melted at 130–131°. The melting point was not depressed when the semicarbazone was mixed with the semicarbazone of eicosanone-2.

Isolation of *d*-Octadecanol-2.—The material recovered from the mother liquor from *d*-eicosanol-2 yielded very small quantities of *d*-octadecanol-2. A portion of this material, 0.9 g., was converted into the phenylurethan. The latter after more than 100 recrystallizations yielded 60 mg. of needle-shaped crystals which had the correct melting point, 76–76.5°, of the phenylurethan of *d*-octadecanol-2. A mixed melting point with an authentic specimen gave no depression. However, this method of purification was too laborious and the yield too small.

Another portion of the crude material, 2.53 g., was first fractionated by distillation through a modified Widmer column into 3 fractions. The first fraction, 0.73 g., which distilled at 170–190° and 3 mm. pressure, was converted into the 3,5-dinitrobenzoate. The product, after treatment with norite, was recrystallized from alcohol until the melting point was constant at 71–72°. The colorless needle-shaped crystals weighed 0.45 g.; $[\alpha]_D$ in $CHCl_3$ +25.3°.

Anal. Calcd. for $C_{26}H_{40}O_6N_2$(464): C, 64.61; H, 8.68. Found: C, 64.78; H, 8.56.

The dinitrobenzoate, 392 mg., was saponified by refluxing with 4% alcoholic potassium hydroxide. After the alcohol had been isolated and recrystallized four times from methyl alcohol, 197 mg. of colorless needles was obtained. The crystals melted at 53–54° and there was no depression when mixed with *d*-octadecanol-2; $[\alpha]_D$ in $CHCl_3$ +4.84°.

Anal. Calcd. for $C_{18}H_{38}O$(270): C, 79.91; H, 14.17. Found: C, 80.15; H, 13.98; mol. wt. (Rast), 271.

The octadecanol-2, 88 mg., was oxidized to the ketone and the latter was recrystallized three times as described by Pangborn and Anderson.[6] The yield was 32 mg. of colorless, plate-shaped crystals. The ketone melted at 50–51° and there was no depression when mixed with a sample of synthetic octadecanone-2.

Summary

1. The chloroform-soluble wax of the avian tubercle bacillus has been purified, saponified and the cleavage products investigated.
2. The principal constituents of the wax are hydroxy fatty acids of very high molecular weight. The acids were acid-fast and were optically active. None of the usual fatty acids were found.
3. The unsaponifiable matter of the wax consisted of *d*-eicosanol-2, $C_{20}H_{42}O$, together with a small amount of *d*-octadecanol-2, $C_{18}H_{38}O$.
4. The water-soluble component of the wax liberated on saponification was identified as the disaccharide trehalose, $C_{12}H_{22}O_{11}$.
5. Glycerol could not be detected among the cleavage products.

NEW HAVEN, CONN. RECEIVED MARCH 8, 1937

[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF THE UNIVERSITY OF MISSISSIPPI]

The Oxidation of Substituted Phenols. The Effect of Iodine in the Ortho and Para Positions

BY G. H. WOOLLETT, F. M. DAVIS, C. N. JONES AND MARY NEILL

Upon oxidation 2,6-dimethoxyphenol is converted almost quantitatively into cedriret (3,5,3′,5′-tetramethoxydiphenoquinone-4,4′)[1] while similar phenols such as 2,6-dimethylphenol[2] and 2,6-diacetamidophenol[3] yield 70% or more of dinuclear quinones. These are highly colored conspicuously crystalline sparingly soluble compounds whose structure has been verified amply. The reaction is commonly cited as an example of steric hindrance. Carboxyl, chlorine, bromine,[4] hydroxyl, methoxyl[2] and methyl para to the hydroxyl prevent the reaction.

Another group of substances often confused with the true dinuclear quinones is the highly colored resinoids obtained by the action of iodine and alkali on phenols having ortho and para positions unsubstituted. One of these (Lautemann's Red), obtained from common phenol, was said to be 3,5,3′,5′-tetraiododiphenoquinone-4,4′, by Kammerer and Benzinger[5] shortly after the report on the structure of cedriret by Hoffman, the similarity in color no doubt being the cause of the mistake. The analogous product from thymol[5,6] (aristol) was also thought to be a dinuclear quinone. Later investigators[7–10] agree that Lautemann's Red and aristol are amorphous and have high molecular weights, although it has been sug-

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(1) A. W. Hoffman, *Ber.*, **11**, 329 (1878).

(2) Auwers and others, *ibid.*, **38**, 226 (1905); **57**, 1270 (1924).

(3) Fromm and Ebert, *J. prakt. Chem.*, **108**, 75 (1924).

(4) Hunter and Levine, THIS JOURNAL, **48**, 1608 (1926).

(5) Kammerer and Benzinger, *Ber.*, **11**, 557 (1878).

(6) Messinger and Vortmann, *ibid.*, **22**, 2314 (1889); Vortmann, *ibid.*, **56B**, 234 (1923).

(7) Bougault, *Compt. rend.*, **146**, 1404 (1908).

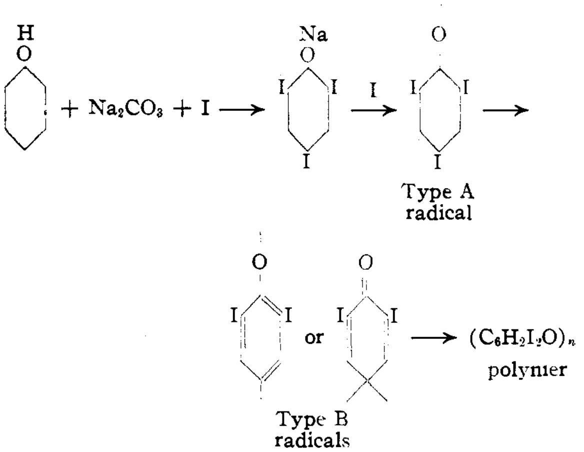
(8) Carswell, *Chem. News*, **68**, 87, 99, 131, 153, 166, 181 (1893).

(9) Hunter and Woollett, THIS JOURNAL, **43**, 131, 135 (1921).

(10) Woollett and others, *ibid.*, (a) **38**, 2474 (1916); (b) **43**, 553 (1921); (c) **52**, 4018 (1930); (d) **55**, 2909 (1933).

gested recently that aristol is a dimer of diiodo-dithymoquinone.[11]

A mechanism suggested by Hunter[9,12] for the formation of Lautemann's Red is shown by the series of reactions



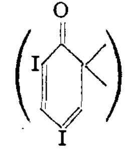
If this is correct some true dinuclear quinone should be formed, the amount depending upon the relative stability of the quinoid form of the type B radical. Showing that the formation of cedriret and the colored resinoids do, after all, have something in common, Hunter and Morse[13] have obtained a 5.6% yield of a true tetraiododiphenoquinone by rapid oxidation of potassium triiodophenolate, the remainder being largely Lautemann's Red. Additional work done in this Laboratory on the role of iodine in the two types of reactions is presented here.

The preparation of tetraiododiphenoquinone from triiodophenol has been repeated and confirmed. Since iodine in the para position in triiodophenol does not prevent the formation of dinuclear quinone, it would be expected that some of this quinone would be made during the preparation of Lautemann's Red in the usual way. This has been shown to occur to the extent of 2.1%.

The largest yield of the quinone would be expected to result from the oxidation of 2,6-diiodophenol. This has proved to be approximately 31%.

Thus the "pro" effect of iodine in the 2,6-position in causing the cedriret reaction may be represented by the figure 31 and the "con" effect of iodine in the para position by the decrease from 31 to 5.3 or 83%. The formation of tetraiododiphenoquinone from 2,6-diiodophenol also shows that the iodine atoms occupy the 3,5- and 3′,5′-positions relative to the bonds between the rings.

By way of checking the effect of iodine it was found that oxidation of 2,6-dibenzamidophenol and 2,6-dibenzamido-4-iodophenol yields 84 and 11.3% of 3,5,3′,5′-tetrabenzamidodiphenoquinone-4,4′, respectively, thus showing a "pro" figure of 80 for benzamido and a "con" of 86% (84 to 11.3) for para iodine.

As the diphenoquinones isolated are para quinones and as it has been shown previously[14] that either ortho or para iodine may be removed in the formation of resinoids but that the resinoids from para cresol[10d] and 2,4-dimethylphenol in which the iodine removed must be from the ortho position are practically colorless it seems probable that the ortho quinoid form of the diiodo type B radical  is not formed.

Experimental

2,6-Diiodo-4-nitrophenol.—Para nitrophenol was iodinated in hot sodium carbonate solution with an excess of iodine–potassium iodide solution. The conditions are not critical.

2,6-Diiodo-4-aminophenol.—A modification of the general method of Hodgson and Kershaw[15] was used. To a hot solution of 50 g. of diiodonitrophenol and 100 g. of sodium carbonate in 1200 cc. of water 80 g. of sodium hydrosulfite was added gradually during energetic stirring. Pure 2,6-diiodo-4-aminophenol, m. p. 170°, separated in 86% yield. Raiford, Taft and Lankelma[16] give 169–171°.

2,6-Diiodophenol.—A cooled solution of 10 g. of diiodoaminophenol in 250 cc. of alcohol and 5 cc. of sulfuric acid was treated gradually with the calculated amount (22 cc.) of *N* sodium nitrite, then refluxed for one hour, cooled, made slightly alkaline with ammonium hydroxide containing a little sodium bisulfite, water added and the phenol extracted with ether; yield 5 g. (52%). This was purified by steam distillation, precipitation from alcoholic solution by a large amount of ice water, and finally from hot glacial acetic acid; white needles, m. p. 67.2°.

Oxidation of 2,6-Diiodophenol and Isolation of 3,5,3′,5′-Tetraiodo-4,4′-dihydroxydiphenyl.—One gram of diiodophenol was dissolved in 10 cc. of water and 1.5 cc. of 2 *N* potassium hydroxide, cooled and poured into a cooled solution of 10 g. of chromium trioxide in 10 cc. of water. The mixture was shaken for ten minutes and filtered by suction. Average weight of red precipitate at this time was 0.775 g.

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(11) Bordeianu, *Arch. Pharm.*, **272**, 8 (1934).

(12) Hunter and Seyfried, This Journal, **43**, 151 (1921).

(13) Hunter and Morse, *ibid.*, **55**, 3701 (1933).

(14) Hunter and Joyce, *ibid.*, **39**, 2640 (1917).

(15) Hodgson and Kershaw, *J. Chem. Soc.*, 2703 (1928).

(16) Raiford, Taft and Lankelma, This Journal, **46**, 2057 (1924).

The red mixture was wet with alcohol and treated with a solution of 1 g. of hydrazine sulfate in 20 cc. of 2 *N* potassium hydroxide, filtered, treated with Norite, refiltered, and precipitated with acetic acid: average yield of white microscopic needles, 0.308 g. (31%). After recrystallizing twice from hot acetone by adding glacial acetic acid it melted with decomposition at 284° if the melting point tubes were inserted in the bath after it had reached 250°. A lower melting point and more decomposition resulted from the usual treatment.

Anal. (Carius). Calcd. for $C_{12}H_6I_4O_2$: I, 73.61; mol. wt. 689.73. Found: I, 73.50, 73.43; mol. wt. (Rast), 662, 640.

Other products of oxidation of 2,6-diiodophenol as found in samples from 1 g. of phenol: by steam distillation, *m*-diiodoquinone, 0,06 g., yellow platelets from hot alcohol, m. p. 175–176°. Amorphous product, 0.067 g.: insoluble in alkali after reduction and when reoxidized by lead dioxide in carbon bisulfide and precipitated by heptane became a red powder. This is evidently Lautemann's Red. A sticky yellow substance soluble in alcohol, 0,338 g.

Tetraiododiphenol from Phenol.—Lautemann's Red was made from 15.7 g. of phenol by treating with sodium carbonate and iodine in the usual way.[5] After thorough washing the wet product was reduced by treating with 320 cc. of 2 *N* potassium hydroxide, 600 cc. of water and 11 g. of hydrazine sulfate. The bleached material was filtered and extracted twice with *N* potassium hydroxide and filtrate and washings acidified. The white precipitate weighed 1.928 g. and consisted mainly of triiodophenol and tetraiododiphenol. Triiodophenol was removed by treating this, dissolved in 3 cc. of 2 *N* potassium hydroxide and 40 cc. of water, with 14 g. of potassium ferricyanide in 60 cc. of water. The red precipitate was filtered, washed and reduced as before using 1.5 g. of hydrazine sulfate, 20 cc. of alkali and 50 cc. of water. The filtrate and washings from this, after warming with Norite, filtration and acidification, yielded 1.20 g. (2.1%) of white microscopic needles which, after recrystallizing twice from acetone and glacial acetic acid, melted at 283° and showed no change in m. p. when mixed with an equal quantity of tetraiododiphenol from 2,6-diiodophenol.

Tetraiododiphenol from Triiodophenol.—The preparation was made according to the directions of Hunter and Morse[13] except that it was crystallized from acetone–acetic acid, m. p. (pre-heated bath) 283°. When mixed with an equal quantity of the analogous product from 2,6-diiodophenol it also melted at 283°.

Oxidation of 3,5,3′,5′-Tetraiodo-4,4′-dihydroxydiphenyl.—Samples from the three sources were oxidized in glacial acetic acid or ethyl acetate by chromium trioxide or ferric chloride; however, oxidation in ethyl acetate by chromium trioxide gave best crystals. All samples behaved identically producing microscopic green needles with metallic luster and red streak and which decomposed without melting. The product apparently may be reduced and reoxidized indefinitely. No satisfactory solvent was found.

2,6-Dibenzamidophenyl Benzoate.—Forty-two grams of sodium hydrosulfite was added in 10-g. portions with energetic shaking to a hot solution of 2,6-dinitrophenol (5 g.) in 650 cc. of water. The faintly colored solution was cooled and 70 cc. of 40% sodium hydroxide added, followed by 25 cc. of benzoyl chloride. Eleven grams (93%) of the tribenzoyl compound separated and after recrystallization twice from glacial acetic acid melted at 220°.

2,6-Dibenzamidophenol.—Fromm and Ebert's[3] method was used, giving light yellow needles of m. p. 179–180°.

Oxidation of 2,6-Dibenzamidophenol.—Sodium nitrite, periodic acid and permanganate produced the quinone in glacial acetic acid. Nitrite, however, gave the cleanest product. Samples of 0.1 to 0.3 g. were dissolved in from 18 to 50 cc. of glacial acetic acid and treated with 0.3 cc. of 20% sodium nitrite solution per 0.1 g. of phenol. After fifteen minutes the quinone was filtered off, dissolved in 150 cc. of chloroform for each 0.1 g. of quinone and precipitated by adding 2.5 volumes of alcohol: average yield from 18 samples, 84% of 3,5,3′,5′-tetrabenzamidodiphenoquinone-4,4′; greenish black microscopic needles which decomposed without melting and which have metallic luster and purple streak. Chloroform solutions were deep permanganate color.

Anal. Calcd. for $C_{40}H_{28}N_4O_6$: N, 8.45; O, 4.84; mol. wt., 660. Calcd. for $C_{20}H_{14}N_2O_4$: N, 8.09; O, 9.25; mol. wt., 346. Found: N (Dumas), 8.79, 8.79; quinoid O (hydrazine) 4.74, 5.08, 4.87, 5.05; mol. wt. (Rast), 696, 557.

2,6-Dinitro-4-iodophenol.—This was made from isopicramic acid and also by iodination of 2,6-dinitrophenol in glacial acetic acid by iodine monochloride. Both melted at 113°.

2,6-Dibenzamido-4-iodophenylbenzoate.—Five grams of dinitroiodophenol and 10 g. of sodium bicarbonate were dissolved in 300 cc. of water to which 25 g. of sodium hydrosulfite was added in portions with energetic shaking. As ordinary Schotten–Baumann procedure removed iodine the mixture was made alkaline with sodium bicarbonate and the amine extracted with ether. The ether solution was filtered and to it added 10 cc. of pyridine and 6 cc. of benzoyl chloride. After the voluminous precipitate had formed 200 cc. of alcohol was added and 4.6 g. (50%) of the tribenzoyl compound filtered off. After recrystallization from hot glacial acetic acid colorless needles melting at 253–254° (dec.) were obtained.

Anal. (Carius). Calcd. for $C_{27}H_{19}N_2O_4I$: I, 22.59. Found: I, 22.75, 22.24.

2,6-Dibenzamido-4-iodophenol.—Four grams of the tribenzoyl compound was dissolved in a mixture of 320 cc. of alcohol and 13 cc. of 10% sodium hydroxide. The yellow solution was diluted with 500 cc. of water and acidified, yielding 3.3 g. (99%) of colorless microscopic needles which after recrystallization from hot acetic acid melted with decomposition at 232°.

Anal. (Carius). Calcd. for $C_{20}H_{15}N_2O_3I$: I, 27.75. Found: I, 27.83, 28.07, 27.64, 28.14.

Oxidation of 2,6-Dibenzamidophenol.—A solution made by mixing 10 cc. of 10% sodium hydroxide with 6 g. of the phenol and adding 1 liter of water was poured with vigorous stirring into a solution containing 40 g. of chromium trioxide and 1200 cc. of water. The red precipitate was digested with 800 cc. of alcohol to dissolve the main product of the reaction—presumably *m*-dibenzamidobenzoquinone. The portion insoluble in alcohol was dissolved in 500 cc. of chloroform and precipitated with 1000 cc. of alcohol. The yield was 0.485 g. (11.3%) of greenish black microscopic needle-shaped crystals having metallic luster and purple streak and which appeared to be identical with those obtained from 2,6-dibenzamidophenol.

Anal. (Kjeldahl). Calcd. for $C_{40}H_{28}N_4O_6$: N, 8.49; quinoid O, 4.84. Found: N, 8.31; quinoid O (hydrazine), 5.22, 5.24.

The alkali salt of the hydroquinone formed by reduction of quinone from either source by hydrazine is yellow. Its yellow solution on acidification yields the colorless hydroquinone which rapidly becomes purple in the air. Reoxidized quinone from the above preparation contained 8.92% N which indicates some saponification of benzamido groups has occurred.

Summary

1. Iodine in the 2,6-position in phenols is about 37% as efficient as benzamido in favoring the cedriret reaction.

2. Placing iodine in the 4-position in 2,6-diiodophenol or 2,6-dibenzamidophenol does not prevent the cedriret reaction but decreases the yield by 83–86%.

3. The positions of the iodine atoms in the tetraiododiphenoquinone have been determined and 2,6-dibenzamido-4-iodophenol and 3,5,3′,5′-tetrabenzamidodiphenoquinone-4,4′ have been prepared.

UNIVERSITY, MISS. RECEIVED MARCH 3, 1937

[CONTRIBUTION NO. 175 FROM THE EXPERIMENTAL STATION OF E. I. DU PONT DE NEMOURS AND COMPANY]

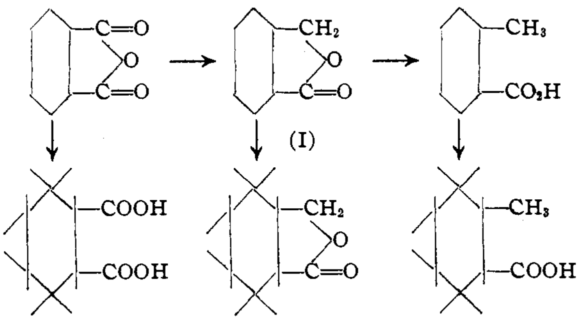
Phthalide. I. The Hydrogenation of Phthalic Anhydride

BY PAUL R. AUSTIN, E. W. BOUSQUET AND WILBUR A. LAZIER

Phthalic anhydride has been hydrogenated over nickel[1] and platinum[2] catalysts by a number of investigators, all of whom note the formation of phthalide (I) accompanied by varying amounts of toluic acid as well as ring-hydrogenated derivatives of the components of the reaction mixture (Chart I).

CHART I

HYDROGENATION OF PHTHALIC ANHYDRIDE



The complexity of the reaction may be illustrated by the recent work of Adkins, Wojcik and Covert[1d] who carried out the hydrogenation with nickel and isolated about equal amounts of phthalide, *o*-toluic acid and hexahydro-*o*-toluic acid. It was thought worth while to investigate further the optimum conditions for the catalytic synthesis of phthalide. Since early trials showed the presence of a solvent to be essential to high conversions, this factor was given primary consideration.

With nickel-on-kieselguhr catalyst yields of phthalide above 80% of the theoretical were realized using ethanol as the reaction medium. This process was carried out at 150–160°, a temperature at which the phthalic anhydride is converted readily to ethyl hydrogen phthalate and one might expect that the hydrogenation of this aromatic ester would be limited to the nucleus[1d] or inhibited completely by the action of the acid on the nickel catalyst.[3] The formation of phthalide which occurs in the presence of alcohol, leads us to postulate the hydrogenation of the tautomeric form of ethyl hydrogen phthalate (II), the course of the reduction proceeding by hydrogenolysis[4] in accordance with the following scheme (Chart II).

Furthermore, the closely related ester, *pseudo*-ethyl phthalaldehydate (III), hydrogenated smoothly to phthalide and *o*-toluic acid as predicted by this hypothesis. It is interesting to note that ester solvents, such as ethyl acetate, ethyl butyrate and butyl acetate may be employed satisfactorily in this process.

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[1] (a) Godchot, *Bull. soc. chim.*, [4] **1**, 829 (1907); (b) Eijkman, *Chem. Weekblad*, **4**, 191 (1907); (c) Lucius and Bruning, German Patent 368,414 (1923), *Friedl.*, **14**, 454; (d) Adkins, Wojcik and Covert, THIS JOURNAL, **55**, 1669 (1933).

[2] Willstätter and Jaquet, *Ber.*, **51**, 767 (1918); Vavon and Peignier, *Bull. soc. chim.*, [4] **45**, 297 (1929).

[3] Covert, Connor and Adkins, THIS JOURNAL, **54**, 1661 (1932).

[4] Connor and Adkins, *ibid.*, **54**, 4678 (1932).