M. Goodman, *J. Am. Chem. Soc.*, **84**, 703 (1962).

Its photolytic behavior was found to differ considerably from that of benzophenone²; irradiation with near-ultraviolet light in the absence of oxygen gave the reduction products benzhydryl mercaptan, dibenzhydryl disulfide, and a tetrasulfide from thiobenzophenone, whereas dibenzopinacol is produced from benzophenone.

The addition of carbonyl compounds to olefins under the influence of light to give oxetanes is a well known reaction.^{3–6} In view of the contrast presented by the photochemical results for thiobenzophenone and benzophenone which have been noted above, it was of interest to us to determine what course the irradiation of the thioketone in the presence of olefins would take. In the present communication we report the novel photolytic reaction which thiobenzophenone undergoes with olefins, as described below for *cis*-2-butene and 1-hexene.



cis-2-Butene (Matheson) and nitrogen were bubbled continuously through a solution of thiobenzophenone⁷ (2.2 g.) in cyclohexane (170 ml.) which was irradiated with a Hanovia No. 608A-36 lamp.⁸ After 4 hr. the thioketone had completely reacted, as evidenced by the disappearance of its blue color. The solvent and excess *cis*-2-butene were removed under reduced pressure, and the residue was distilled at 0.5 mm. giving a light blue-tinged liquid. Chromatography of the liquid on Woelm Activity Grade 1 acid alumina with petroleum ether (b.p. 30–60°) as the eluent gave a white crystalline solid (0.71 g.), m.p. 47–49°. Recrystallization of the solid from 95% ethanol yielded pure 1,1-diphenyl-1-propene (0.5 g., 23% yield based on thiobenzophenone), m.p. 49–50°; a mixture melting point with an authentic sample prepared by the dehydration of 1,1-diphenyl-1-propanol was undepressed (lit.^{9,10} m.p. 51°, 51–52°). When the photolysis was carried out using *trans*-2-butene, the same reaction occurred, yielding an equal amount of 1,1-diphenyl-1-propene.

In order to ascertain what, if any, specificity thiobenzophenone exhibits in its reactions with olefins, it was treated photochemically with the terminal olefin, 1-hexene. A mixture of thiobenzophenone (2.0 g.) and 1-hexene (65 ml., Phillips 99 mole %) was irradiated for 5 hr. while a slow stream of nitrogen was bubbled through. The solvent and 1-hexene were removed under reduced pressure, and the residue was distilled at 0.1 mm. giving a clear liquid. Chromatography on

(2) J. N. Pitts, R. L. Letsinger, R. P. Taylor, J. M. Patterson, G. Recktenwald, and R. B. Martin, *ibid.*, **81**, 1068 (1959).

(3) E. Paterno and G. Chieffii, *Gazz. chim. ital.*, **39**, 341 (1909).

(4) G. Büchi, C. G. Inman, and E. S. Lipinsky, *J. Am. Chem. Soc.*, **76**, 4327 (1954).

(5) R. Srinivasan, *ibid.*, **82**, 775 (1960).

(6) J. F. Harris, Jr., and D. D. Coffman, *ibid.*, **84**, 1553 (1962).

(7) R. H. Abeles, R. F. Hutton, and F. H. Westheimer, *ibid.*, **79**, 712 (1957).

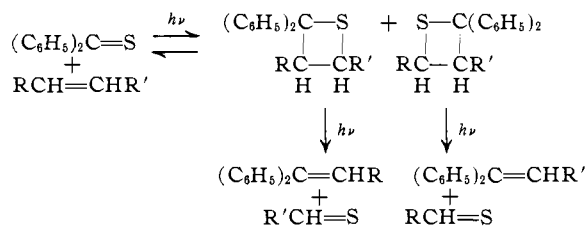
(8) The reaction did not proceed when a Pyrex filter was placed between the lamp and the photolysis mixture. However, the reaction was not affected by the placement of a Vycor filter between the lamp and the photolysis mixture. This suggests that the reaction observed is due to irradiation with light in the range 210–280 m μ . It has been previously shown in ref. 1 that thiobenzophenone in an inert solvent, cyclohexane, and in the absence of oxygen undergoes a net chemical change when irradiated with far-ultraviolet light (254 m μ). However, the products of this reaction were not isolated.

(9) R. Lagrave, *Ann. chim. (Paris)*, [10] **8**, 386 (1927).

(10) K. V. Auwers, *Ber.*, **62**, 693 (1929).

60 g. of Woelm Activity Grade 1 acid alumina gave 0.32 g. of an oil upon elution with 600 ml. of petroleum ether. Analysis of this oil by gas chromatography and n.m.r., and comparison with known mixtures, showed that it was composed of $60 \pm 3\%$ of 1,1-diphenyl-1-hexene⁹ and $40 \pm 3\%$ of 1,1-diphenylethylene. Hence, the more highly substituted olefinic product is formed in slight preference to the less highly substituted one, but it appears that thiobenzophenone is not very selective in its photochemical reaction with a simple terminal olefin.

We have succeeded in extending this reaction to other olefins. A possible mechanistic route which is in agreement with our observations involves the addition of thiobenzophenone to the olefin to give a cyclic sulfide, followed by the decomposition of the cyclic sulfide to the products.¹¹



Studies in our laboratory on the mechanism and scope of the photochemical reaction of thiobenzophenone with olefins and its extension to other thioketones are being actively pursued.¹²

(11) This mechanism leads to several predictions which can be tested. Among these is the obvious requirement that the cyclic sulfides which have been postulated as intermediates should be capable of reacting in the manner indicated. Experiments on this fundamental point are in progress. Furthermore, since aliphatic thioketones and thioaldehydes are generally unstable as monomers and tend to trimerize, it is quite likely that trimeric and other polymeric sulfur-containing compounds are produced from $\text{RCH}=\text{S}$ and $\text{R}'\text{CH}=\text{S}$ in our photolyses.

(12) This work was initiated while both authors were in the Department of Chemistry at Washington University, St. Louis. We wish to express our gratitude to Professor C. D. Gutsche for permission to use his photolytic equipment and Dr. G. L. Bachman for carrying out some of the exploratory experiments.

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Phosphonic Acids and Esters. VII.¹ Intramolecular Electrophilic Catalysis of Phosphonate Ester Hydrolysis by Neighboring Carboxyl

Sir:

The hydrolysis of dialkyl arylphosphonates to the corresponding phosphonic acids is well known to require pH extremes^{2,3} and vigorous conditions, e.g., refluxing concentrated hydrobromic acid for 24 hr. On the other hand, the hydrolysis of alkyl and aryl phosphates is much more facile,⁴ and numerous examples of intramolecular facilitation of phosphate hydrolyses have been reported.^{5,6} We have observed

(1) Part VI: D. J. Martin and C. E. Griffin, *J. Organometallic Chem.*, **1**, 292 (1964).

(2) Acidic hydrolyses: K. Sasse, "Methoden der Organischen Chemie," Vol. XII/1, E. Muller, Ed., Georg Thieme Verlag, Stuttgart, 1963, pp. 352-356; R. F. Hudson and L. Keay, *J. Chem. Soc.*, 2463 (1956).

(3) Basic hydrolyses: R. Rabinowitz, *J. Am. Chem. Soc.*, **82**, 4564 (1960).

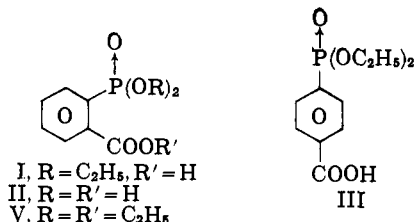
(4) G. S. Hartley, Special Publication No. 8, The Chemical Society, London, 1957, pp. 33-40.

(5) F. R. Atherton, *ibid.*, pp. 77-88.

(6) M. L. Bender and J. M. Lawlor, *J. Am. Chem. Soc.*, **85**, 3010 (1963), and references cited therein.

the occurrence of similar intramolecular assistance in a dialkyl arylphosphonate leading to hydrolysis under extremely mild conditions with an extraordinarily large enhancement of the rate of hydrolysis.

The initial observation of this rate enhancement was made during the attempted recrystallization of diethyl *o*-carboxyphenylphosphonate (I) from hot water; after a relatively short contact period, only the free acid (II) was recovered. Hydrolysis of I in DMSO-*d*₆ containing 2 molar equiv. of D₂O gave II and ethanol and was essentially complete after 7 hr. at 36°.⁷ In



30% aqueous DMSO at 36°, I underwent similar hydrolysis to II with a half-life of 15.0 min.; under identical conditions, the *para* isomer (III) underwent no detectable hydrolysis during a period of 77,960 min. Since a minimum of 0.4% of ethanol could be detected in this system, the rate of hydrolysis of I is at least 7.85×10^7 times greater (pseudo-first-order calculations) than that of the *para* isomer in which no intramolecular catalysis is possible. Further evidence for the intramolecular nature of the observed catalysis was provided by the failure of a 1:1 mixture of diethyl phenylphosphonate and benzoic acid to undergo hydrolysis under these conditions at a detectable rate.

The sodium salt (IV) of I underwent approximately 30% hydrolysis to a salt of II in D₂O at 36° during a period of 1 week; acidification of this solution of partially hydrolyzed sodium salt with 1:1 hydrochloric acid led to immediate hydrolysis at the rate observed for the hydrolysis of I. The ethyl ester (V) failed to undergo detectable hydrolysis under these conditions.⁸ Hydrolysis of I in wet benzene proceeded (with precipitation of II) at a rate comparable to that in aqueous DMSO, indicating that catalysis of hydrolysis by II is probably negligible.

These results indicate that the un-ionized carboxyl group is involved in the facilitation of hydrolysis, probably by assistance in removal of ethanol by a proton transfer to give the zwitterion VI in a manner analogous to that postulated by Bender and Lawlor in the hydrolysis of salicyl phosphate.⁶ Alternatively, proton transfer from carboxyl to phosphoryl giving zwitterion VII may be involved¹²; in either case, proton transfer

(7) Hydrolyses were conveniently followed by proton magnetic resonance spectra determinations. Quantitative determinations of the relative amounts of I and ethanol were obtained from integrals of methylene peaks [I, τ 5.83 (center of quintet); ethanol, τ 6.50 (center of quartet)] in DMSO-*d*₆; plots of the integrals gave good mirroring curves. All p.m.r. spectra were determined with a Varian Associates A-60 spectrometer; integrals were obtained at a sweep width of 250 c.p.s.

(8) Compounds I, V, and the ethyl ester of III were prepared by photolysis of the corresponding aryl iodide in the presence of triethyl phosphite.⁹ Compound III was prepared by partial saponification of its ethyl ester,¹⁰ III¹¹ was isolated by recrystallization of I from water, and IV was prepared by neutralization of I with sodium hydroxide in DMSO. All compounds gave satisfactory elemental analyses and their spectra (infrared, p.m.r., and ultraviolet) were consistent in all respects with assigned structures.

(9) J. B. Plumb and C. E. Griffin, *J. Org. Chem.*, **27**, 4711 (1962).

(10) L. D. Freedman and H. H. Jaffé, *J. Am. Chem. Soc.*, **77**, 920 (1955).

(11) L. D. Freedman, H. Tauber, G. O. Doak, and H. J. Magnuson, *ibid.*, **75**, 1379 (1953).