successful reaction was indicated by the precipitation of sodium chloride. Water was added and the acidic reaction product was precipitated with sulfuric acid, filtered and recrystallized from dilute alcohol and dilute acetic acid. The crystals melted at 230–231°, 17.4 mg. in 2 cc. absolute acetone, αD + 0.48, $[\alpha]^{24}$D +55°. Experiment showed that this halogen-free dicarboxylic acid crystallizes with one molecule of water, which is still retained after drying in vacuum at 110°.

Anal. Calcd. for $C_{27}H_{44}O_4 \cdot H_2O$: C, 71.97; H, 10.29; neut. equiv., 226. Found: C, 72.16; H, 10.28; neut. equiv., 230.

Preparation of α_2-i-Cholestane-diacid-6,7 (IX).—This acid was prepared from α-3-chlorocholestane-diacid-6,7 (m. p. 263°) in a manner similar to the one described above. In this case, however, the reaction had to be carried out at 150°, and the time had to be increased to eight hours. The halogen-free dicarboxylic acid melts at 265°, 18.8 mg. in absolute dioxane, αD +0.43, $[\alpha]^{25}$D +46° in dioxane.

Anal. Calcd. for $C_{27}H_{44}O$: C, 74.95; H, 10.25; neut. equiv., 216. Found: C, 75.03; H, 10.46; neut. equiv., 217.

We wish to take this opportunity to express our thanks to Merck and Company, Inc., of Rahway, New Jersey, for the analyses published in this paper, for the determination of the absorption of Δ^4-cholestenone and for the cholesterol used as the starting material.

Summary

Further evidence has been given to show that Windaus' method of removing hydrogen chloride from α-3-chlorocholestanone-6 gives i-cholestanone and not the unsaturated ketone heterocholestenone.

The true heterocholestenone, Δ^4-cholestenone-6, has been obtained and characterized.

A new dicarboxylic acid, m. p. 233°, has been prepared from i-cholestanone. This acid has been shown to be an isomer of another new acid, m. p. 231°, obtained from β-3-chlorocholestanone-6. A third isomeric acid, m. p. 265°, has been prepared from α-3-chlorocholestanone-6.

A detailed discussion of the stereochemical relationships of these compounds has been given.

The Oxidation of Certain Heteronuclear-Substituted Polybromodiphenyls

BY FRANCIS H. CASE

In the course of various investigations in this Laboratory dealing with the structures of certain heteronuclear polybromodiphenyls, it seemed desirable to obtain more information as to the behavior of these compounds on oxidation. Although it is known, in general, that in the case of those diphenyls substituted by bromine in one ring only, the unsubstituted ring is destroyed by oxidation, there appears to be no information concerning the oxidation of those compounds in which bromine is a substituent in both rings. The method of oxidation employed utilizes chromic anhydride in approximately 75% acetic acid solution.[1] In each case a considerable amount of the total molecule was destroyed.

The oxidation of 3,4'-[2] and of 2,3'-dibromodiphenyls yielded p- and m-bromobenzoic acids, respectively, as the sole resulting products. The tribromodiphenyls investigated may (with the exception of 2,4,6-tribromodiphenyl) be divided into two groups in each of which the dibromo substituted nucleus remains the same, while the position of the monobromo substituent in the other nucleus is varied. Group A consists of 2,3',5'-(I),[3] 3,3',5'-(II), and 3',4,5'-(III) tribromodiphenyls. Group B contains 2,2',5'-(IV), 2',3,5'-(V) and 2',4,5'-(VI) tribromodiphenyls. The results of the oxidation of these six isomers are as follows: I and II yield only 3,5-dibromobenzoic acid; III, only p-bromobenzoic acid; IV, only 2,5-dibromobenzoic acid; V, both m-bromobenzoic and 2,5-dibromobenzoic acid; VI, both p-bromobenzoic and 2,5-dibromobenzoic acid.

The oxidation of 2,4,4',6-tetrabromodiphenyl was found to yield only p-bromobenzoic acid, while 2,4,6-tribromodiphenyl, subjected to the same treatment, also yielded a certain amount of p-bromobenzoic acid. This surprising result was at first attributed to the presence of a small amount of 2,4,4',6-tetrabromo-3-aminodiphenyl in the 2,4,6-tribromo-3-aminodiphenyl from which the 2,4,6-tribromodiphenyl was obtained by deamination. However, this explanation had to be

(1) L. F. Fieser, "Experiments in Organic Chemistry," D. C. Heath and Co., Inc., Boston, Mass., 1935, p. 230.

(2) Case, THIS JOURNAL, **60**, 424 (1938).

(3) Case, THIS JOURNAL, **61**, 767 (1939).

discarded when it was found that 2,4,6-tribromo-diphenyl prepared by Ullmann's reaction from 2,4,6-tribromoiodobenzene and iodobenzene yielded the same product on oxidation. It is possible that bromine liberated during the oxidation of the tribromo compound attacks the unsubstituted nucleus of some of the still unoxidized material, thus producing momentarily the tetrabromo derivative.

The synthesis of 2,4,6-tribromodiphenyl by Ullmann's reaction and the establishment of its identity with that produced by the method of Blakey and Scarborough[4] leave no further doubt as to the structure of the latter. The structure of 2,4,4',6-tetrabromodiphenyl, obtained by bromination of 4-bromo-3'-aminodiphenyl,[4] followed by deamination, is based on analogy with that of 2,4,6-tribromodiphenyl obtained similarly from 3-aminodiphenyl.

As a result of these studies of the oxidation of various polybromo substituted diphenyls, it is possible to arrange the various bromo-substituted phenyl radicals in the order of decreasing stability toward oxidation as follows: 4-bromo-, 3,5-dibromo-, (2,5-dibromo- and 3-bromo-), 2-bromo-, and 2,4,6-tribromo- phenyl.

The 2,3'-dibromodiphenyl used in this work was prepared by the deamination of 2,3'-dibromo-4'-aminodiphenyl.[8]

3,3',5'-Tribromodiphenyl was obtained by the following series of reactions: 2-amino-3'-bromo-diphenyl[8] → 2-amino-3,3',5-tribromodiphenyl → 3,3',5'-tribromodiphenyl. Since on oxidation 3,3',5'-tribromodiphenyl yields 3,5-dibromo-benzoic acid, the positions taken by the two entering bromine atoms in the dibromination of 2-amino-3'-bromodiphenyl are proved.
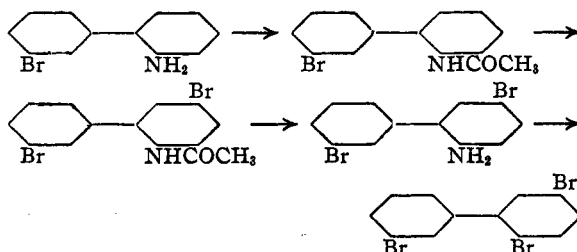
3',4,5'-Tribromodiphenyl was prepared by deamination of 3',4,5'-tribromo-4'-aminodiphenyl.[5] It evidently is identical with the tribromodiphenyl synthesized by Bellavita[6] from 2-amino-3,5-dibromo-4'-nitrodiphenyl.

2',4,5'-Tribromodiphenyl was synthesized by the following series of reactions: 4-bromo-3'-acetaminodiphenyl[4] → 2',4-dibromo-5'-acetaminodiphenyl → 2',4-dibromo-5'-aminodiphenyl → 2',4,5'-tribromodiphenyl.

The structure of the dibromo base was proved by its conversion to 2,4'-dibromodiphenyl on deamination. The final product is evidently iden-
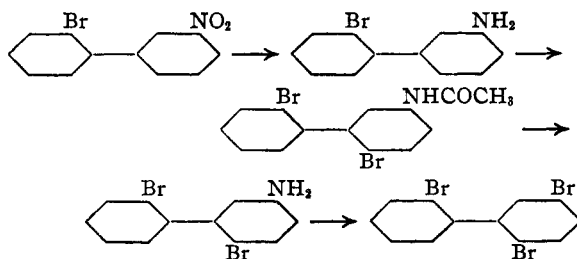
tical with the tribromodiphenyl prepared by Bellavita[7] from o, p'-bianiline.

2',3,5'-Tribromodiphenyl was prepared in the manner indicated[8]

The structure of the dibromo base was proved by its conversion to 3,3'-dibromodiphenyl on deamination.

The synthesis of 2,2',5'-tribromodiphenyl was effected by the following procedure[2]

The structure of the dibromo base was proved by its conversion to 2,2'-dibromodiphenyl on deamination.

Attempts to prepare 3,3',5'-tribromodiphenyl from 3-nitrobenzidine[9] by monobromination of the corresponding diurethan, removal of the urethano groups, reduction of the resulting 3-bromo-3'-nitrodiphenyl, followed by acetylation, monobromination, hydrolysis, and replacement of amino by bromine were unsuccessful, as it was found that 3-nitrobenzidine formed only a mono-urethan under the experimental conditions. This product upon monobromination, hydrolysis and deamination yielded 3-bromo-5-nitrodiphenyl, whose structure is proved by the fact that on reduction, replacement of amino by bromine and oxidation, 3,5-dibromobenzoic acid was formed. This bromonitrodiphenyl is evidently identical with that obtained by Scarborough and Waters[10] by deamination of 5-bromo-3-nitro-4-aminodiphenyl.

Experimental Part

The compounds described in Table I, grouped according to their generic relationships, were

(4) Blakey and Scarborough, *J. Chem. Soc.*, 3000 (1927).

(5) Scarborough and Waters, *ibid.*, 557 (1926).

(6) Bellavita, *Gazz. chim. ital.*, **67**, 574 (1937).

(7) Bellavita, *ibid.*, **65**, 632 (1935).

(8) Lesslie and Turner, *J. Chem. Soc.*, 1590 (1933).

(9) Le Fèvre and Turner, *ibid.*, 245 (1928).

(10) Scarborough and Waters, *ibid.*, 1138 (1927).

TABLE I

Compound	Crystallizing solvent	M. p. or b. p., °C.	Anal. for bromine, % Calcd.	Found
2,3'-Dibromodiphenyl		B. p. 165–168 (3 mm.)	51.28	51.51
2-Amino-3,3',5-tribromodiphenyl	Methanol	M. p. 111–112	59.08	59.29
Acetyl derivative	Ethanol	M. p. 185–186	53.53	53.60
3,3',5'-Tribromodiphenyl	Ethanol	M. p. 112–113	61.34	61.49
3',4,5'-Tribromodiphenyl	Ethanol	M. p. 102–103	61.34	61.48
2,4,4',6-Tetrabromo-3-aminodiphenyl[a]	Ethanol	M. p. 93–94	66.18	65.95
Acetyl derivative	Ethanol	M. p. 260–261	60.69	60.88
2,4,4',6-Tetrabromodiphenyl	Ethanol	M. p. 105–106	68.06	67.86
3-Amino-5-bromodiphenyl	Bz–pet. ether	M. p. 89–90	32.26	32.19
Acetyl derivative	Benzene	M. p. 142–143	27.56	27.34
2-Acetamino-3'-bromodiphenyl	Ether–pet. ether	M. p. 93–94	27.56	27.79
3,3'-Dibromo-6'-acetaminodiphenyl[b]	Bz–pet. ether	M. p. 145–146	43.35	43.11
2',3,5'-Tribromodiphenyl		B. p. 213–216 (6 mm.)	61.34	61.08
2,6'-Dibromo-3'-acetaminodiphenyl[b]	EtOH–water	M. p. 142	43.35	43.32
2,2',5'-Tribromodiphenyl	Pet. ether	M. p. 77–78	61.34	61.13
2',4-Dibromo-5'-aminodiphenyl	Bz–pet. ether	M. p. 91–92	48.89	49.07
Acetyl derivative	Ethanol	M. p. 163–164	43.35	43.62
2',4,5'-Tribromodiphenyl	Methanol	M. p. 77–78	61.34	61.75

[a] Blakey and Scarborough[4] record m. p. 104° for this compound   [b] Free base not isolated.

prepared by the following general methods according to the scheme already indicated: (1) reduction of nitro compounds was effected by stannous chloride in ethanol; (2) acetylation of amines by means of an acetic acid–acetic anhydride mixture in the presence of a small amount of sulfuric acid; (3) bromination of acetamino derivatives by the use of one mole of bromine in acetic acid solution containing sodium acetate; (4) deamination of amines by means of saturated sodium nitrite solution in a boiling alcoholic solution of the amine containing dilute sulfuric acid; (5) hydrolysis of acetamino compounds by alcoholic hydrobromic acid.

2,4,6-Tribromodiphenyl.—To 45 g. of iodobenzene heated to 180°, was added gradually a mixture of 44 g. of 2,4,6-tribromoiodobenzene and 40 g. of copper powder. The mixture was heated for two hours at 200° with stirring. After cooling, the mass was extracted with ether and the ether residue distilled. From it was obtained, after two distillations, 17.5 g. of a fraction, b. p. 190–198° (4 mm.), which after crystallization from petroleum ether yielded a pure tribromodiphenyl, m. p. 65–66°.

Anal. Calcd. for C₁₂H₇Br₃: Br, 61.34. Found: Br, 61.45.

This product melted unchanged when mixed with 2,4,6-tribromodiphenyl prepared by the method of Blakey and Scarborough.[4] The tribromodiphenyl prepared by either method yields on oxidation only p-bromobenzoic acid.

3-Nitrobenzidine.—The following method was found superior to that of Le Fèvre and Turner.[9] Twenty grams of 3,4'-dinitro-4-aminodiphenyl,[9] dissolved in 200 cc. of dioxane, was treated with 4 g. of sulfur and 24 g. of hydrated sodium sulfide and the mixture heated on the steam-bath for ten hours. After removal of the dioxane

on the steam-bath by means of an aspirator, the residue was purified by washing with hot water, followed by extraction with hot 1–1 acetic acid. The base was precipitated by ammonia from the acetic acid solution, and not further purified; yield of crude base, 17 g.

Monourethan of 3-Nitrobenzidine.—A boiling solution of 121 g. of crude 3-nitrobenzidine and 169 g. of diethylaniline in 1250 cc. of ethanol was treated gradually with 146 g. of ethyl chlorocarbonate. The mixture was boiled for ten minutes after the reaction had subsided, and then poured into a large volume of water. The resulting precipitate was crystallized from benzene: yield, 88 g. of a product melting at 163–164°. The pure monourethan melts at 167–168°.

Anal. Calcd. for C₁₅H₁₅N₃O₄: C, 59.77; H, 5.02. Found: C, 59.58; H, 4.81.

Monourethan of 3-Nitro-5-bromobenzidine.—This was prepared by the bromination of the monourethan of 3-nitrobenzidine in glacial acetic acid containing anhydrous sodium acetate. It was crystallized from benzene, m. p. 167–168°.

Anal. Calcd. for C₁₅H₁₄O₄N₃Br: Br, 21.03. Found: Br, 21.24.

3-Nitro-5-bromobenzidine.—The crude base was prepared from the urethan by hydrolysis with hot 60% sulfuric acid.

3-Nitro-5-bromodiphenyl.[10]—Eighty grams of crude 3-nitro-5-bromobenzidine was dissolved in 326 cc. of concd. sulfuric acid, and the mixture diluted with 300 cc. of water. Diazotization was then effected by the slow addition of 80 g. of sodium nitrite, keeping the temperature below 10°. Following this, the mixture was treated with 300 cc. of 20% oleum at a temperature below 30°, and poured into 2 liters of boiling alcohol. After refluxing for two hours, the alcohol was removed and water added. The desired product was extracted with ether, and, after removal of ether, distilled *in vacuo*, yielding 31 g., b. p. 200–242°

(5 mm.). The crude distillate was recrystallized from methanol: yield, 10.5 g.; m. p. 71–72°.

Anal. Calcd. for $C_{12}H_8NO_2Br$: Br, 28.75. Found: Br, 29.12.

Summary

1. A study has been made of the oxidation products of the following polybromodiphenyls: 2,3'- and 3,4'-dibromodiphenyl, 2,3',5'-, 3,3',5'-, 3',4,5'-, 2,2',5'-, 2',3,5'-, 2',4,5'- and 2,4,6-tribromodiphenyls, and 2,4,4',6-tetrabromodiphenyl.

2. The preparation of those polybromodiphenyls not previously recorded is described.
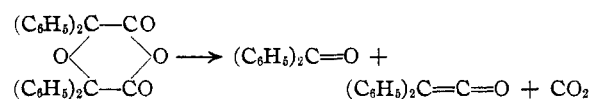

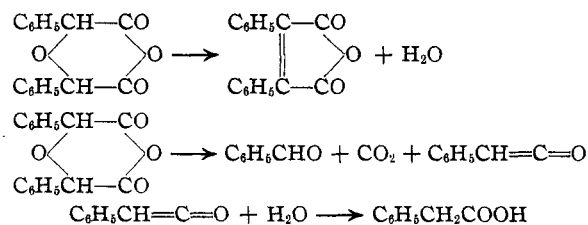[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF NORTHWESTERN UNIVERSITY]

The Pyrolysis of Diglycolic Anhydride

BY CHARLES D. HURD AND HOWARD G. GLASS

On pyrolysis, dibenzilic anhydride[1] yields benzophenone and diphenylketene. Dimandelic an-
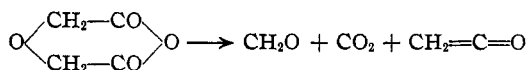
$$(C_6H_5)_2C\text{---}CO$$
$$O<\quad>O \longrightarrow (C_6H_5)_2C\text{==}O +$$
$$(C_6H_5)_2C\text{---}CO$$
$$(C_6H_5)_2C\text{==}C\text{==}O + CO_2$$

hydride[2] decomposes thermally at 250° into diphenylmaleic anhydride, phenylacetic acid, benzaldehyde, and oxides of carbon.

$$C_6H_5CH\text{---}CO\qquad C_6H_5C\text{---}CO$$
$$O<\quad>O \longrightarrow \quad \|\quad\quad>O + H_2O$$
$$C_6H_5CH\text{---}CO\qquad C_6H_5C\text{---}CO$$

$$C_6H_5CH\text{---}CO$$
$$O<\quad>O \longrightarrow C_6H_5CHO + CO_2 + C_6H_5CH\text{==}C\text{==}O$$
$$C_6H_5CH\text{---}CO$$

$$C_6H_5CH\text{==}C\text{==}O + H_2O \longrightarrow C_6H_5CH_2COOH$$

The present work deals with diglycolic anhydride. From the above one would predict for it a bidirectional breakdown on heating. One reaction should give rise to maleic anhydride

$$CH_2\text{---}CO\qquad CH\text{---}CO$$
$$O<\quad>O \longrightarrow \|\quad\quad>O + H_2O$$
$$CH_2\text{---}CO\qquad CH\text{---}CO$$
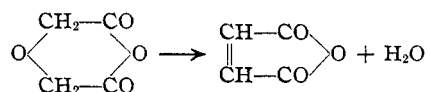
whereas the other should yield ketene

$$CH_2\text{---}CO$$
$$O<\quad>O \longrightarrow CH_2O + CO_2 + CH_2\text{==}C\text{==}O$$
$$CH_2\text{---}CO$$

A good yield of maleic anhydride was obtained at 450–500°. Some ketene was observed too, but since water was formed in this reaction it must have changed much of the ketene into acetic acid.

The production of maleic anhydride from diglycolic anhydride involves lengthening of the carbon chain. This is an interesting, unusual method of bringing about such an effect.

(1) Staudinger, *Ber.*, **44**, 543 (1911).
(2) Hurd and Raterink, THIS JOURNAL, **55**, 1541 (1933).

Experimental

Diglycolic Anhydride.—To 35 g. of diglycolic acid was added 65 g. of acetic anhydride and the mixture was refluxed four hours. Then 35 g. of acetic acid was distilled off, 30 g. more of acetic anhydride added and the mixture was refluxed for two hours longer. On distillation 5 g. more of acetic acid was collected and 61 g. of acetic anhydride was recovered. The residue was vacuum distilled. There was collected 32 g. (94% yield) of diglycolic anhydride at 130° and 20 mm. It solidified on cooling; m. p. 94–95°. The derivative with aniline, diglycolic phenylimide, was prepared. Its melting point of 109–110° confirmed Anschütz' value[3] of 111°.

Analysis of Mixtures of Maleic and Diglycolic Anhydrides.—The separation of these two anhydrides was accomplished satisfactorily by the selective solvent action of benzene. Both anhydrides were soluble in hot benzene whereas diglycolic anhydride separated on cooling the solution to 6°. After concentrating the filtrate and cooling till crystals of this compound no longer appeared, furan was added to the solution. After a time, crystals of the addition product of furan and maleic anhydride separated.[4] This material melted at 122–124° and at 125° after recrystallization (literature, 125°).

In various mixtures, recovery of the diglycolic anhydride was almost quantitative and recovery of the maleic anhydride derivative was 89–95%. The results are presented in Table I.

TABLE I

SEPARATION OF MALEIC AND DIGLYCOLIC ANHYDRIDES

Maleic anhydride	Diglycolic anhydride	Diglycolic anhydride found G.	%	Maleic anhydride found Furan deriv. G.	%
3.0	12.0	11.6	97	4.75	94
1.0	1.0	1.0	100	1.6	95
0.8	1.0	0.97	97	1.25	93
.6	1.0	.95	95	0.90	89
.4	1.0	.96	96	.60	89
.2	1.0	.97	97	.30	89

Pyrolysis of Diglycolic Anhydride.—The sample of diglycolic anhydride was placed in a test-tube with a side

(3) Anschütz, *Ann.*, **273**, 66 (1892).
(4) Diels and Alder, *Ber.*, **62**, 554 (1929).