

tion or the cleavage. Some evidence has been obtained which indicates that the apparent rates of these reactions may be dependent on solubility factors.

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DIHYDRO-1,4-PYRANS. III. THE SYNTHESIS OF THE 1,2-DIBENZOYLCYCLOBUTANES

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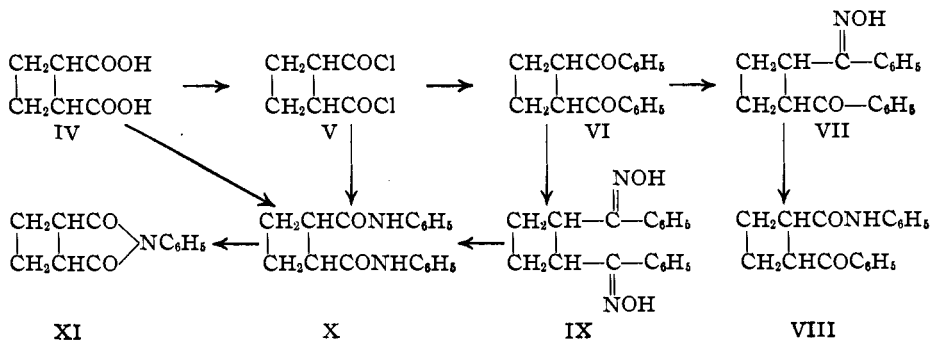
RECEIVED OCTOBER 14, 1931

PUBLISHED MARCH 5, 1932

In assigning the structures of the dihydro-1,4-pyrans the alternative formulas considered were 1,2-dibenzoylcyclobutane derivatives.¹ Since these are not known it was determined to synthesize a compound of this type for comparison with the dihydro-1,4-pyrans.

Of the cyclobutane compounds which would offer a direct comparison with the pyrans, 1,2-dibenzoylcyclobutane promised to be easiest to prepare. This compound has now been synthesized and has been found to exist in *cis* and *trans* modifications. This report describes the preparation of these diketones and gives a proof of their structure.

The starting material was the *trans*-1,2-cyclobutanedicarboxylic acid (IV). The *trans* modification of this acid was chosen because it was to be expected that its chloride would be less likely to react in the unsymmetrical form to yield a lactone derivative in the Friedel and Crafts condensation. It was prepared by the methods of Perkin² and Fuson and Kao.³ On treatment with thionyl chloride it gave the corresponding acid chloride (V). This compound when treated with benzene in the presence of aluminum chloride gave two isomeric compounds whose properties corresponded with those predicted for the 1,2-dibenzoylcyclobutane (VI).



¹ Kao and Fuson, *THIS JOURNAL*, **54**, 313 (1932).

² Perkin, *J. Chem. Soc.*, **65**, 585 (1894).

³ Fuson and Kao, *THIS JOURNAL*, **51**, 1536 (1929).

The diketone melting at 97° will be called the α -diketone and its isomer melting at 120 – 121° the β -diketone. Both were found to be insoluble in hot 10% alkali. This excludes the butyrolactone structure because a compound of that type would be soluble in hot alkali. Since the symmetrical diketone can exist in only two forms and since neither of the two isomers obtained is identical with the 1,2-dibenzoylcyclobutane obtained by Conant and Lutz,⁴ a proof of the structure was necessary. From the α -diketone were obtained a monoxime (VII) melting at 147 – 148° and a dioxime (IX) melting at 169 – 170° . These were transformed into the corresponding anilides by means of the Beckmann rearrangement. The monoanilide (VIII) melted at 130 – 131° . The dianilide (X) was isolated in two forms which were designated as the α - and β -forms. The α -dianilide melting at 236 – 236.5° was the principal product of the reaction. The β -dianilide which melted at 219 – 220° proved to be of more interest because it was found possible to prepare it directly from the original acid, *trans*-1,2-cyclobutanedicarboxylic acid, as well as from the acid chloride of that acid. Moreover, when heated it was transformed into the corresponding phenylimide (XI).⁵

This identification of the dianilide as that of 1,2-cyclobutanedicarboxylic acid establishes the structure of the β -dianilide and leaves no doubt as to the correctness of the structures assigned to the two isomeric diketones. That the latter represent the *cis* and *trans* forms of the 1,2-dibenzoylcyclobutane seems certain but the evidence does not show which is the *cis* and which is the *trans*. Since the starting material was pure *trans*-1,2-cyclobutanedicarboxylic acid, it is evident that an isomerization to the *cis* form must have occurred at some step in the synthesis in order to give rise to the second dibenzoylcyclobutane.

The properties of the α -diketone are such as to show clearly that compounds having this type of structure cannot be confused with the dihydro-1,4-pyrans, for the diketone forms a dioxime and a dibromide—reactions not to be expected of the pyrans. By the principle of exclusion, therefore, this work strongly supports the dihydro-1,4-pyran structures for the products obtained from 1,4-dibromo-1,4-diaroylbutanes by the cyanide ring-closure.

⁴ Conant and Lutz, *THIS JOURNAL*, **49**, 1090 (1927). By reduction of 1,4-dibromo-1,4-dibenzoylbutane with zinc dust a compound melting at 163° was obtained and reported as 1,2-dibenzoylcyclobutane. The structure of this compound was not proved. After this article had been submitted to the Editor, it was found that a third isomer melting at 158 – 159° (with decomposition) and possibly identical with the diketone of Conant and Lutz, was obtained in small quantity from the mother liquor. This discovery throws doubt on the structure here assigned to the β -diketone since there are now three isomeric forms where but two are theoretically possible. This point is being investigated.

⁵ Perkin, *J. Chem. Soc.*, **65**, 584 (1894).

Experimental

α -1,2-Dibenzoylcyclobutane.—Twenty-eight and eight-tenths grams (0.2 mole) of *trans*-1,2-cyclobutanedicarboxylic acid (m. p. 129–130°) was placed in a round-bottomed flask equipped with a condenser. Fifty-nine and one-half grams of thionyl chloride was poured in at once. The mixture was heated gently in a water-bath until solution was complete and the evolution of hydrogen chloride had practically ceased. The flask was then connected through a downward condenser with a water pump. The crude product was heated for a while under diminished pressure to remove any excess thionyl chloride. A mixture of 60 g. of aluminum chloride and 300 cc. of dry benzene was placed in a 3-necked flask fitted with a mercury-sealed stirrer, a condenser and a dropping funnel. The acid chloride obtained as described above was added through the dropping funnel during a period of thirty minutes. The reaction was not allowed to become too vigorous and the temperature was kept below 60°. After the addition of the acid chloride was completed the stirring was continued for two hours longer. During this period the temperature of the reaction mixture was kept at 50–60°.

The reaction mixture darkened in color slowly and was almost black at the end of the reaction. It was poured slowly into 200 g. of cracked ice and 50 cc. of concd. hydrochloric acid. The mixture was stirred vigorously for a few minutes. The benzene layer was decanted and the aqueous solution was extracted two or three times with benzene. The benzene was removed by distillation. The crude product after one recrystallization from 95% ethyl alcohol gave 41.8 g. of an almost pure product melting at 94–97°. The yield was 79.2% of the theoretical. Two more recrystallizations gave fairly large colorless needles melting at 97°. The compound, α -1,2-dibenzoylcyclobutane, was insoluble in boiling 10% sodium hydroxide solution and did not decolorize a warm solution of potassium permanganate.

Anal. Calcd. for $C_{18}H_{16}O_2$: C, 81.8; H, 6.1. Found: C, 81.6; H, 6.2.

β -1,2-Dibenzoylcyclobutane.—The mother liquor from which the α -1,2-dibenzoylcyclobutane was obtained, gave 0.8 g. of a substance which formed fine needles from 95% alcohol and melted at 120–121°. It was insoluble in boiling 10% sodium hydroxide solution and its analysis showed it to be isomeric with the 1,2-dibenzoylcyclobutane.

Anal. Calcd. for $C_{18}H_{18}O_2$: C, 81.8; H, 6.1. Found: C, 81.4; H, 6.2.

The Dibromo Derivative of α -1,2-Dibenzoylcyclobutane.—To a solution of 2.64 g. of α -1,2-dibenzoylcyclobutane in 45 cc. of carbon tetrachloride was added rapidly 3.2 g. of dry bromine. The mixture was shaken vigorously for a few minutes and then allowed to stand for fifteen minutes at room temperature. There was a rapid evolution of hydrogen bromide. The solvent, together with the hydrogen bromide and excess bromine, was then evaporated under diminished pressure. The crude dibromo compound was purified by recrystallization from ethyl acetate. It melted at 148–149°; the yield was 80.6% of the theoretical.

Anal. Calcd. for $C_{18}H_{14}O_2Br_2$: Br, 37.9. Found: Br, 37.8.

The Monoxime of α -1,2-Dibenzoylcyclobutane.—Five and three-tenths grams of α -1,2-dibenzoylcyclobutane was dissolved in 25 cc. of hydroxylamine hydrochloride solution⁶ to which 100 cc. of sodium hydroxide solution⁷ was then added. The mixture was heated at 95–100° for one-half hour while it was vigorously stirred. After being cooled the mixture was diluted with 500 cc. of water and acidified with dilute hydro-

⁶ Made by dissolving 7.25 g. of hydroxylamine hydrochloride in 9 cc. of water and diluting with ethyl alcohol to 35 cc.

⁷ Prepared by dissolving 10 g. of sodium hydroxide in 20 cc. of water and diluting with alcohol to 140 cc.

chloric acid. The monoxime was obtained as a yellow gummy substance which after repeated recrystallization from 95% ethyl alcohol separated in clusters of large needles melting at 147–148°.

Anal. Calcd. for $C_{18}H_{17}NO_2$: C, 77.4; H, 6.1. Found: C, 77.3; H, 6.1.

The Anilide of 2-Benzoyl-1-cyclobutanecarboxylic Acid.—One gram of the monoxime was added to a mixture of 3 cc. of thionyl chloride and 7 cc. of chloroform in a small Erlenmeyer flask surrounded with cracked ice. The mixture was thoroughly shaken, allowed to stand in the ice water-bath for a few minutes and then at room temperature for one hour. Some cracked ice was added to the reaction mixture. The chloroform layer was separated and washed with a little water. The chloroform was removed and the solid which remained was dried on a clay plate and recrystallized from 95% alcohol. In this way 0.4 g. of fine long needles melting at 130–131° was obtained.

Anal. Calcd. for $C_{18}H_{17}NO_2$: C, 77.4; H, 6.1. Found: C, 76.8; H, 6.2.

The Dioxime of α -1,2-Dibenzoylcyclobutane.—Six grams of α -1,2-dibenzoylcyclobutane was dissolved in 60 cc. of absolute alcohol. To this solution a mixture of 6.0 g. of hydroxylamine hydrochloride and 12.0 g. of potassium acetate in 50 cc. of water was added. The mixture was refluxed for half an hour. It was then allowed to stand at room temperature in an open flask. Crystals collected on the bottom of the flask. The liquor was decanted into another flask and the crystals were filtered and washed with water. After a few days the mother liquor deposited a second crop of crystals. Sometimes a third or even fourth crop of crystals was obtained. The combined crude product amounting to 3.8 g. melted at 160–164°. After two or three recrystallizations from 95% alcohol it melted at 169–170°.

Anal. Calcd. for $C_{18}H_{18}N_2O_2$: C, 73.4; H, 6.2. Found: C, 73.4; H, 6.3.

Dianilides of 1,2-Cyclobutanedicarboxylic Acid

A. By the Beckmann Rearrangement of 1,2-Dibenzoylcyclobutane Dioxime.—Seven-tenths of a gram of the dioxime was dissolved in 14 cc. of chloroform. This solution was cooled to 0° and 6 cc. of thionyl chloride was added. The mixture had a yellow color at first and later turned red. At the end of an hour the reaction mixture was decomposed with ice. Twenty cc. of chloroform was added and the chloroform solution was separated from the aqueous layer. There was obtained 0.2 g. of a product melting at 234–236°. After it was recrystallized from 95% alcohol the α -dianilide melted at 236–236.5°. A small amount of a different substance was obtained from the mother liquor. This compound which has been called the β -dianilide was isomeric with the α -dianilide but was different from it in crystalline form. The β -dianilide melted at 219–220°.

Anal. Calcd. for $C_{18}H_{18}N_2O_2$: C, 73.4; H, 6.2; N, 9.5. Found: α -dianilide: C, 73.1; H, 6.6. β -dianilide: C, 73.5; H, 6.3; N, 9.6.

B. By Heating *Trans*-1,2-cyclobutanedicarboxylic Acid with Aniline.—Four and three-tenths grams of *trans*-1,2-cyclobutanedicarboxylic acid was heated in a test-tube with 11.2 g. of pure aniline at 150–160° for three hours. Water was given off when the temperature reached 140°. The dark mass was ground in a mortar with 20 cc. of dilute hydrochloric acid. It was filtered, ground with hydrochloric acid once more, filtered again and washed several times with water. In this way 7.41 g. of product melting at 219–220° was obtained. The yield was 84% of the theoretical. This product was identified as the β -dianilide by the method of mixed melting points.

C. By the Reaction of *Trans*-1,2-cyclobutanedicarboxylic Acid Chloride and Aniline.—One and four-tenths grams of *trans*-1,2-cyclobutanedicarboxylic acid was mixed with 2.5 g. of phosphorus pentachloride and warmed at 70° for a few minutes. The

acid chloride thus obtained was poured drop by drop into 10 cc. of aniline. The reaction mixture solidified on cooling and was purified as described in B. By recrystallization of the product from 95% alcohol 2.2 g. of the β -dianilide was obtained. The yield was 75% of the theoretical.

Phenylimide of 1,2-Cyclobutanedicarboxylic Acid.—Two grams of the β -dianilide of 1,2-cyclobutanedicarboxylic acid was heated in a test-tube. The temperature was raised slowly until aniline began to come off. This took place at a temperature of about 240°. The mixture was then maintained at 240–250° for sixteen hours. The contents of the test-tube was dissolved in alcohol, boiled with animal charcoal and filtered. The filtrate, on being allowed to cool, deposited long needles, melting at 126.5–127°. The yield of the imide was 1 g. or 73% of the theoretical.

Summary

The acid chloride of *trans*-1,2-cyclobutanedicarboxylic acid has been shown to react normally with benzene in the presence of aluminum chloride to give a mixture of the *cis* and *trans* forms of 1,2-dibenzoylcyclobutane.

The structure of one of these diketones has been proved by its transformation successively into the dioxime and the corresponding dianilide, which in turn has been shown to be that of 1,2-cyclobutanedicarboxylic acid.

In their reactions these compounds differ widely from the isomeric dihydro-1,4-pyran derivatives. The cyclobutane structures previously considered for the latter compounds are, accordingly, eliminated as possibilities. By the exclusion principle, therefore, the present work strongly supports the dihydro-1,4-pyran structures for the derivatives obtained from 1,4-dibromo-1,4-diaroylbutanes by the cyanide ring-closure.

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THE PINACOL-PINACOLIN REARRANGEMENT. THE RELATIVE MIGRATION APTITUDES OF ARYL GROUPS¹

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RECEIVED OCTOBER 14, 1931

PUBLISHED MARCH 5, 1932

The rearrangement of symmetrical mixed pinacols of the type $RR'-(OH)C-C(OH)RR'$ has been recognized as one of the best means of comparing migration aptitudes² of groups since the groups are in structurally identical positions. Moreover, the nature of the pinacolin which is formed indicates which of the two groups has migrated. The two possibilities may be represented as follows:

¹ The material here presented is from a dissertation submitted by Frank H. Moser to the Faculty of the University of Michigan in partial fulfilment of the requirements for the degree of Doctor of Philosophy, 1931.

² See Tiffeneau and Orekhoff, *Bull. soc. chim.*, 35, 1639 (1924), and *Ann. Reports*, 27, 114 (1930), for reviews of the subject.