CCCLX.—*The Condensation of Phenols with Chloral.*

By Frederick Daniel Chattaway.

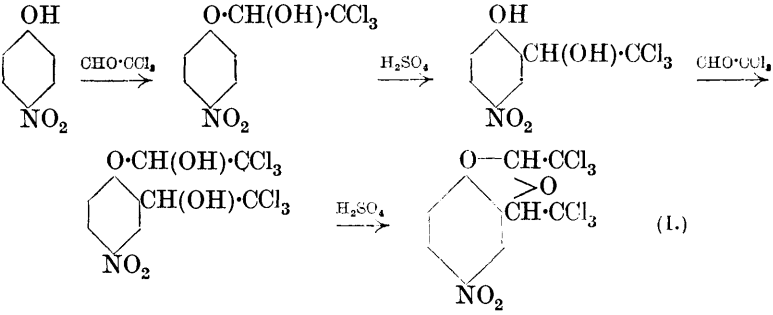
Chloral reacts with phenols in presence of sulphuric acid, yielding more complicated compounds than any hitherto described.

For example, when *p*-nitrophenol and chloral are brought together in presence of a large excess of concentrated sulphuric acid, a beautifully crystalline solid is formed whose composition and molecular weight are expressed by the formula $C_{10}H_5O_4NCl_6(OH{\cdot}C_6H_4{\cdot}NO_2 + 2CCl_3{\cdot}CHO - H_2O)$.

No phenolic or alcoholic hydroxyl group is present in the molecule, since the compound does not dissolve in dilute alkalis and can be recrystallised without change from boiling acetic anhydride. It contains the nitro-group unchanged, since this can be reduced to an amino-group which can be acetylated, or diazotised and replaced or removed.

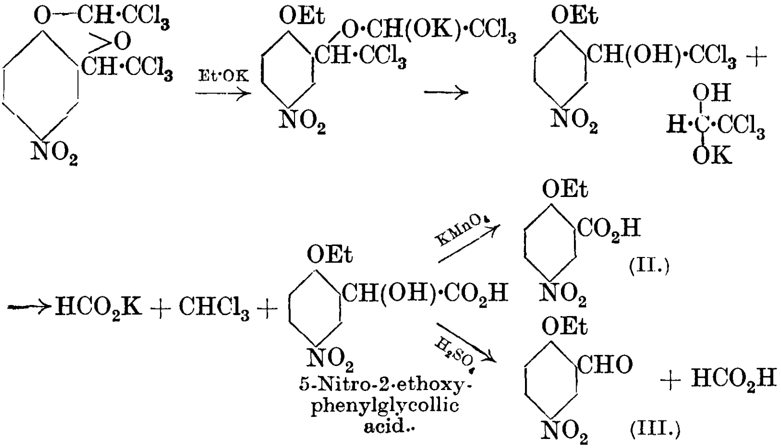
It reacts vigorously with alcoholic potash, liberating chloroform and yielding a compound of the composition $C_{10}H_{11}O_6N$. This proves to be *5-nitro-2-ethoxyphenylglycollic acid*, since it is broken up by sulphuric acid into 5-nitro-2-ethoxybenzaldehyde and formic acid and yields 5-nitro-2-ethoxybenzoic acid on oxidation by aqueous alkaline permanganate.

The condensation therefore appears to take the following course. The *p*-nitrophenol and chloral first unite to form a compound resembling chloral alcoholate in structure, which then, under the influence of the sulphuric acid, undergoes intramolecular rearrangement, the migrating $-CH(OH){\cdot}CCl_3$ group taking up the ortho-position in the nucleus, the para-position being already occupied by the nitro-group. A further similar combination followed by elimination of water yields the final product, which is therefore *anhydro-5-nitro-2-βββ-trichloro-α-hydroxyethoxy-1-βββ-trichloro-α-hydroxyethylbenzene* (I).



(I.)

The reaction of this compound (I) with alcoholic potash and the subsequent oxidation of the product to 5-nitro-2-ethoxybenzoic acid (II) and its conversion by sulphuric acid into 5-nitro-2-ethoxybenzaldehyde (III) and formic acid may be represented as follows:



EXPERIMENTAL.

Anhydro-5-nitro-2-βββ-trichloro-α-hydroxyethoxy-1-βββ-trichloro-α-hydroxyethylbenzene (I).—Chloral hydrate (331 g.; 2 mols.) and 139 g. of *p*-nitrophenol (1 mol.) were heated together in an open dish until a clear brown liquid was formed. When this was poured, with constant stirring, into 1000 c.c. of concentrated sulphuric acid, no evolution of heat occurred and the colour of the mixture, the temperature of which did not rise above 35°, gradually deepened until it became dark greenish-brown. The mixture, which was frequently shaken to prevent the formation of a compact crust, after 5—8 days had become a pulp of colourless crystals of the condensation product. This was filtered off and thoroughly washed first with warm water and finally with warm very dilute aqueous ammonia until the filtrate was no longer yellow; it was then dried on a water-bath, and recrystallised first from acetic acid and finally from alcohol, being thus obtained in very faintly yellow crystals. Usually the yield is somewhat less than the weight of chloral hydrate used.

The substance is insoluble in water, dilute acids and alkalis, but dissolves moderately easily in boiling alcohol, benzene, or acetone, easily in boiling acetic acid, giving pale yellow solutions from which it separates in glistening, colourless prisms, m. p. 146° (Found: C, 28·9; H, 1·3; N, 3·5; Cl, 51·1; *M*, ebullioscopic in benzene and acetone, 418, 423. $C_{10}H_5O_4NCl_6$ requires C, 28·9; H, 1·2; N, 3·4; Cl, 51·2%; *M*, 416). The compound was recovered unchanged after being heated for several hours on a water-bath with a large excess of acetic anhydride. 100 G. of alcohol dissolve 2·51 g. at 15·6°, 2·78 g. at 21°, and 3·78 g. at 30°.

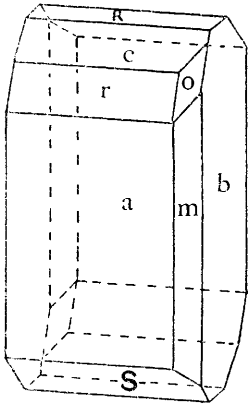
Mr. Curjel of Keble College, who has very kindly examined the crystals, describes them as follows :

Well-formed, colourless crystals were obtained by allowing a solution in alcohol to cool slowly. The crystals belong to the holohedral class of the anorthic system. The axial elements are $a : b : c = 2{\cdot}4895 : 1 : 1{\cdot}1368$; $\alpha = 90° 28'$, $\beta = 115° 32'$, $\gamma = 81° 8'$. The forms observed were *a* {100}, *m* {110}, *b* {010}, *r* {101}, *c* {001}, *R* {$\bar{1}$01}, *S* {20$\bar{1}$}, and *o* {111}.

The interfacial angles are given in the accompanying table.

Angle.	No. of measurements.	Limits.	Mean observed.	Calc.
100 : 110	10	74° 42′—75° 13′	75° 0′	—
110 : 010	10	24° 29′—24° 45′	24° 36′	—
100 : 101	6	44° 54′—45° 15′	45° 6′	—
010 : $\bar{1}$01	4	89° 10′—89° 17′	89° 14′	—
100 : $\bar{1}$01	6	91° 37′—91° 55′	91° 48′	—
101 : 001	6	18° 53′—19° 7′	19° 1′	19° 8′
$\bar{1}$01 : $\bar{2}$01	4	26° 29′—26° 43′	26° 38′	26° 50′
110 : 111	4	38° 12′—38° 21′	38° 16′	38° 24′
111 : 001	4	43° 35′—45° 1′	44° 28′	44° 44′
0$\bar{1}$0 : 101	4	83° 33′—83° 42′	83° 36′	83° 34′
010 : 001	2	93° 32′—93° 36′	93° 34′	93° 42′
101 : 111	2	43° 25′—43° 29′	43° 27′	43° 46′

The predominant forms are *a* {100} and *b* {010}. There are fair cleavages parallel respectively to *a* {100} and *b* {010}. A cleavage fragment parallel to either of these faces shows one optic axis, when examined in convergent light between crossed Nicols. The crystals are biaxial, with a fairly wide axial angle. The double refraction is negative and very strong. The interference figure exhibits crossed dispersion. $\rho > v$.



The specific gravity of the crystals was found by the suspension method to be 1·733 at 19°, a Westphal balance being used.

Conversion of Anhydro-5-nitro-2-βββ-trichloro-α-hydroxyethoxy-1-βββ-trichloro-α-hydroxyethylbenzene into dl-5-*Nitro-2-ethoxyphenylglycollic Acid*, $NO_2{\cdot}C_6H_3(OEt){\cdot}CH(OH){\cdot}CO_2H$.—The anhydro-compound (50 g.; 1 mol.) was gradually added to a solution of 60 g. of potassium hydroxide (about 9 mols.) in 200 c.c. of alcohol, the vigorous action which took place being moderated by cooling. Chloroform was liberated and ethyl orthoformate produced, both of which could be recognised by their smell. The deep brownish-yellow liquid produced (a little of which gave a clear, deep yellow solution on being heated with an excess of water) was partly neutralised by addition of hydrochloric acid, until distinctly but not very strongly alkaline, the alcohol was then distilled off in steam, and the resulting clear yellow liquid made strongly acid with hydrochloric acid. A small quantity of a pale brownish-yellow solid separated, which was decolorised by animal charcoal and recrystallised several times from boiling water, in which it was sparingly soluble; 5-*nitro*-2-*ethoxybenzoic acid* was thus obtained in thin, colourless plates, m. p. 163° (Found: C, 51·2; H, 4·4; N, 6·75. $C_9H_9O_5N$ requires C, 51·1; H, 4·3; N, 6·6%). The yield was less than 1% of the weight of the condensation product decomposed.

The strongly acid mother-liquor from which the 5-nitro-2-ethoxybenzoic acid had been filtered, on standing for about 24 hours, deposited a large quantity of another acid in very pale brownish-yellow crusts. This acid was moderately easily soluble in boiling water and very easily soluble in boiling alcohol, giving clear yellow solutions. From an alcoholic solution to which boiling water (10—12 vols.) had been added, it separated, on cooling, in aggregates of small, almost colourless plates or flattened prisms showing a faint yellow tint, m. p. 138° (Found: C, 49·7; H, 4·6; N, 5·9. $C_{10}H_{11}O_6N$ requires C, 49·8; H, 4·6; N, 5·8%). Its composition and the facts that it contains an ethoxyl, a hydroxyl, and a carboxyl group, that it is decomposed by sulphuric acid into 5-nitro-2-ethoxybenzaldehyde and formic acid, and that on oxidation by alkaline potassium permanganate it yields 5-nitro-2-ethoxybenzoic acid, show that it has the constitution of dl-5-*nitro*-2-*ethoxyphenylglycollic acid.* It dissolves in alkalis and in a solution of ammonia, forming salts of a deep yellow colour. The *silver* salt, prepared from silver nitrate and the ammonium salt in strong neutral solution, separates as a thick, white, crystalline pulp, which is sparingly soluble in boiling water and crystallises on cooling in small, colourless plates (Found: Ag, 30·6. $C_{10}H_{10}O_6NAg$ requires Ag, 31·0%).

The *acetyl* derivative, $NO_2{\cdot}C_6H_3(OEt){\cdot}CH(OAc){\cdot}CO_2H$, prepared by boiling for a few minutes a solution of the acid (5 g.) in about 10 c.c. of acetic anhydride containing two drops of strong sulphuric acid, separated, on cooling after the addition of a few drops of water, as a white, crystalline solid. It was easily soluble in boiling chloroform and sparingly soluble in light petroleum, and separated from a mixture of the two in very small, rhombic plates, m. p. 147·2° (Found: C, 50·9; H, 4·75; N, 5·0. $C_{12}H_{13}O_7N$ requires C, 50·9; H, 4·6; N, 4·95%).

Decomposition of dl-5-*Nitro*-2-*ethoxyphenylglycollic Acid into* 5-*Nitro*-2-*ethoxybenzaldehyde and Formic Acid by Concentrated Sulphuric Acid.*—The *dl*-acid (5 g.) was gently heated with about 6 c.c.

of concentrated sulphuric acid, carbon monoxide being evolved at 60—70° and a deep yellow solution obtained. This was cooled and poured into water; 5-nitro-2-ethoxybenzaldehyde then separated as a pale yellow solid. This was dissolved in acetic acid and warmed with semicarbazide hydrochloride and excess of sodium acetate.

5-*Nitro-2-ethoxybenzaldehydesemicarbazone*,

$NO_2\cdot C_6H_3(OEt)\cdot CH\colon N\cdot NH\cdot CO\cdot NH_2$,

thus obtained as a yellowish-white solid, exists in two very well-characterised, polymorphic forms. It is somewhat sparingly soluble in boiling alcohol and, on cooling, the labile form separates in slender, flattened prisms, so thin that they curl up like watch springs. On standing, the stable form soon makes its appearance as small, compact, golden-yellow, rhombic prisms or plates; these grow at the expense of the labile form, which dissolves and in a few days completely disappears. Both forms melt at 234—235° with decomposition and evolution of gas (Found: C, 47·9; H, 5·2; N, 22·1. $C_{10}H_{12}O_4N_4$ requires C, 47·6; H, 4·8; N, 22·2%).

Oxidation of dl-5-*Nitro-2-ethoxyphenylglycollic Acid.*—The *dl*-acid (10 g.) was dissolved in the smallest possible quantity of a strong aqueous solution of potassium hydroxide, a solution of 6 g. of potassium permanganate in about a litre of hot water added, and the whole boiled vigorously for about ½ hour. The excess of permanganate was destroyed with alcohol, the manganese dioxide filtered off, and to the bright yellow filtrate a slight excess of hydrochloric acid was added. The colourless solution obtained, on cooling, deposited 5-*nitro-2-ethoxybenzoic acid*, which crystallised from boiling water, in which it was somewhat sparingly soluble, in almost colourless, long, irregularly grown, thin, rhombic plates with a faint yellow tint, m. p. 163° (Found: C, 51·0; H, 4·3; N, 6·7. $C_9H_9O_5N$ requires C, 51·1; H, 4·3; N, 6·6%). It dissolves in aqueous potassium hydroxide, giving an intense deep yellow solution, and forms a very sparingly soluble *sodium* salt which crystallises from aqueous solution in small, bright yellow prisms.

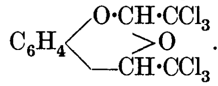
The acid was identical with a specimen of 5-nitro-2-ethoxybenzoic acid made by nitrating salicylic acid, converting the 5-nitrosalicylic acid into ethyl 5-nitro-2-ethoxybenzoate, saponifying this by caustic potash, and acidifying the product.

*Anhydro-5-amino-2-*βββ*-trichloro-*α*-hydroxyethoxy-*1-βββ*-trichloro-*α*-hydroxyethylbenzene* (formula similar to I).—The corresponding 5-nitro-compound (10 g.) was dissolved in 30 c.c. of acetic acid, and about 20 g. of granulated tin were added; the heat of reaction caused the liquid to boil freely. When vigorous action had ceased, the liquid was allowed to cool and then poured into concentrated hydrochloric acid (4—5 vols.). The *hydrochloride* of the base, which separated in an almost pure condition as a colourless solid, crystallised from boiling dilute hydrochloric acid, in which it was moderately easily soluble, in thin, colourless plates which when heated decomposed without melting. It was easily soluble in alcohol (Found: Cl, 58·6. $C_{10}H_7O_2NCl_6,HCl$ requires Cl, 58·7%). On warming the hydrochloride with a dilute solution of sodium carbonate, the *base* was liberated as a white solid. It crystallised from boiling alcohol, in which it was readily soluble, in long, colourless, flattened, very slender, hair-like prisms, m. p. 176° (Found: N, 3·7. $C_{10}H_7O_2NCl_6$ requires N, 3·6%).

The *acetyl* derivative was formed with evolution of heat when the base was added to acetic anhydride. It is readily soluble in alcohol, dilute acetic acid, and chloroform and sparingly soluble in light petroleum. It separates from a mixture of the last two solvents in thin, colourless, rhombic plates, m. p. 206° (Found: C, 33·7; H, 2·1; N, 3·3; Cl, 49·8. $C_{12}H_9O_3NCl_6$ requires C, 33·5; H, 2·1; N, 3·4; Cl, 49·6%).

The 5-*diazonium chloride* was readily formed when nitrous fumes were passed into a solution, at 0°, of 15 g. of the preceding hydrochloride in about 50 c.c. of alcohol through which a little dry hydrogen chloride had been passed.

The *sodium* salt of the 5-azo-β-naphthol derivative separated as a brilliant scarlet precipitate when a solution of the preceding diazonium salt was poured into a cooled solution of β-naphthol in excess of aqueous caustic soda. After the liquids had been made slightly acid with acetic acid, the scarlet *azo*-compound was filtered off. It crystallised from boiling acetic acid, in which it was readily soluble, in long, deep red needles, m. p. 196° (Found: Cl, 39·3. $C_{20}H_{12}O_3N_2Cl_6$ requires Cl, 39·4%).

Anhydro-2-ββ*β*-*trichloro*-α-*hydroxyethoxy*-1-βββ-*trichloro*-α-*hydroxyethylbenzene*,  $C_6H_4\left<\begin{array}{l}O\cdot CH\cdot CCl_3\\ \qquad >O\\ CH\cdot CCl_3\end{array}\right.$.—A solution of the diazonium chloride in alcohol obtained as described above from 15 g. of the amine hydrochloride was heated and finally boiled gently for some minutes. The liquid became dark coloured, nitrogen was steadily evolved, and aldehyde was liberated. The whole was then poured into water, when *anhydro*-2-βββ-*trichloro*-α-*hydroxyethoxy*-1-βββ-*trichloro*-α-*hydroxyethylbenzene* separated as a slightly brown solid. It crystallised from boiling alcohol, in which it was moderately easily soluble, in clusters of colourless, very thin, slender, flattened prisms, m. p. 119° (Found: C, 32·5; H, 1·7; Cl, 37·5. $C_{10}H_6O_2Cl_6$ requires C, 32·4; H, 1·6; Cl, 37·35%).

The action of chloral upon other phenols and phenolic compounds in presence of concentrated sulphuric acid is being studied.

THE QUEEN'S COLLEGE, OXFORD.

[*Received, March* 31*st*, 1926.]