Evidence for the Isomerization of 2,3-Dibenzoyl-2-propen-1-ol to 2,3-Dibenzoylpropanal[1,2]
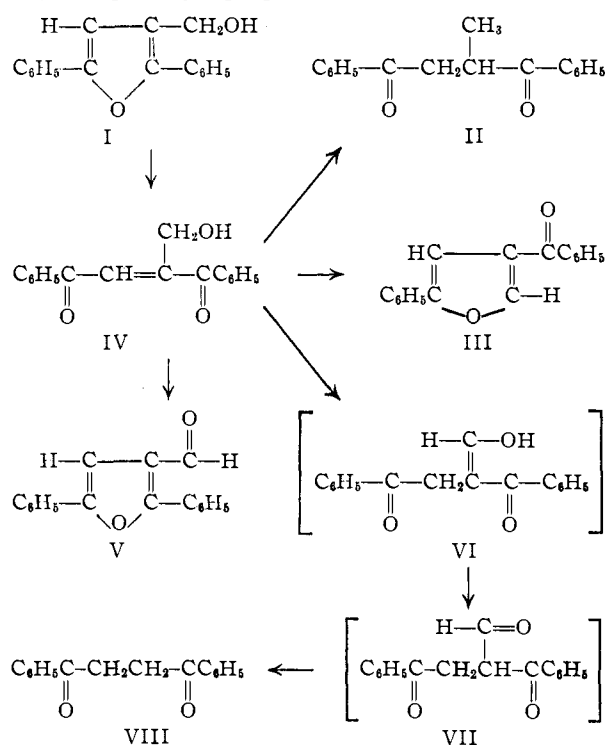
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Received August 19, 1953

This paper is concerned with the preparation and novel reactions of 2,3-dibenzoyl-2-propen-1-ol. The reactions include catalytic and metal combination reduction to 1,2-dibenzoylpropane, cyclization to 4-benzoyl-2-phenylfuran, cyclization to 3-formyl-2,5-diphenylfuran, and loss of carbon and oxygen to form 1,2-dibenzoylethane upon treatment with sodium hydroxide or secondary amines. The latter reaction of the propenol can best be explained on the basis of its isomerization to 2,3-dibenzoylpropanal through the 1,3-shift of hydrogen discussed in earlier papers. Possible mechanisms for the other reactions are given.

In view of the interesting reactions of cis-1,2-dibenzoyl-3-(4-morpholinyl)-propene discussed in an earlier paper,[3] it seemed desirable to synthesize and study the reactions of the structurally similar 2,3-dibenzoyl-2-propen-1-ol (IV). The synthesis of IV consisted of the hydrolysis of 3-(chloromethyl)-2,5-diphenylfuran[4] to 3-(hydroxymethyl)-2,5-diphenylfuran, (I)[3] followed by the nitric acid oxidation of I to IV. Because of the method of preparation, the propenol IV presumably has the cis configuration.[5]

Two of the reactions of the dibenzoylpropenol IV are analogous to the reactions of 1,2-dibenzoyl-3-(4-morpholinyl)-propene.[3] It is easily converted to 1,2-dibenzoylpropane (II) through a combination hydrogenolysis and hydrogenation using either zinc and acetic acid or hydrogen with a catalyst. The reduction of the morpholinyl compound differed from this only in the respect that zinc and acetic acid reduction gave 1,2-dibenzoyl-3-(4-morpholinyl)-propane.[3]

The other reaction of the dibenzoylpropenol IV analogous to that of the morpholinylpropene was the easy cyclization, through the loss of water, to give 4-benzoyl-2-phenylfuran (III). Though this reaction has not been observed to occur spontaneously, as does the cyclization of the morpholinylpropene,[3] it occurs in good yield when IV is heated with pyridine in ethanol solution or in fair yield when treated with acetyl chloride or triethylamine at room temperature. A possible mechanism for these cyclizations of the morpholinylpropene was given in the earlier paper.[3]

Like the morpholinylpropene the dibenzoylpropenol IV will also cyclize to 3-formyl-2,5-diphenylfuran (V), but under considerably different conditions. Whereas the morpholinylpropene cyclized only in the presence of concentrated methanolic hydrogen chloride,[3] the propenol cyclized when an absolute ethanol solution of it was refluxed. The reaction did not occur when 95% ethanol was used. Two possible mechanisms suggest themselves for these reactions. One was discussed in the earlier paper concerning the morpholinylpropene[3]; it involves the formation and readjustment of an intermediate such as IX. The other involves the isomerization of the propenol IV to 2,3-dibenzoylpropanal (VII) followed by cyclization to V. This isomerization would have to proceed through the 1,3-shift of hydrogen (to give VI) found in earlier work to be common in the reactions of 1,2-dibenzoylpropene and similar compounds.[4,6] The morpholinylpropene could also undergo similar changes, since acidic conditions are required, involving intermediates X and XI.

Because it explains why acidic conditions are required for the cyclization of the morpholinylpropene, but not the propenol, to V, we tend to favor the second mechanism. One is tempted, in fact, to assume that VII is an intermediate in both cyclizations of the propenol IV, to V through its 1,4-diketo system, and to III through its 1,4-aldo-keto system. However, it seems unlikely that the slight

(1) This is the eighth in a series of papers dealing with 1,3- or 1,5-shifts of hydrogen in the reactions of dibenzoylalkenes and related compounds. For paper seven see P. S. Bailey and S. H. Pomerantz, This Journal, 75, 281 (1953).

(2) This paper was given, in part, before the Organic Chemistry Division of the American Chemical Society at the September, 1950, Meeting in Chicago, Illinois.

(3) P. S. Bailey and R. E. Lutz, This Journal, 67, 2232 (1945).

(4) Prepared from 1,2-dibenzoylpropene as described by P. S. Bailey, G. Nowlin, S. H. Pomerantz, J. V. Waggoner and E. E. Kawas, ibid., 73, 5560 (1951).

(5) R. E. Lutz and F. N. Wilder, ibid., 56, 1193 (1934).
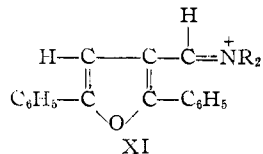
(6) (a) R. E. Lutz and P. S. Bailey, ibid., 67, 2229 (1945); (b) P. S. Bailey and G. Nowlin, ibid., 71, 732 (1949); (c) P. S. Bailey and W. W. Hakki, ibid., 71, 2886 (1949); (d) P. S. Bailey and S. H. Pomerantz, ibid., 75, 281 (1953).

IX
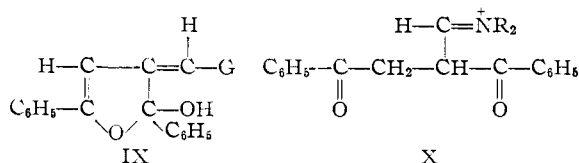
a, G = OH
b, G = morpholinyl

X

XI

NR₂ = morpholinyl

difference in conditions involved would cause VII to cyclize entirely to V one time and entirely to III the other. Also, since the cyclization to III is spontaneous for the morpholinylpropene and nearly so for the propenol, it seems likely that the mechanisms are similar. This could not involve intermediate X for the morpholinylpropene since the reaction conditions are not acidic.

The most interesting reaction of 2,3-dibenzoyl-2-propen-1-ol (IV) is one that would be difficult to explain on any basis other than its isomerization to 2,3-dibenzoylpropanal (VII). When treated with sodium hydroxide in aqueous ethanol solution, or with morpholine or diethylamine in ether solution, IV is converted to 1,2-dibenzoylethane (VIII). Although no logical mechanism for this result directly from IV suggests itself, there are two possible paths by which dibenzoylethane (VIII) could be formed from VII. One is hydrolysis, or aminolysis, and there is ample analogy for such reactions with 1,3-aldo-keto systems such as that present in VII. The other is a Cannizarro-type reaction of VII. The high yield of dibenzoylethane from the morpholine reaction would certainly seem to eliminate the Cannizarro mechanism and cause one to favor the aminolysis mechanism. However, in the sodium hydroxide reaction the failure to find sodium formate in the reaction mixture tends to cast doubt on a hydrolysis mechanism in this case. So far, all efforts to further establish the mechanism have not been fruitful.

The formation of dibenzoylethane from IV, plus some qualitative tests made on IV, caused us to wonder whether the isomerization to VII occurred at the time of reaction or whether it occurred during the preparation of IV from I. The compound decolorizes acetone–potassium permanganate solutions and carbon tetrachloride–bromine solutions much slower than does 1,2-dibenzoylpropene. Also, it readily reduces Fehling solution and Tollens reagent.[7] The infrared spectra of IV, however, shows a strong hydroxyl band at 2.88 μ; also, the reduction experiments cannot be explained on the basis of the propanal structure. The structure assigned to IV, therefore, seems to be correct. The reaction leading to dibenzoylethane, however, can-

(7) Of course, the Fehling solution and Tollens reagent tests involve alkaline conditions which could promote the isomerization to 2,3-dibenzoylpropanal (VII). Also, 2,3-dibenzoyl-2-propen-1-ol (IV) is a vinylog of an α-hydroxyketone and substances like benzoin are known to reduce these reagents.

not be explained without assuming an easy base-catalyzed isomerization to 2,3-dibenzoylpropanal.

Experimental

3-(Hydroxymethyl)-2,5-diphenylfuran (I).—A mixture of 10 g. of 3-(chloromethyl)-2,5-diphenylfuran,[4] 150 ml. of ethanol and 60 ml. of a 4% sodium hydroxide solution was refluxed with stirring for 25 minutes; solution occurred after 10 minutes. The solvent was then removed under an air blast and the residue was washed with ligroin and filtered off; m.p. 113–118°; recrystallized from 60% ethanol, m.p. 121–123°; identified as I by a mixture melting point with an authentic sample.[3] The yield varied from 4 to 6 g. in several runs (43–63%).

2,3-Dibenzoyl-2-propen-1-ol (IV).—To a solution of 5 g. of 3-(hydroxymethyl)-2,5-diphenylfuran (I) in 40 ml. of propionic acid, cooled to −5°, was added a cooled solution of 7 ml. of concentrated nitric acid in 20 ml. of propionic acid. The mixture was kept at −5° for 15 minutes, after which it was neutralized by pouring into a mixture of ice and sodium carbonate solution. Extraction with ether, drying and evaporation of the ether, and crystallization of the residue from 50% ethanol or benzene–ligroin mixtures gave crystals melting at 107–109°; recrystallized same way, m.p. 111–112°; yield 70%.

Anal. Calcd. for C₁₇H₁₄O₃: C, 76.67; H, 5.30. Found: C, 76.67; H, 5.08.

The compound gave positive Fehling solution and Tollens reagent tests. An acetone solution of it decolorized 5 drops of a dilute acetone–potassium permanganate solution in 3 minutes, whereas 1,2-dibenzoylpropene decolorized 10 drops immediately. A carbon tetrachloride solution of it failed to decolorize 2 drops of a 5% bromine–carbon tetrachloride solution until put in strong sunlight where the decolorization occurred with the evolution of hydrogen bromide. An equivalent amount of 1,2-dibenzoylpropene in carbon tetrachloride solution decolorized 15 drops of the bromine solution in ordinary light without the evolution of hydrogen bromide.

Catalytic reduction of IV at atmospheric pressure with platinum oxide in ethanol involved absorption of 2 moles of hydrogen in 1.5 hours; yield of II, 74%, m.p. 103–105°, identified by mixture m.p. with an authentic sample.[8]

Reduction of IV with zinc and acetic acid for 5 minutes by the usual method gave an 80% yield of 1,2-dibenzoylpropane (II), m.p. 102–105°, mixture m.p. undepressed. When the reaction was stopped after 1 minute the results were the same but the yield was lower.

Cyclization of IV to 4-Benzoyl-2-phenylfuran (III)[9] (a). With Pyridine.—A solution of 0.4 g. of IV, 6 ml. of absolute ethanol and 6 ml. of pyridine was refluxed for 2 hours. The solvent was removed by a stream of air and the residue was triturated with cold water, whereupon it crystallized; recrystallized from ethanol, yield 90%, m.p. 112–114°.

(b) With Acetyl Chloride.—A solution of 1 g. of IV in 10 ml. of acetyl chloride was allowed to stand at room temperature for 30 minutes, after which it was poured onto ice and the resulting mixture was extracted with ether. The ether extract was washed, dried and evaporated and the residue was recrystallized from ethanol; 0.4 g. (43% yield); m.p. 113–115°.

(c) With triethylamine in ether solution overnight, IV was converted to VI in about the same yield as in part (b).

Cyclization of IV to 3-Formyl-2,5-diphenylfuran (V).—A solution of 0.3 g. of IV in 15 ml. of absolute ethanol was refluxed for 2 hours after which it was poured into water and the resulting mixture was extracted with ether. Evaporation of the ether and recrystallization of the residue from ethanol gave 0.25 g. (90% yield) of material melting at 85–87°; identified as V by a mixture melting point with an authentic sample.[3] When 95% ethanol was used, only starting material was recovered. Likewise, no reaction was obtained with ligroin or with carbon tetrachloride.

In three experiments the oxime of V was obtained when IV was treated with hydroxylamine by the pyridine method[10];

(8) R. E. Lutz and R. J. Taylor, THIS JOURNAL, 55, 1168 (1933).

(9) R. C. Fuson, C. L. Fleming and R. Johnson, *ibid.*, 60, 1994 (1938). Identifications below were made by the mixture melting point method.

(10) R. L. Shriner and R. C. Fuson, "Identification of Organic Compounds," 2nd Edition, John Wiley and Sons, Inc., New York, N. Y., 1940, p. 167.

identification by mixture melting point method.[3] In about ten other attempts, however, this result could not be accomplished.

Reaction of IV with Morpholine or Diethylamine to Give 1,2-Dibenzoylethane (VIII).—A solution of 2 g. of IV, 10 ml. of morpholine or diethylamine and 10 ml. of ether was allowed to stand at room temperature overnight. The reaction mixture was then diluted with ether, extracted with water and evaporated. Several recrystallizations of the residue from ethanol gave 1.5 g. (85% yield) of material melting at 143–145° which was shown to be 1,2-dibenzoylethane (VIII) by a mixture melting point with an authentic sample.[11]

Reaction of IV with Sodium Hydroxide to Give VIII.—A solution of 2 g. of IV, 70 ml. of ethanol and 75 ml. of 4% sodium hydroxide solution was allowed to stand overnight, after which was added 50 ml. of 0.5% aqueous sodium hydroxide and 10 ml. of ethanol and the mixture was allowed

(11) P. S. Bailey and R. E. Lutz, THIS JOURNAL, **70**, 2412 (1948).

to stand for 6 days. A precipitate formed, was filtered off and triturated with cold ethanol; 0.8 g. (43% yield) of VIII, m.p. 136–140°; recrystallized from ethanol, m.p. 143–145°; identification by the mixture melting point method. From the filtrate, after some evaporation, was obtained 0.7 g. of an intractable oil. The filtrate was diluted with water and acidified with phosphoric acid; some carbon dioxide was evolved and 0.1 g. of an intractable oil precipitated. The filtrate was steam distilled; the distillate was made alkaline and reduced in volume to 10 ml. A test for formic acid, made with S-benzylthiouronium chloride according to the directions of Wild, was negative.[12]

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Cyclic Dienes. VI. Synthesis of Substituted 1,2-Dimethylenecyclohexanes[1,2]

BY WILLIAM J. BAILEY,[3] JOSEPH ROSENBERG[4] AND LEWIS J. YOUNG[5]

By pyrolyzing a diacetate in the final step of the procedure, 4,5-dimethyl-1,2-dimethylenecyclohexane (III) was synthesized in five steps in an over-all yield of 75%. Similarly, 4-methyl-1,2-dimethylenecyclohexane (II) was synthesized in four steps in an over-all yield of 75%. The structures of these two cyclic dienes were proved by analysis, ultraviolet absorption and conversion to known derivatives. The method of synthesis illustrates a procedure for ascending a series by the addition of a cyclohexane ring.

The synthesis of 1,2-dimethylenecyclohexane (I) in high yield by the pyrolysis of a diacetate,[6] was recently reported from this Laboratory. This diene is of interest since it is a cyclic diene that will give multicyclic Diels–Alder adducts and at the same time it is a 2,3-disubstituted butadiene that will undergo free radical polymerization. It was shown that the reaction of two molecules of I with quinone produced a pentacyclic adduct that could be converted to pentacene.[7] It was further noted that this diene should polymerize to yield an all-cis diene polymer and should serve as a source of cyclodecane derivatives. In order to show that the pyrolysis of esters is an excellent general method for the synthesis of dienes with rather strained exocyclic double bonds, the synthesis of 4-methyl- and 4,5-dimethyl-1,2-dimethylenecyclohexane (II and III) was undertaken. These dienes would be useful in order to determine the effect of substituents on the properties of an all-cis polymer and to produce substituted linear condensed polynuclear hydrocarbons.

Although 1,2-dimethylenecyclohexane (I) was synthesized from diethyl phthalate, the substituted phthalic acids required for the synthesis of II and III were not readily available. However, the substituted tetrahydrophthalic acid derivatives

(1) Previous paper in this series, THIS JOURNAL, **76**, 1940 (1954).

(2) Presented at the 119th National Meeting of the American Chemical Society, April, 1951, Cleveland, Ohio.

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(4) Office of Naval Research Fellow, 1950–1951.

(5) Office of Naval Research Fellow, 1949–1950; Atomic Energy Commission Fellow, 1950–1952.

(6) W. J. Bailey and H. R. Golden, THIS JOURNAL, **75**, 4780 (1953).

(7) W. J. Bailey and M. Madoff, ibid., **75**, 5603 (1953).

were readily available through the Diels–Alder reaction of a diene plus maleic anhydride. Thus 2,3-dimethylbutadiene (IV) was treated with maleic anhydride to give a 95% yield of the adduct 4,5-dimethyl-Δ^4-tetrahydrophthalic anhydride (V). Reduction of V with lithium aluminum hydride gave a good yield of 4,5-dimethyl-Δ^4-tetrahydrophthalyl alcohol (VI), provided that care was taken never to let the solution become more acidic than pH 2 in working up the product. VI was esterified with acetic anhydride in a 98% yield to form the unsaturated diacetate VII, which on catalytic hydrogenation gave a high yield of 4,5-dimethylhexahydrophthalyl diacetate (VIII). This diacetate VIII was dropped through a helix-packed pyrolysis tube at 520° under such conditions that only 74% of the theoretical acetic acid was cracked out. Under these optimum conditions, a 65% conversion to 4,5-dimethyl-1,2-dimethylenecyclohexane (III), 19% yield of the olefin acetate IX, and a 13% recovery of the diacetate VIII were obtained. The yield of diene III, based on unrecovered VIII and IX, was 96%. If more vigorous conditions are used in order to crack out more acetic acid, a lower yield of a less pure diene is obtained. This again emphasizes that the optimum conditions for the pyrolysis of a diester are those that crack out less than 100% of the acetic acid. The over-all yield of the diene III from IV was 75%.

The structure of III was proved by analysis, ultraviolet absorption and conversion to a known derivative. The ultraviolet absorption spectrum, which shows no maximum above 220 mμ but increases sharply and appears to reach a maximum