S 7. *Preparation of the Substituted* 1 : 2-*Dibenzoylethylenes.*

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The preparation, properties, and structures of the 1 : 2-dibenzoylethylenes are discussed. The methods of preparation include bromination of the 1 : 2-dibenzoylethanes followed by dehydrobromination; the action of aqueous potassium hydroxide on ω-bromoacetophenones; and the selenium dioxide oxidation of 1 : 2-dibenzoylethanes the rate of which is increased by traces of acid. The standard methods for the preparation of the 1 : 2-dibenzoylethanes are found to be of limited application.

We have examined five general methods available for the preparation of substituted 1 : 2-dibenzoylethylenes required for another research. (1) The serviceable method of Conant and Lutz (*J. Amer. Chem. Soc.*, 1923, **45**, 1303) with fumaryl chloride gave in our hands the *trans*-forms of 1 : 2-dibenzoylethylene (65% yield), bis-*p*-methylbenzoylethylene (52%), bis-*p*-chlorobenzoylethylene (54%), and bis-*p*-bromobenzoylethylene (42%), but cannot be used to prepare dibenzoylethylenes with substituents in any desired position.

(2) We have confirmed the findings of Weygand and Lanzendorf (*J. pr. Chem.*, 1938, **151**, 204) that, contrary to the statement of Smedley (*J.*, 1909, **95**, 219), phenylglyoxal and acetophenone do not give 1 : 2-dibenzoylethylene when treated with acetic anhydride. They do so, however, with glacial acetic acid containing a drop of sulphuric acid. 1 : 2-Dibenzoylethylene and 1 : 2-bis-*p*-bromobenzoylethylene were thus obtained, but *m*-nitrophenylglyoxal and *m*-nitroacetophenone, etc., failed to give the corresponding dibenzoylethylenes.

(3) The selenium dioxide oxidation of acetonylacetone (Armstrong and Robinson, *J.*, 1934, 1650) and diethyl succinate (Astin, Riley, and Newman, *J.*, 1933, 391) suggested a similar conversion of the 1 : 2-dibenzoylethanes into the ethylenes. The method proved serviceable giving 50—60% yields of the *trans*-1 : 2-dibenzoyl-, -bis-*p*-methylbenzoyl-, -bis-*p*-chlorobenzoyl-, and -bis-*p*-bromobenzoyl-ethylenes, but with bis-*p*-methoxybenzoylethane only an orange oil resulted. It was established that a little hydrochloric acid accelerated the oxidation and increased the yields and this is in harmony with the findings of Melnikov and Rokitsakja (*J. Gen. Chem. Russia*, 1944, **14**, 1054) that the rate of oxidation of acetone by selenious acid is proportional to the hydrogen-ion concentration of the solution.

(4) We applied Bogoslovskii's method (*J. Gen. Chem. Russia*, 1944, **14**, 993) successfully to the preparation of 1 : 2-dibenzoylethylene by the action of warm aqueous potassium hydroxide on ω-bromoacetophenone in ethanol, but unsuccessfully to the preparation of 1 : 2-bis-*m*- and -*p*-nitrobenzoylethylenes. ω-Bromo-*o*-nitroacetophenone gave what is possibly 1 : 2-bis-*o*-nitrobenzoylethylene and ω-chloro-*p*-methoxyacetophenone yielded a compound which is possibly 1 : 2-*epoxy*-1 : 2-*bis*-p-*methoxybenzoylethylene*. Fuson and Johnson (*J. Amer. Chem. Soc.*, 1946, **68**, 1668) were unable to prepare 1 : 2-di-(2 : 4 : 5-trimethylbenzoyl)ethylene by this method.

(5) An obvious route to the 1 : 2-dibenzoylethylenes is by bromination of one of the methylene groups in the corresponding ethanes followed by dehydrobromination with quinoline or pyridine, and we found that this provides a good method for the preparation of several dibenzoylethylenes.

Bromination of 1 : 2-bis-*o*-carboxybenzoylethane (Gabriel *et al.*, *Ber.*, 1877, **10**, 1559; 1898, **31**, 1160; Roser, *Ber.*, 1885, **18**, 3115) proved unsatisfactory, but diazomethane gave the *dimethyl* ester easily, which by bromination in glacial acetic acid yielded 1-*bromo*-1 : 2-*bis*-*o*-*carbomethoxybenzoylethane*. Dehydrobromination with pyridine at 120° gave 1 : 2-*bis*-*o*-*carbomethoxybenzoylethylene*. Unfortunately the ester could not be hydrolysed to the diacid, the products being uncrystallisable oils or solids with properties other than those required.

It is important to differentiate clearly between the various bromo-compounds which can be converted into 1 : 2-dibenzoyl-ethanes or -ethylenes. The so-called γ-diphenacyls with the generic formula $R{\cdot}CO{\cdot}CH_2{\cdot}CHBr{\cdot}CO{\cdot}R$ are the bromo-compounds mentioned in the previous paragraph and may be reduced to the corresponding dibenzoylethanes or dehydrohalogenated to the ethylenes. The α- and β-diphenacyls are probably ring compounds (O. Widman, *Ber.*, 1909, **42**, 3261; *Annalen*, 1913, **400**, 86) obtained by the action of alkali on ω-bromoacetophenones (Fritz, *Ber.*, 1895, **28**, 3033; 1896, **29**, 1751). They are reduced to dibenzoylethanes, but are not readily dehydrohalogenated to dibenzoylethylenes. Ajello's statement (*Gazzetta*, 1937, **67**, 608) that, by the action of sodium hydroxide on ω-bromoacetophenone, he obtained γ-bromodiphenacyl, *i.e.*, 1-bromo-1 : 2-dibenzoylethane, is patently incorrect and by repeating his work we have shown that his product was a mixture of α- and β-bromodiphenacyls.

For the dehydrohalogenation method of preparing the 1 : 2-dibenzoylethylenes to be effective a good general method for preparing 1 : 2-dibenzoylethanes is obviously required. We found that the methods in the literature are of limited application and this is in agreement with the conclusions of Hunsdiecker (*Ber.*, 1942, **75**, 447) on the synthesis of the aliphatic 1 : 4-diketones.

The colourless 1 : 2-bis-*p*-chloro- and -*p*-bromo-benzoylethylenes in glacial acetic acid reacted quickly in the cold with hydrazine hydrate yielding the corresponding pyridazines, while the yellow isomers reacted only when the solutions were boiled for several minutes. Colourless 1 : 2-dibenzoylethylene in ethanol rapidly gave 2 : 5-diphenylpyridazine, while the yellow isomer gave a *monohydrazone*, converted to the pyridazine by boiling in ethanol or acetic acid. 1 : 2-Bis-*p*-methylbenzoylethane and hydrazine hydrate gave a product which is probably 2 : 5-di-*p*-tolyldihydropyridazine, since on short exposure to the air it was oxidised to 2 : 5-di-*p*-tolylpyridazine (cf. Paal and Dencks, *Ber.*, 1903, **36**, 495).

Experimental.

The identity of substances was established by mixed m. p.s with authentic samples and the purity of products determined by the sharpness of their m. p.s on a Kofler micro-melting point apparatus. Analyses were by Drs. Weiler and Strauss, Oxford.

Condensation of Substituted Phenylglyoxals and Acetophenones.—These condensations are typified by the following example. *p*-Bromoacetophenone (20 g.) was heated for 6 hours on a water-bath with selenium dioxide (11·2 g.), ethanol (70 c.c.), and water (8 c.c.) with frequent shaking. Filtration followed by distillation gave *p*-bromophenylglyoxal, as an orange-coloured liquid (12·3 g.), b. p. 135—142°/17 mm., which was refluxed for 1½ hours with *p*-bromoacetophenone (6·8 g.) and glacial acetic acid (20 c.c.) and one drop of sulphuric acid. With water the solution gave *trans*-1 : 2-bis-*p*-bromobenzoylethylene (3·8 g.) in yellow leaflets, m. p. 187°, after crystallisation from chloroform, no m. p. depression when mixed with a sample prepared by the method of Conant and Lutz (*J. Amer. Chem. Soc.*, 1925, **47**, 891). The cis-*isomer* was obtained by exposure of the *trans*-compound (1 g.) in chloroform (30 c.c.) to sunlight for 6 hours. Colourless crystals (light petroleum, b. p. 100—120°), m. p. 123° (Found : Br, 40·3. $C_{16}H_{10}O_2Br_2$ requires Br, 40·5%). Condensation by Smedley's method (*loc. cit.*) yielded an uncrystallisable oil. The following compounds failed to condense satisfactorily : phenylglyoxal and *o*- or *m*-nitroacetophenone, phenylglyoxal and *p*-acetamidoacetophenone, *m*-nitrophenylglyoxal and *m*-nitroacetophenone, *p*-methoxyphenylglyoxal and *p*-methoxyacetophenone.

Selenium Dioxide Oxidation of Dibenzoylethanes.—1 : 2-Dibenzoylethane (1·7 g.), selenium dioxide (0·8 g.), ethanol (25 c.c.), and water (1 c.c.) were refluxed for 24 hours, filtered, and concentrated to half-volume. *trans*-Dibenzoylethylene, m. p. 109—110°, pale yellow needles (ethanol), separated in 56% yield. The same mixture heated for 16 hours with a drop of hydrochloric acid added gave a 73% yield. Similarly 1 : 2-bis-*p*-methylbenzoylethane gave, on 72 hours' heating, a 62% yield of *trans*-1 : 2-bis-*p*-methylbenzoylethylene, pale yellow needles (ethanol), m. p. 145—146°, the same yield being obtained by refluxing for 40 hours with the addition of a drop of hydrochloric acid. 1 : 2-Bis-*p*-bromobenzoylethane when refluxed as above for 60 hours deposited very little selenium, but addition of a drop of hydrochloric acid followed by 20 hours' refluxing gave a 64% yield of *trans*-1 : 2-bis-*p*-bromobenzoylethylene, m. p. 184—187°. Similarly 1 : 2-bis-*p*-chlorobenzoylethane gave *trans*-1 : 2-bis-*p*-chlorobenzoylethylene, m. p. 170—172°, 58% yield after 60 hours' refluxing or 36 hours with a drop of hydrochloric acid added. Attempts to oxidise 1 : 2-bis-*p*-methoxybenzoylethane were unsuccessful.

Action of Potassium Hydroxide on ω-Bromoacetophenones.—Bogoslovskii's method (*loc. cit.*) gave a 70% yield of the isomeric 1 : 2-dibenzoylethylenes, but it was noted that rapid filtration and immediate crystallisation of the product was needed to avoid resinification. ω-Chloro-*p*-methoxyacetophenone (7·1 g.) dissolved in ethanol (25 c.c.) was added to potassium hydroxide (2·2 g.) in ethanol (10 c.c.) and water (2 c.c.). After being shaken for 5 min. the mixture was added to 200 c.c. of cold water and the

orange-brown product extracted with ether. The ether was well washed with water and evaporated to give a product which, by extraction with light petroleum (b. p. 100—120°) followed by evaporation, gave an oily substance. Trituration with, and crystallisation from, methanol yielded colourless crystals (1 g.), m. p. 148°, the analysis of which was in fair agreement with that required for 1 : 2-*epoxy*-1 : 2-*bis*-p-*methoxybenzoylethylene* (Found : C, 69·98; H, 4·7. $C_{18}H_{16}O_5$ requires C, 69·23; H, 5·1%). ω-Bromo-*o*-nitroacetophenone (5·1 g.) in warm methanol (40 c.c. at 35—40°) was added to potassium hydroxide (1·19 g.) in ethanol (10 c.c.) and water (2 c.c.) and the mixture, after 5 minutes' shaking, added to 200 c.c. of cold water and filtered at once. The orange-yellow precipitate was dissolved in glacial acetic acid (15 c.c.), the solution filtered, water (20 c.c.) added, and the precipitate crystallised from 1 : 1-ethanol–glacial acetic acid. The compound is possibly 1 : 2-*bis*-o-*nitrobenzoylethylene*, colourless needles, m. p. 163—164° (Found : C, 58·46; H, 3·10. $C_{16}H_{10}O_6N_2$ requires C, 58·9; H, 3·06%), but this must be accepted with reserve since no crystalline product was obtained with hydrazine hydrate.

Preparation and Dehydrobromination of 1-*Bromo*-1 : 2-*dibenzoylethanes*.—1 : 2-Dibenzoylethane (0·45 g.), glacial acetic acid (10 c.c.), and bromine (0·1 c.c.) were warmed until the solution became straw-coloured. Cooling deposited 1-bromo-1 : 2-dibenzoylethane, colourless crystals (ethanol–acetic acid), m. p. 138—139° (Found : Br, 25·35. Calc. for $C_{16}H_{13}O_2$: Br, 25·2%), identical with a sample prepared from 1 : 2-dibenzoylethylene and hydrogen bromide in glacial acetic acid. The bromo-compound (0·65 g.) was heated for 20 minutes in quinoline (2 c.c.) at 170—175°, poured into dilute hydrochloric acid, and the precipitate worked up in the usual way to give *trans*-1 : 2-dibenzoylethylene, pale yellow needles (ethanol), m. p. 108—110°, yield 95%. *trans*-1 : 2-Bis-*p*-methylbenzoylethylene was similarly obtained as pale yellow needles (ethanol), m. p. 145—147°, yield 95%. 1 : 2-Bis-*o*-carbethoxybenzoylethane (0·53 g.) in glacial acetic acid (10 c.c.) was treated with bromine (0·07 c.c.), warmed, then added to ice. 1-*Bromo*-1 : 2-*bis*-o-*carbethoxybenzoylethane* separated and was crystallised from aqueous ethanol, m. p. 94—97° (Found : Br, 17·8. $C_{22}H_{21}O_6Br$ requires Br, 17·35%). Heating with quinoline or pyridine yielded no crystallisable product. 1-*Bromo*-1 : 2-*bis*-o-*carbomethoxybenzoylethane* was similarly obtained and was purified by trituration with, and crystallisation from, methanol. Colourless crystals, m. p. 107—108° (Found : Br, 18·7. $C_{20}H_{17}O_6Br$ requires Br, 18·47%). The compound (0·20 g.) and dry pyridine (3 c.c.) were heated for 20 minutes at 120°. The mixture was poured into water and the 1 : 2-*bis*-o-*carbomethoxybenzoylethylene* crystallised from methanol. Pale yellow needles, m. p. 109—110°, yield 97% (Found : C, 68·08; H, 4·56. $C_{20}H_{16}O_6$ requires C, 68·18; H, 4·54%). Hydrolysis with various reagents was unsuccessful, but refluxing the ester (0·35 g.) with dilute hydrochloric acid (15 c.c. of concentrated acid and 25 c.c. of water) gave an orange solid which crystallised from glacial acetic acid, m. p. 312—313°, and is possibly the *anhydride* (Found : C, 70·68; H, 3·56. $C_{18}H_{10}O_5$ requires C, 70·6; H, 3·2%).

Repetition of Ajello's method (*loc. cit.*) gave a mixture which was separated by crystallisation from benzene into α- and β-bromodiphenacyls, m. p. 129° and 161° respectively.

Attempted Preparation of 1 : 2-*Dibenzoylethanes*.—Diethyl bis-*p*-nitrobenzoylsuccinate (2·1 g.) was warmed at 45° with 3% sodium hydroxide (15 c.c.) and after 5 minutes the solution was cooled and acidified. The precipitate crystallised from hot water in leaflets, m. p. 236—237°, which gave no m. p. depression when mixed with *p*-nitrobenzoic acid (Found : C, 50·3; H, 3·0; N, 8·15. Calc. for $C_7H_5O_4N$: C, 50·3; H, 3·0; N, 8·4%). Hydrolysis with 1% sodium hydroxide gave the same result, and syrupy phosphoric acid no crystallisable product. Similar results were obtained with the *m*-nitro-ester, the only product isolated being *m*-nitrobenzoic acid, m. p. 137—139° (Found : C, 50·0; H, 2·74%).

By the method of Bodforss (*Ber.*, 1918, **51**, 198) benzoylacetone (4·1 g.) and ω-bromoacetophenone (5 g.) gave acetyldiphenacyl, compact prisms, m. p. 87—88° (lit., 88—89°), yield 4·32 g., which was converted into 1 : 2-dibenzoylethane, m. p. 142—144°, yield 93%. No crystallisable product could be obtained from the condensation of benzoylacetone and ω-bromo-*o*-, -*m*-, or -*p*-nitroacetophenones.

1 : 2-Bis-*o*-carboxybenzoylethane, m. p. 166—168°, obtained by the method of Gabriel and Leupold (*loc. cit.*) when heated for 1 hour with ethanol and sulphuric acid gave chiefly unreacted acid and a small amount of the *diethyl* ester, m. p. 202°, after crystallisation from ethanol–acetic acid (Found : C, 68·82; H, 5·70. $C_{22}H_{22}O_6$ requires C, 69·11; H, 5·75%). Attempted esterification by heating an ethanolic solution with hydrogen chloride passing through gave diphthalidylidene-ethane (Found : C, 73·96; H, 3·58. Calc. for $C_{16}H_{10}O_4$: C, 74·4; H, 3·44%). The *bis*-p-*nitrodibenzyl* ester, m. p. 183—184° (Found : C, 64·23; H, 4·07. $C_{32}H_{24}O_{10}N_2$ requires C, 64·43; H, 4·02%), was easily prepared. By adding the acid (7 g.) in acetone (20 c.c.) over a period of 7 minutes to a solution of diazomethane (2 g.) in ether (70 c.c.) followed by warming for 15 minutes and evaporation the *dimethyl* ester was obtained. Colourless needles (methanol), m. p. 79—80°, yield 7·23 g. (Found : C, 68·23; H, 5·09. $C_{20}H_{18}O_6$ requires C, 67·98; H, 5·1%).

3-Nitrophthalic anhydride (10 g.) and succinic acid (8 g.) were fused at 195—200° and dry powdered potassium acetate (4 g.) gradually added. The temperature was raised to 215—220° and an orange-brown precipitate began to separate. The mixture was maintained at this temperature for 2 hours, cooled, triturated with warm water, filtered, and the dark-brown residue crystallised from nitrobenzene. Yellow crystals of *bis*-m-*nitrophthalidylidene-ethane*, m. p. >350°, separated, yield 0·8 g. (8%) (Found : C, 57·98; H, 2·15. $C_{18}H_8O_8N_2$ requires C, 58·0; H, 2·3%). *Bis*-p-*nitrophthalidylidene-ethane*, m. p. >350°, was similarly prepared (Found : C, 57·5; H, 2·3%). Attempts to prepare the corresponding acids were unsuccessful.

Reaction of the 1 : 2-*Dibenzoylethylenes with Hydrazine Hydrate*.—*cis*-1 : 2-Dibenzoylethylene (0·1 g.; m. p. 134°) in ethanol (10 c.c.) and ethanolic hydrazine hydrate (0·5 c.c.; 50%) were left overnight. 2 : 5-Diphenylpyridazine, m. p. 266°, separated in needles (Found : N, 11·8. Calc. for $C_{16}H_{12}N_2$: N, 12·07%). The *trans*-isomer under identical conditions gave the *monohydrazone* in yellow leaflets, m. p. 146—147° (Found : N, 11·3. $C_{16}H_{14}ON_2$ requires N, 11·2%), which, on heating for a few minutes in glacial acetic acid, gave the above pyridazine. *cis*-1 : 2-Bis-*p*-methylbenzoylethylene gave 2 : 5-di-*p*-tolylpyridazine, m. p. 231—232°, colourless needles (ethanol) (Found : N, 10·2. Calc. for $C_{18}H_{16}N_2$: N, 10·7%), while the *trans*-isomer gave only unchanged material. 1 : 2-Bis-*p*-methylbenzoylethane with hydrazine hydrate gave a crystalline precipitate, m. p. 177—178°, probably the dihydropyridazine,

which on standing overnight in suspension gave the pyridazine, m. p. 230—232°. *cis*-1 : 2-Bis-*p*-chlorobenzoylethylene (0·11 g.; m. p. 101°) in glacial acetic acid (11 c.c.) and ethanolic hydrazine hydrate (0·5 c.c.; 50%) on standing overnight gave 2 : 5-*bis*-p-*chlorophenylpyridazine*, colourless needles, m. p. 264° (Found : N, 9·7. $C_{16}H_{10}N_2Cl_2$ requires N, 9·3%). Under the same conditions the *trans*-isomer gave unchanged compound, but yielded the pyridazine in colourless needles (ethanol), m. p. 262—264°, when refluxed for 5 minutes. Similarly *cis*-1 : 2-bis-*p*-bromobenzoylethylene, m. p. 123°, gave 2 : 5-*bis*-p-*bromophenylpyridazine*, m. p. 285° (Found : N, 7·00. $C_{16}H_{10}N_2Br_2$ requires N, 7·18%), while the *trans*-isomer remained unchanged.

Grignard Reagents and Ethylene Cyanide.—Ethylene cyanide (1·60 g.) in dry ether (50 c.c.) and dry benzene (10 c.c.) was treated with phenylmagnesium bromide (7·3 g.). A precipitate separated and after 5 minutes, shaking the mixture was added to 10% sulphuric acid (50 c.c.) and ice (30 g.). From the ether–benzene layer diphenyl was isolated, m. p. and mixed m. p. with authentic sample 68—69° (Found : C, 92·8; H, 6·66. Calc. for $C_{12}H_{10}$: C, 93·5; H, 6·5%).

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