EFFECTS Of SUBSTITUTION On The FORMATION And CYCLISATION Of 11-CARBOXY-BENZANTHRONES.

By

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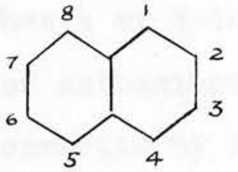
INTRODUCTION.

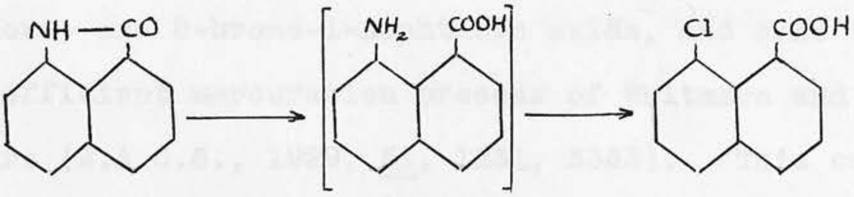
Amid the extraordinary complexities of organic chemistry it is only natural that certain particular aspects of the subject should attract general and continuous attention. In the study of the chemistry of naphthalene which, by reason of the possibilities of isomerism, constitutes a relatively enormous field, we find that especial attention has been devoted to its peri-derivatives, that is, those compounds in which the 1:8-(or 4:5-) positions are substituted.



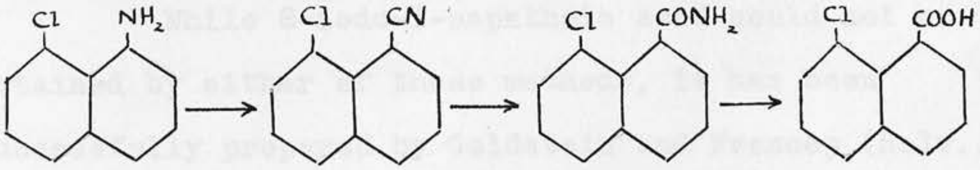
This is not only because of the interesting and significant analogy in behaviour between certain peri-derivatives of naphthalene and the corresponding ortho-derivatives of benzene, the former frequently possessing the properties of the latter to an enhanced degree, but is also due, firstly, to the ready accessibility of certain compounds of this type and, secondly, to their reactivity, which enables them to be used in the synthesis of numerous and important derivatives.

Peri-halogenated Naphthoic Acids.

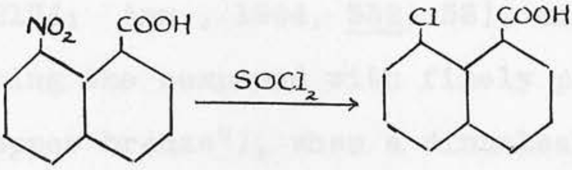
Among the most interesting peri-derivatives are the 8-halogeno-1-naphthoic acids. Early investigations of peri-substituted naphthoic acids include the comprehensive researches of Ekstrand (J. prakt. Chem., 1888, 38, 139, 241). The only 8-halogeno-1-naphthoic acid to be prepared by him was the 8-chloro-acid, obtained by the application of the Sandmeyer reaction to naphthastyril.



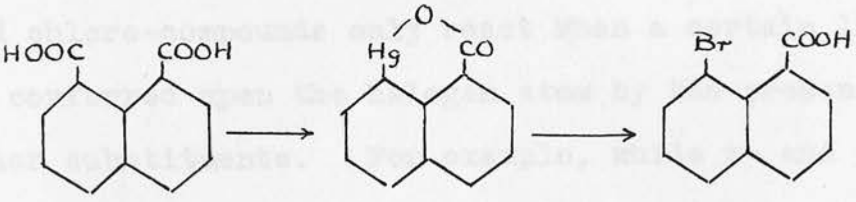
Kalb (Ber., 1914, 47, 1724) employed a somewhat different synthesis of 8-chloro-1-naphthoic acid in the preparation of anthanthrone. 1:8-Chloronaphthylamine was converted by the Sandmeyer reaction into the nitrile, the latter on hydrolysis yielding the acid amide. The amide was then treated with nitrous acid to form 8-chloro-1-naphthoic acid.



The replacement of nitro-groups by halogen under various conditions has been familiar for some time, thionyl chloride being a particularly useful reagent. Rule and Spence (J., 1929, 2516) observed the ready replacement of the nitro-group in 8-nitro-1-naphthoic acid on warming the acid in benzene solution with thionyl chloride, thus yielding 8-chloro-1-naphthoic acid.



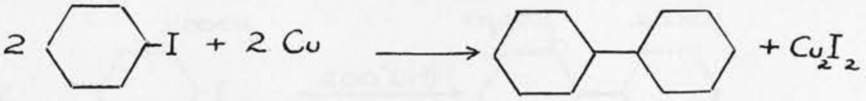
Rule and Barnett (J., 1932, 175) employed this reaction in various forms for the preparation of 8-chloro- and 8-bromo-1-naphthoic acids, and also the more efficient mercuration process of Whitmore and co-workers (J.A.C.S., 1929, 51, 1831, 3363). This consists of the mercuration of naphthalic acid to give anhydro-8-hydroxy-mercuri-1-naphthoic acid which, on treatment with bromine (or chlorine), yields the 8-halogeno-1-naphthoic acid (cf. Rule and co-workers, J., 1934, 170).



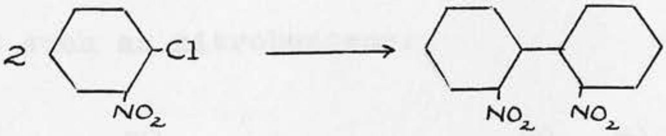
While 8-iodo-1-naphthoic acid could not be obtained by either of these methods, it has been successfully prepared by Goldstein and Francey (Helv., 1932, 15, 1362) by means of a modification of the Sandmeyer reaction with naphthastyril.

The Ullmann Reaction.

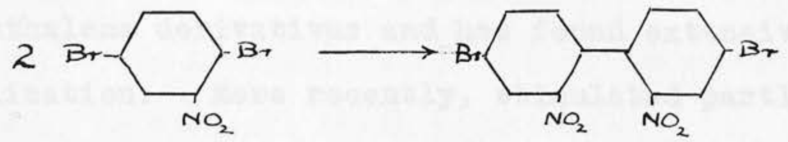
One of the most important reactions of halogenated aromatic compounds is the Ullmann Reaction. This reaction was discovered by Ullmann in 1900 (Ber., 1901, 34, 2174; Ann., 1904, 332, 38), and is carried out by heating the compound with finely powdered copper ("copper bronze"), when a dinuclear compound with a new carbon to carbon linkage is formed, the halogen being eliminated as cuprous halide. Thus, diphenyl is formed by heating iodobenzene with copper powder at 230°C. in a sealed tube.



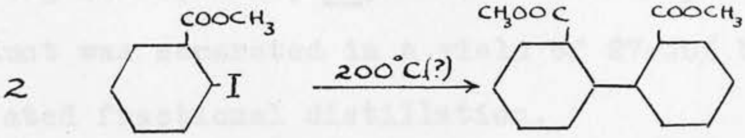
It was found by Ullmann that while the reaction with copper bronze proceeds smoothly with almost all iodo-compounds, the corresponding bromo- and chloro-compounds only react when a certain lability is conferred upon the halogen atom by the presence of other substituents. For example, while m- and p-nitro-chlorobenzenes (or -bromobenzenes) were unreactive, the o-nitro-isomers reacted readily to give 2:2'-dinitro-diphenyl.

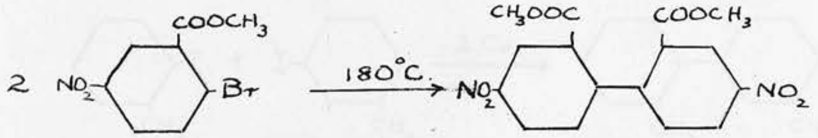


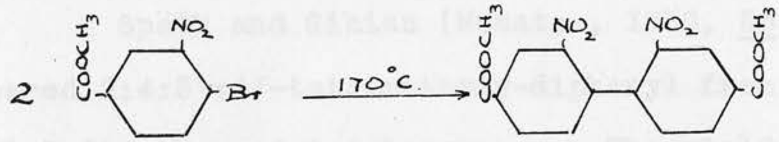
Similarly, 2:5-dibromo-nitrobenzene gave a good yield of 2:2'-dinitro-4:4'-dibromo-diphenyl.



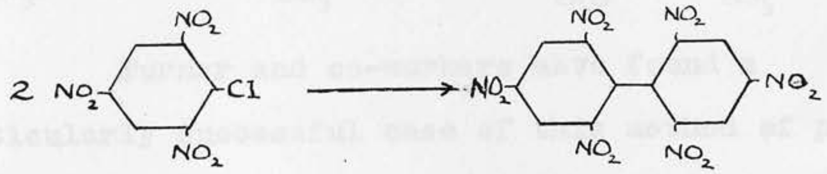
When a carbomethoxy group is in the ortho-position to the halogen, however, an additional p-nitro-group had a considerable activating effect. While methyl o-iodo- benzoate apparently did not react below 200°C., methyl 2-bromo-5-nitro-benzoate reacted readily at 180°C. Strong activation was also apparent in the case of methyl 3-nitro-4-bromo-benzoate.





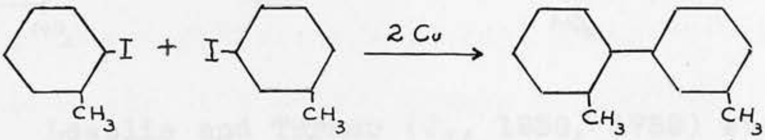


When two nitro-groups are ortho to the halogen, as in picryl chloride, the reaction tends to become explosive unless carried out in an inert solvent such as nitrobenzene.

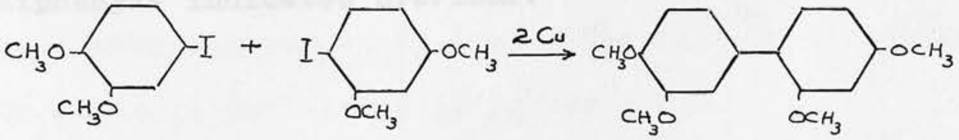


The reaction is equally suitable for naphthalene derivatives and has found extensive application. More recently, stimulated partly by the interest of certain substituted diphenyl and related compounds with regard to optical activity due to restricted rotation, it has been applied to the formation of unsymmetrical derivatives from mixtures of halogenated compounds.

The first recorded instance of this variation of the reaction is the preparation of 2:3'-ditolyl from a mixture of o- and m-iodotoluenes by Mayer and Freitag (Ber., 1921, 54, 356). The unsymmetrical product was separated in a yield of 27-30% by repeated fractional distillation.

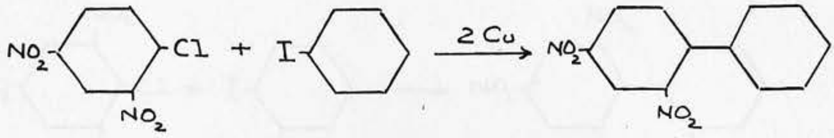


Späth and Gibian (Monats., 1930, 55, 342) prepared 2:4:3':4'-tetramethoxy-diphenyl from 1:2- and 1:3-dimethoxy-4-iodobenzenes. The yield of the compound, isolated by fractional crystallisation, was relatively low.

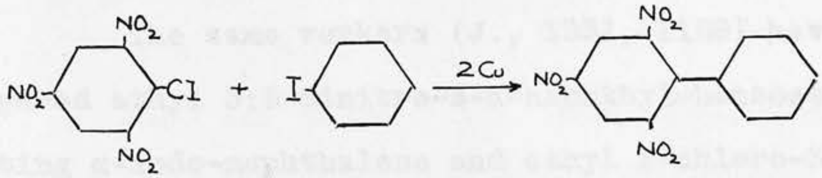


Turner and co-workers have found a particularly successful case of this method of preparing unsymmetrical diphenyl derivatives. Gull and Turner

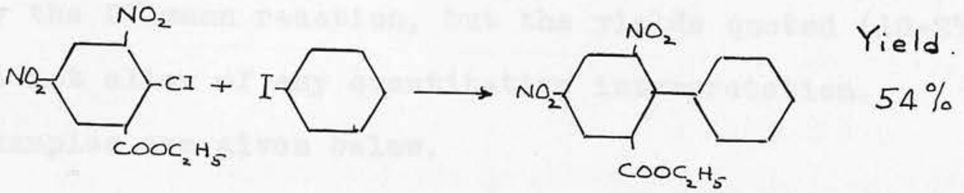
(J., 1929, 491) obtained a 20% yield of 2:4-dinitro-diphenyl from iodobenzene and 2:4-dinitro-chloro-benzene, no diphenyl being isolated.

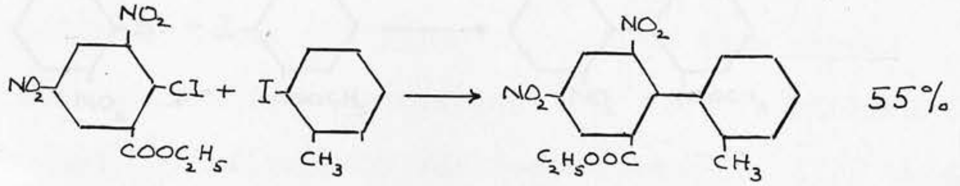


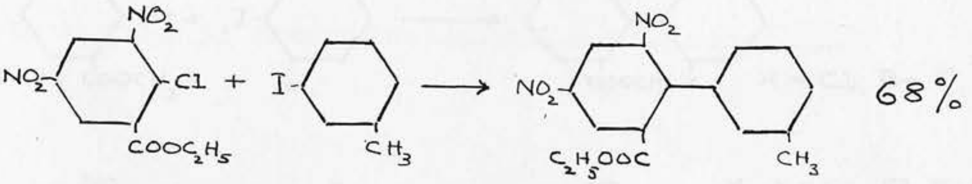
By heating picryl chloride, iodobenzene and copper powder at about 200°C., 2:4:6-trinitro-diphenyl was obtained. No yield is quoted but no hexanitro-diphenyl was detected, its apparent non-formation being attributed to spatial effects.



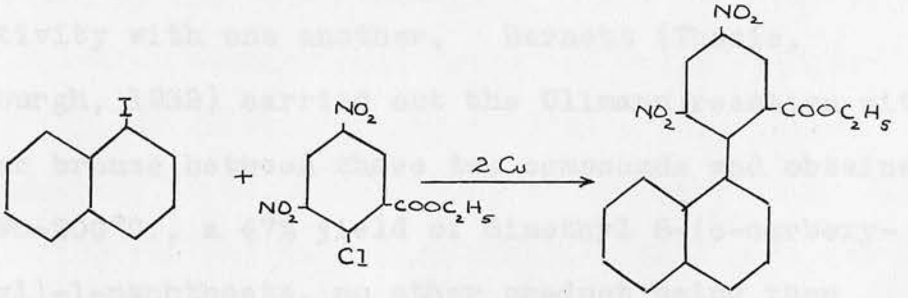
Lesslie and Turner (J., 1930, 1758) state that when equimolecular quantities of ethyl 2-chloro-3:5-dinitro-benzoate and an aromatic iodo-compound are heated together in presence of copper bronze, ethyl 2:4-dinitro-diphenyl-6-carboxylates alone are formed. In this manner they obtained the unsymmetrical diphenyls indicated overleaf.





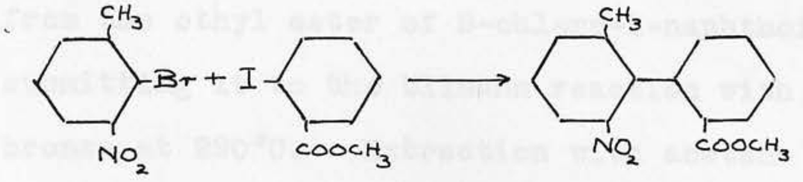


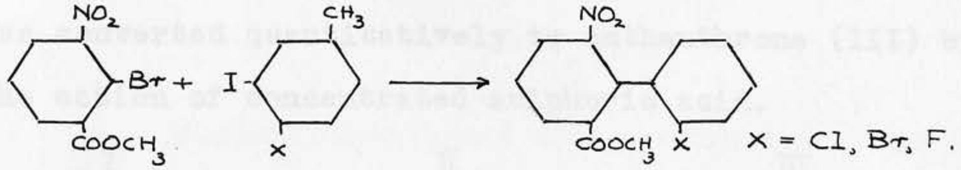
The same workers (J., 1931, 1188) have prepared ethyl 3:5-dinitro-6-α-naphthyl-benzoate by heating α-iodo-naphthalene and ethyl 2-chloro-3:5-dinitro-benzoate with copper bronze at 180°C.

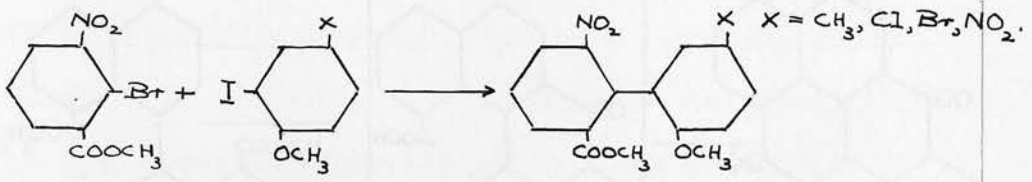


Though quoting only a 53% yield of the unsymmetrical compound, they state that no dinaphthyl or diphenyl derivative is formed.

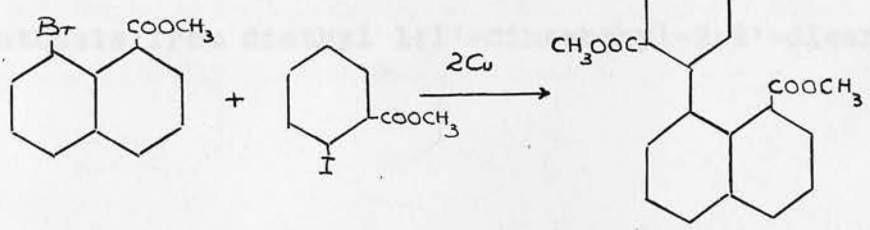
Adams and co-workers (cf. J.A.C.S., 1930, 52, 5263; 1932, 54, 4426, 4434; etc.) have also prepared a number of unsymmetrical diphenyl derivatives by the Ullmann reaction, but the yields quoted (10-27%) do not allow of any quantitative interpretation. Examples are given below.





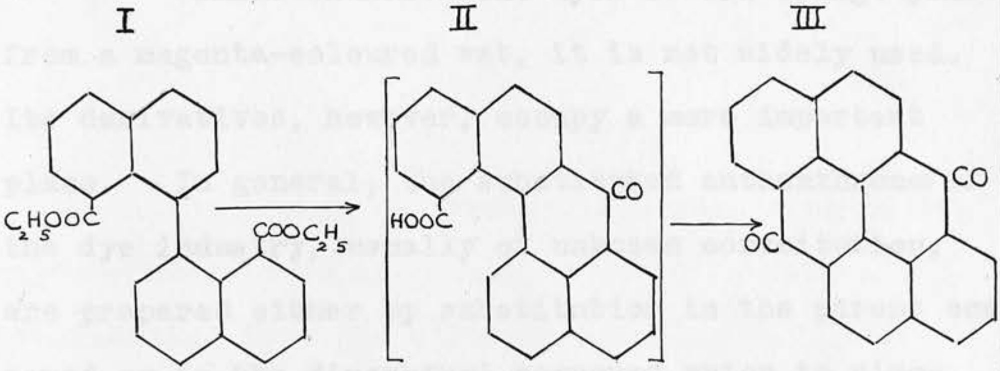


Rule and Barnett (J., 1932, 2728) concluded from their investigation that methyl o-iodo-benzoate and methyl 8-bromo-1-naphthoate were comparable in reactivity with one another. Barnett (Thesis, Edinburgh, 1932) carried out the Ullmann reaction with copper bronze between these two compounds and obtained, at 190-200°C., a 47% yield of dimethyl 8-(o-carboxyphenyl)-1-naphthoate, no other product being then isolated.

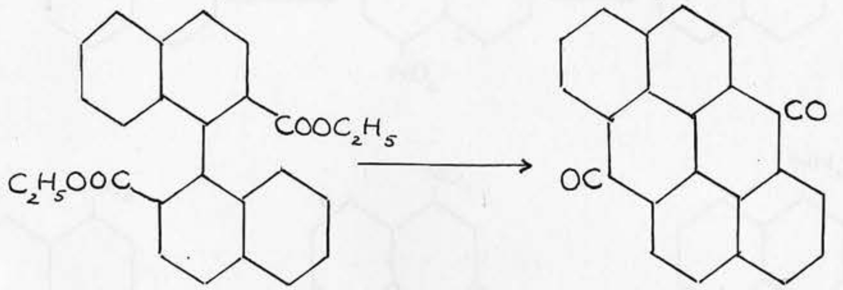


Anthanthrone.

Anthanthrone was prepared by Kalb (loc.cit.) from the ethyl ester of 8-chloro-1-naphthoic acid by submitting it to the Ullmann reaction with copper bronze at 290°C. Extraction with acetone yielded the diethyl 1:1'-dinaphthyl-8:8'-dicarboxylate (I), which was converted quantitatively to anthanthrone (III) by the action of concentrated sulphuric acid.

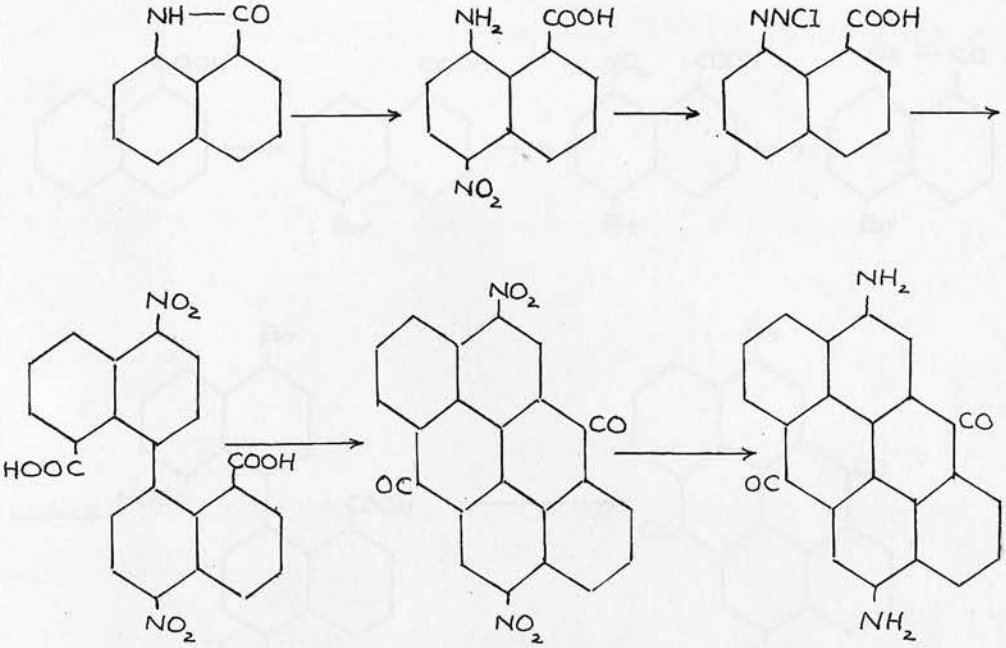


This reaction proceeds in two stages, as indicated by the colour-changes; the almost colourless cold solution becomes an intense red which changes gradually, or quickly on heating, to a pure green. Anthanthrone is precipitated as an orange-yellow solid on pouring the solution into water. Kalb suggests that the intermediate product is the carboxy-benzo-benzanthrone (II). (Compare, however, p. 38). The structure of anthanthrone was confirmed by a similar synthesis from diethyl 1:1'-dinaphthyl-2:2'-dicarboxylate.



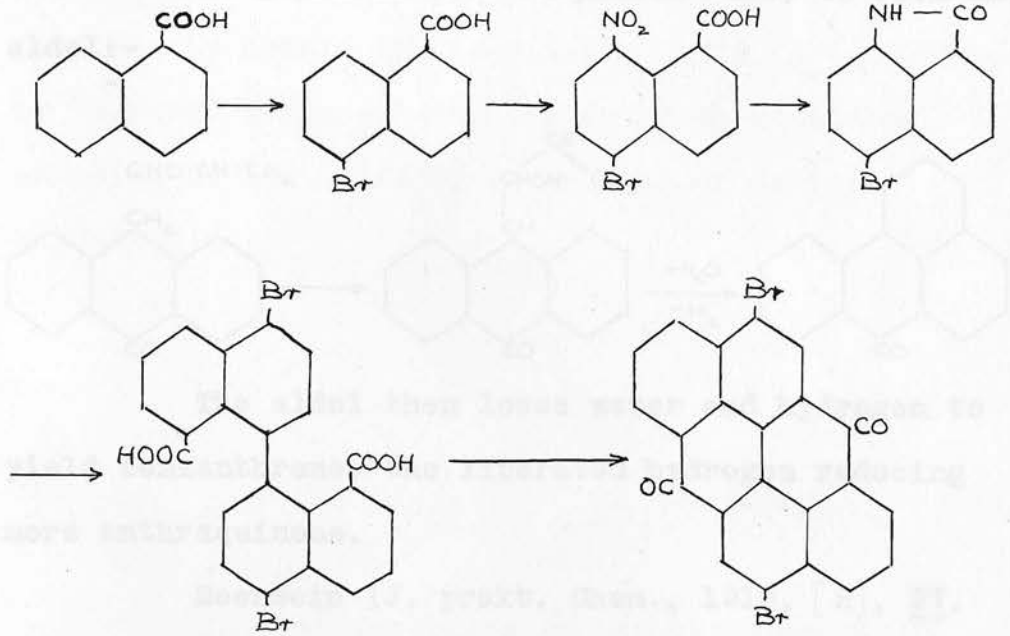
While anthanthrone dyes cotton orange-yellow from a magenta-coloured vat, it is not widely used. Its derivatives, however, occupy a more important place. In general, the substituted anthanthrones of the dye industry, usually of unknown constitution, are prepared either by substitution in the parent compound or in the dinaphthyl compound prior to ring-closure.

Two examples of substituted anthanthrones of known constitution may be given. 4:9-Dinitro-anthanthrone was prepared (I.G. Farb., E.P. 327, 712) by nitrating naphthastyril to give 5-nitro-8-amino-1-naphthoic acid, which was then diazotised and treated with ammoniacal cuprous oxide. Elimination of the diazo-group occurred, yielding the dinaphthyl dicarboxylic acid, which on ring-closure formed the yellow 4:9-dinitro-anthanthrone.



Owing to irreversible reduction of the nitro-groups to amino-groups, the dye is blue after re-oxidation from the alkaline reducing vat.

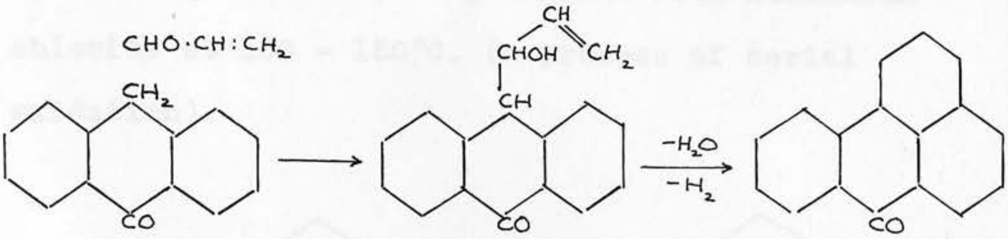
Corbellini and Barbaro (G. Chim. ind. appl., 1933, 15, 335) have described the preparation of 4:9-dibrom-anthanthrone by the following method (Cf. p. 99). α-Naphthoic acid, prepared by the action of hydrochloric acid on the mercuration product of naphthalic acid, was brominated (position 5), nitrated (position 8) and reduced to 5-bromo-naphthastyril. The latter was diazotised and treated with ammoniacal cuprous oxide, yielding 4:4'-dibromo-1:1'dinaphthyl-8:8'-dicarboxylic acid, which on treatment with concentrated sulphuric acid yielded 4:9-dibrom-anthanthrone, a red crystalline compound, dyeing cotton an orange colour from a violet vat.



Benzanthrone.

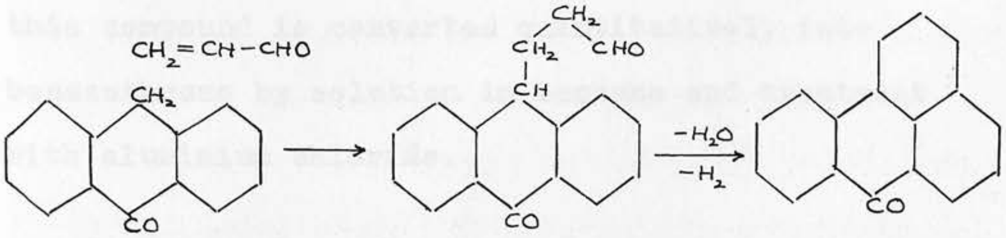
While it is only recently that the Ullmann reaction has enabled a direct connection between 8-halogenated-1-naphthoic acids and benzanthrone, the earlier homologue of anthanthrone, to be established, this compound has been known for some time and occupies an important position as a dye-intermediate.

It was first prepared by Bally (Ber., 1905, 38, 194) by the action of glycerol and sulphuric acid on anthraquinone in presence of a reducing agent. The reaction is supposed (Bally and Scholl, Ber., 1911, 44, 1656) to proceed as follows: some anthraquinone is reduced to anthrone which combines with acrolein (formed from glycerol with sulphuric acid) to form an aldol:-



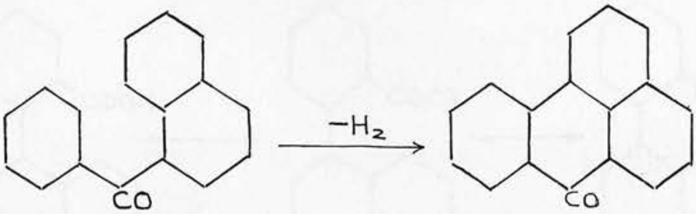
The aldol then loses water and hydrogen to yield benzanthrone, the liberated hydrogen reducing more anthraquinone.

Meerwein (J. prakt. Chem., 1918, [2], 97, 284) has proposed an alternative mechanism to avoid the assumption of this unusual cyclisation. Since it is known that anthrone adds to unsaturated substances such as benzal-malonic ester, the anthraquinone nucleus becoming attached to the carbon of the double bond further removed from the ester-group, Meerwein suggests that the first stage of benzanthrone formation is addition of this type, followed by ring-closure at the aldehyde group:-

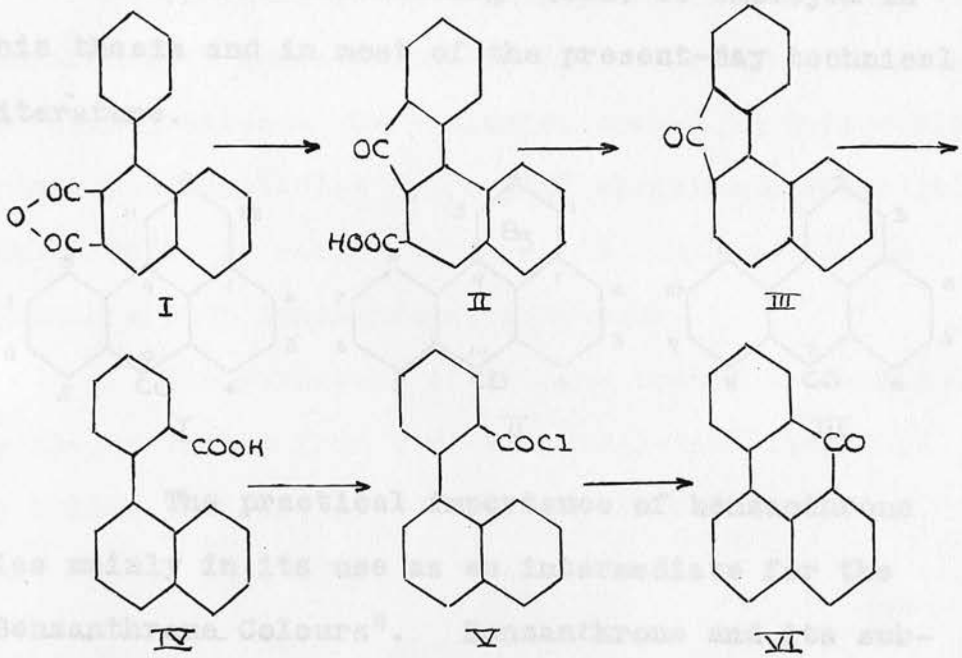


In modern practice, the anthraquinone is reduced in situ with copper powder and sulphuric acid, followed by addition of glycerol at 120°C.

An interesting synthesis of benzanthrone was made by Scholl and Seer (Ann., 1912, 394, 111) by "baking" 1-benzoyl-naphthalene with aluminium chloride at 100 - 150°C. (a process of aerial oxidation).

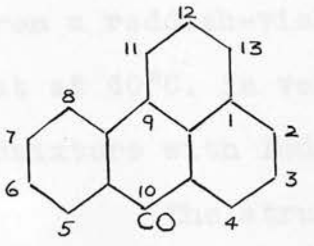


Another synthesis of benzanthrone which leaves no doubt as to its structure was that carried out by Schaarschmidt (Ber., 1918, 51, 1082). Allochrysoketone-carboxylic acid (II) was prepared by the action of aluminium chloride in hot benzene on 1-phenyl-naphthalene-2:3-dicarboxylic anhydride (I). When II is slowly heated above its melting-point it loses carbon dioxide to form benzofluorenone (III). Fusion with alkali converts this compound into ortho-1-naphthyl-benzoic acid (IV). The acid chloride of this compound is converted quantitatively into benzanthrone by solution in benzene and treatment with aluminium chloride.



Benzanthrone forms yellow needles of melting-point 170-171°C., dissolving in concentrated sulphuric acid with deep red colour (cf. A. G. Perkin, J., 1920, 696). On chlorination it yields a monochloro-derivative of m.p. 182°C., described as 3-chloro-benzanthrone, and on further chlorination a mixture of isomeric dichloro-derivatives results (Cahn, Jones, and Simonsen, J., 1933, 444). Bromo-derivatives are also known (see pp. 56, 58). Nitration of benzanthrone in nitrobenzene gives 3-nitro-benzanthrone, while in acetic or sulphuric acid solution, a mixture of mono-nitro-benzanthrones is obtained (cf. p. 59). The hydroxy- and methoxy-derivatives have a special interest in connection with dyestuffs.

The systematic numbering of benzanthrone and its more complicated derivatives is somewhat confusing. The systems formerly in general use are based on the anthracene nucleus and are given below (I and II). The "International Numbering" (III) is employed in this thesis and in most of the present-day technical literature.



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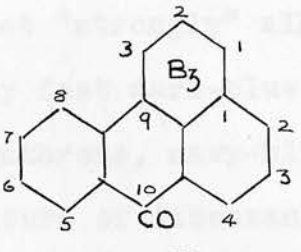

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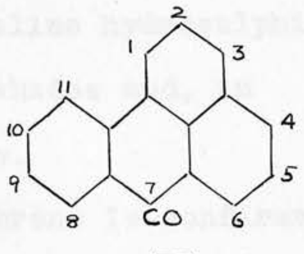
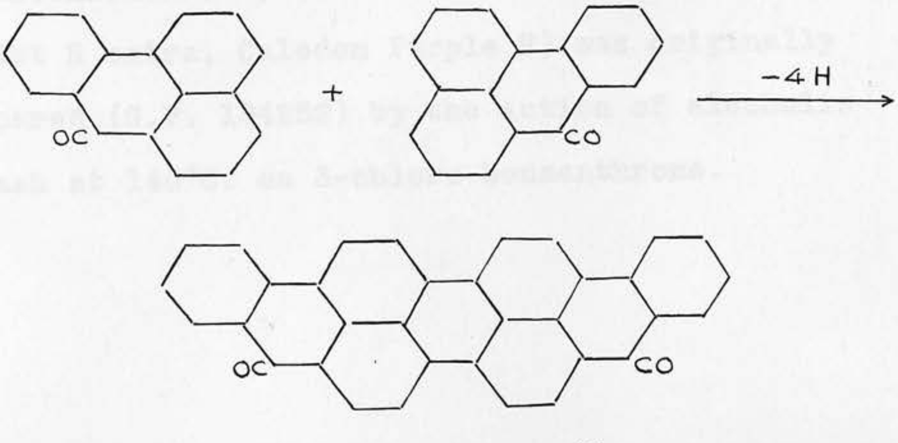


III

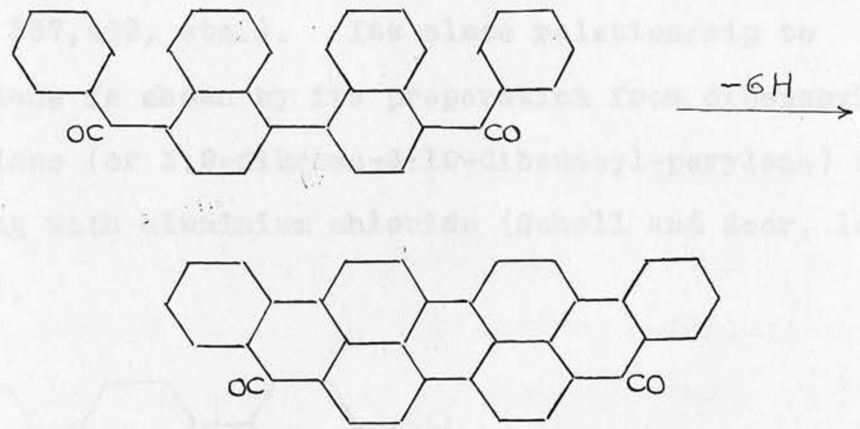
The practical importance of benzanthrone lies mainly in its use as an intermediate for the "Benzanthrone Colours". Benzanthrone and its substituted derivatives are not highly coloured, and although it forms a greenish-yellow hydro-sulphite vat containing dihydrobenzanthrone, it is of no value as a colouring matter. Bally, the discoverer of benzanthrone, found, however, (Ber., 1905, 38, 195; G.P. 185221) that fusion with caustic alkali at 230-240°C. yielded a dark-blue vat-dye, dibenzanthrone. It has since been shown that union occurs at the points 3 and 4.



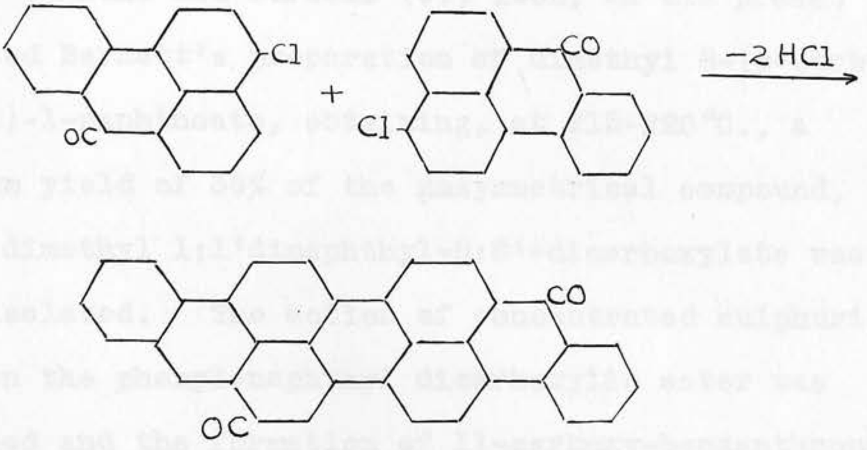
3:3':4:4'-dibenzanthrone.

The commercial product, originally known as Violanthrone, comes on the market as Indanthrene Dark Blue B.O., Caledon Dark Blue B, etc. It dyes cotton from a reddish-violet "strongly" alkaline hydrosulphite vat at 60°C. in very fast dark-blue shades and, in admixture with Indanthrone, navy-blue.

The structure of dibenzanthrone is confirmed by its synthesis from 4:4'-dibenzoyl-1:1'dinaphthyl by baking with aluminium chloride (Scholl and Seer, Ann., 1912, 394, 126).

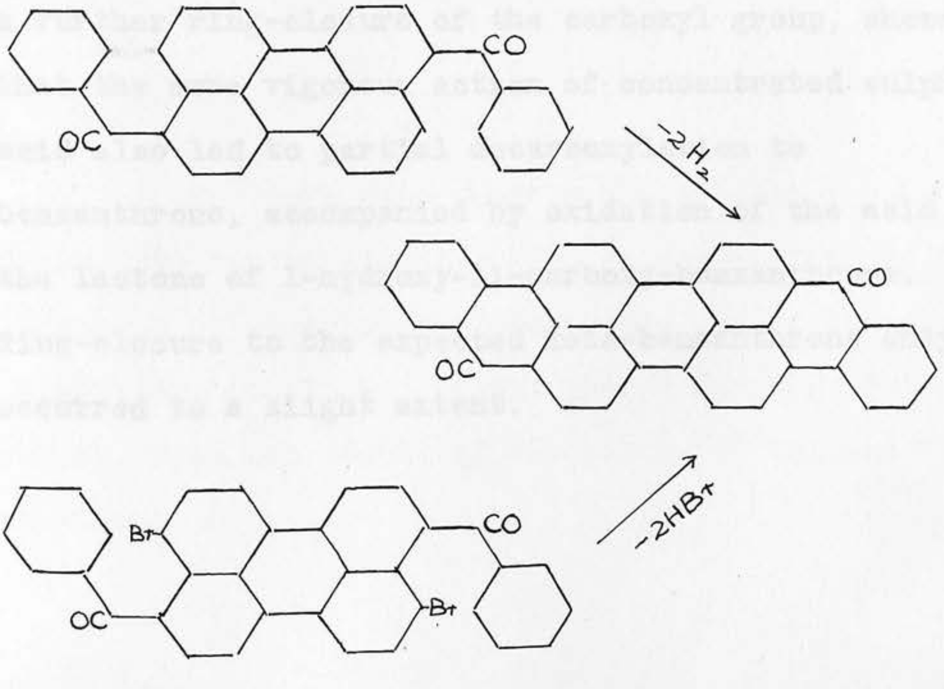


Iso-dibenzanthrone, the symmetrical isomer of dibenzanthrone, (Isoviolanthrone, Indanthrene Violet R extra, Caledon Purple R) was originally prepared (G.P. 194252) by the action of alcoholic potash at 140°C. on 3-chloro-benzanthrone.

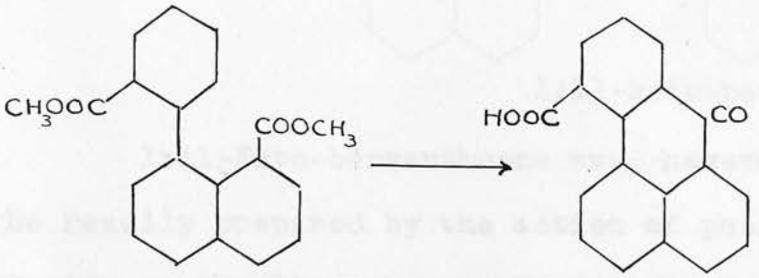


Iso-dibenzanthrone.

More recently it has been prepared by the action of alcoholic potash on 3:3'-dibenzanthronyl sulphides and selenides (G.P. 448262, B.P. 242,620 ; B.P. 367,462, etc.). Its close relationship to perylene is shown by its preparation from dibenzoylperylene (or 3:9-dibromo-4:10-dibenzoyl-perylene) by baking with aluminium chloride (Scholl and Seer, loc. cit.).

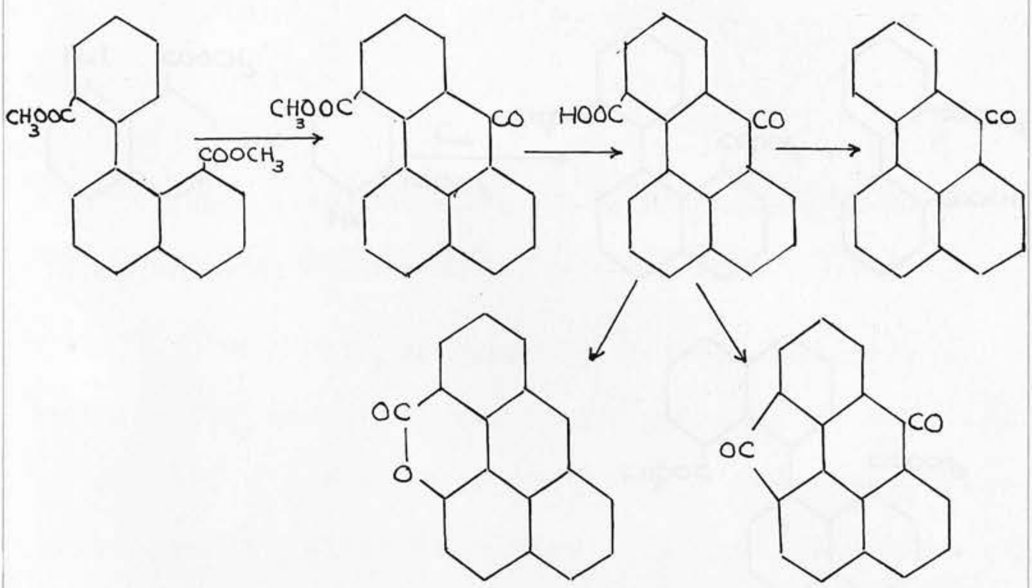


Rule and Pursell (J., 1935, in the press) repeated Barnett's preparation of dimethyl 8-(o-carboxyphenyl)-1-naphthoate, obtaining, at 215-220°C., a maximum yield of 36% of the unsymmetrical compound, while dimethyl 1:1'dinaphthyl-8:8'-dicarboxylate was also isolated. The action of concentrated sulphuric acid on the phenyl-naphthyl dicarboxylic ester was examined and the formation of 11-carboxy-benzanthrone was demonstrated.



11-carboxy-benzanthrone.

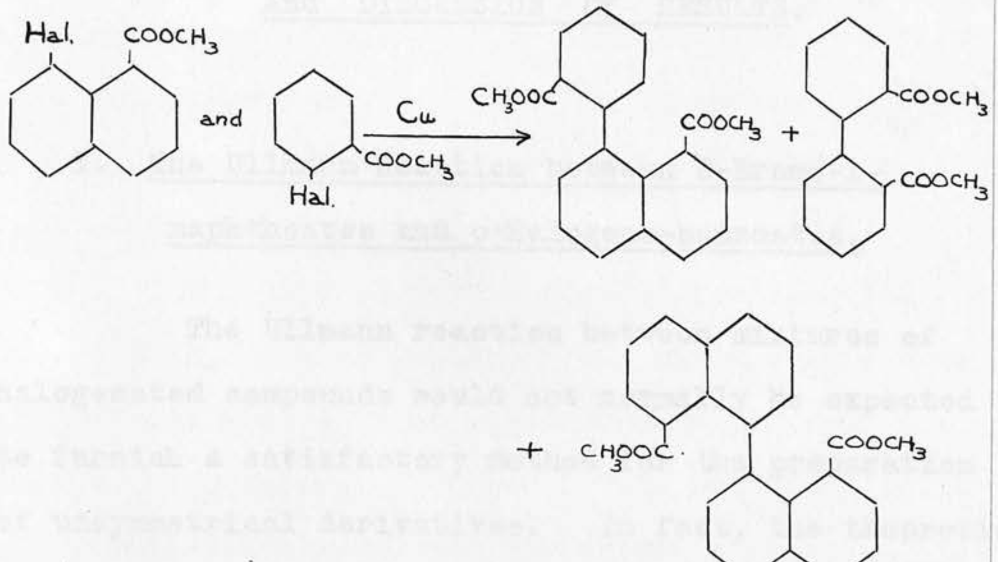
Rule and Bigelow (J., 1935, in the press) in an attempt to prepare 1:11-keto-benzanthrone by a further ring-closure of the carboxyl group, showed that the more vigorous action of concentrated sulphuric acid also led to partial decarboxylation to benzanthrone, accompanied by oxidation of the acid to the lactone of 1-hydroxy-11-carboxy-benzanthrone. Ring-closure to the expected keto-benzanthrone only occurred to a slight extent.



1:11-keto-benzanthrone.

1:11-Keto-benzanthrone was, however, found to be readily prepared by the action of phosphorus pentoxide on the 11-carboxy-acid dissolved in molten phthalic anhydride at 200°C. It is an orange-yellow substance of melting-point 328-9°C., very stable and possessing no strong dyeing properties.

The work described in the present thesis falls into two main parts: (a) an examination of the influence of experimental conditions and of substituents, chiefly Br- and NO_2- , in the phenyl and naphthyl nuclei, upon the course of the following Ullmann reaction:



(b) the conversion of the phenyl-naphthyl and dinaphthyl dicarboxylic esters so obtained into derivatives of benzanthrone and anthanthrone respectively.

II. SUMMARY Of EXPERIMENTAL WORK And DISCUSSION Of RESULTS.

I. The Ullmann Reaction between 8-Bromo-1-naphthoates and o-Halogeno-benzoates.

The Ullmann reaction between mixtures of halogenated compounds would not normally be expected to furnish a satisfactory method for the preparation of unsymmetrical derivatives. In fact, the theoretical yield of unsymmetrical product to be anticipated from a mixture of equimolecular proportions of two halogenated compounds, which are presumed to be equally reactive in the formation of dinuclear compounds, is only $33\frac{1}{3}\%$.

$$3RX + 3R'X \longrightarrow RR + R'R' + RR'$$

Many cases in which the anticipated difficulty of isolating the unsymmetrical product has been encountered are, in fact, on record. A close approximation to the theoretical result has been obtained by Mayer and Freitag (loc. cit., p. 6) who obtained from a mixture of o- and m-iodo-toluenes, in which presumably neither steric nor activation effects will be marked, a yield of about 30% of the unsymmetrical ditolyl by careful fractional distillation.

In view of this, it is the more noteworthy that the method has nevertheless proved conspicuously satisfactory in certain cases, one of the most successful being the reactions between methyl 8-bromo-1-naphthoate and methyl o-iodo-benzoate carried out by Rule and co-workers (J., 1935, in the press). Further work on this reaction and its application to substituted derivatives are now described.

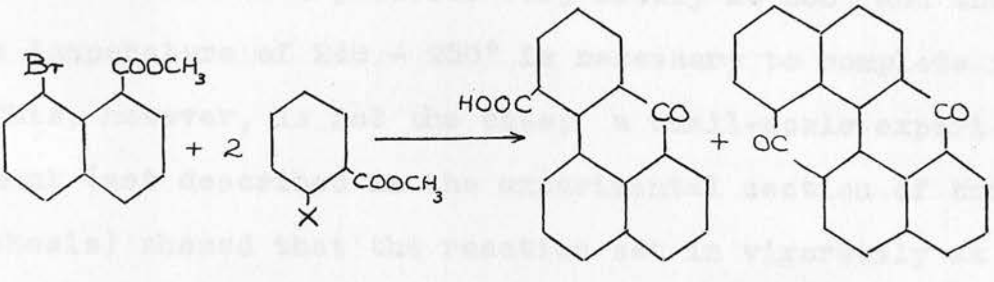
The general method adopted for carrying out the reactions was as follows: the mixed esters were stirred and heated in an oil-bath maintained at the desired temperature. Copper bronze was added in portions and the reaction completed by further heating. The organic compounds were then extracted with acetone and the solvent removed. Any solid products, consisting of phenyl-naphthyl dicarboxylic ester, alone or together with dinaphthyl dicarboxylic ester, which could be isolated by the addition of ether to the extract were removed and treated separately with concentrated (93 - 4%) sulphuric acid at 100°C. for one hour. This treatment sufficed to convert the former ester to 11-carboxy-benzanthrone and the latter to anthanthrone, these products being then separated by means of alkali. The residual mixed esters were treated in a similar manner; the alkali-insoluble anthanthrone was readily isolated, and the benzanthrone-carboxylic acid was separated from other acidic products by crystallisation, a process which is satisfactory in view of the comparative insolubility of the compound in question. In the case of the more readily soluble unsubstituted derivative (p. 102) the phenyl-naphthyl dicarboxylic ester was determined for the most part as 11-carbomethoxy-benzanthrone (produced by sulphuric acid treatment at 50°C.), the separation of the latter from anthanthrone being effected by means of alcohol.

It is evident that this procedure, by which the relatively insoluble dinaphthyl derivative, anthanthrone, is isolated directly in a state of comparative purity, allows a reasonably exact estimate of the yield of the symmetrical dinaphthyl product to be made. The estimation of the yield of unsymmetrical product is less exact, but is sufficiently accurate to serve as a basis for the comparisons made in this discussion; the fact that 80 - 90% of the naphthoate used could generally be accounted for and that the results were quite closely reproducible, substantiates this claim. (All yields quoted in this connection are based on the naphthoate used).

Since the reaction is carried to completion in each case, no exact estimate of reaction velocities can be obtained. If, however, the particular reaction leading to the formation of the unsymmetrical product has been favoured under the conditions employed, the product from this reaction will appear in proportionately larger amount. (It may be noted that if the reaction leading either to diphenyl or to dinaphthyl derivatives is the one actually stimulated, the yields of both these products are increased). In some cases certain conclusions can be drawn, however, from the regularities observed.

The effect of varying conditions on the reaction between methyl 8-bromo-1-naphthoate and methyl o-iodo-benzoate was first examined. Pursell (Thesis, Edin., 1933) had examined this reaction and concluded that the optimum yield of unsymmetrical product (36%) was obtained at 220°C. Barnett (Thesis, Edin., 1932) quoted a yield of 47%, obtained by working at 190 - 200°. These yields, obtained by recrystallisation of the esters, are not strictly comparable. Though Pursell stated that the reaction was incomplete below 200°, this was not found to be the case in the present work and, in fact, no significant difference was noted whether the reaction was carried out at 200° or 180°. At the latter temperature, using equimolecular proportions of naphthoate and benzoate, the yield of dinaphthyl derivative was 31%, and of unsymmetrical phenyl-naphthyl compound 54%. Under similar conditions, but employing two molecular proportions of the benzoate, the yields were 11% and 75% respectively. This figure represents the maximum yield of unsymmetrical product so far obtained from this reaction, and since it was desired to obtain reasonable yields of the unsymmetrical compounds, these optimum conditions were employed throughout for purposes of comparison.

The effect of varying the reactive halogen in the benzoate was next examined. The use of the o-bromo-benzoic ester gave a 44% yield of anthanthrone, the yield of unsymmetrical product falling to 41% ; employing methyl o-chloro-benzoate, the yield of anthanthrone rose to 71%. (p. 106).



X = I,	75%,	11%.
X = Br,	41% ,	44%.
X = Cl,	— ,	71 %.

There is no doubt that the decrease in yield of the unsymmetrical product is due to the decreasing activity of the benzoate; the series in which iodine is more reactive than bromine, which is in turn more active than chlorine (I > Br > Cl) is well known in various reactions involving nuclear halogen substituents.

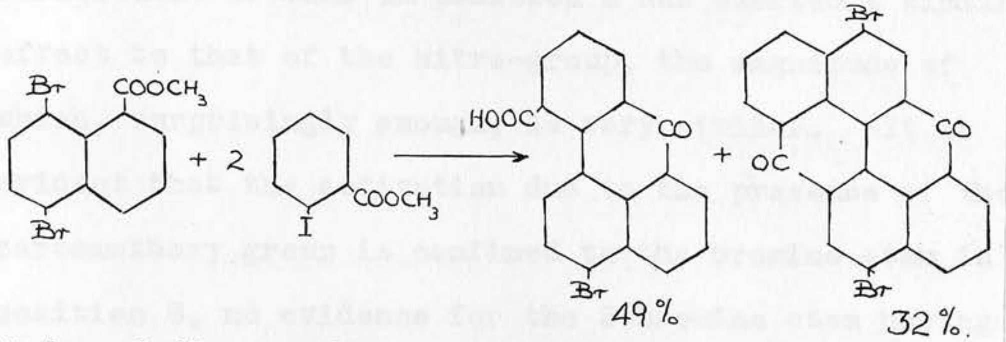
Rule and Barnett (J., 1932, 2728) concluded that methyl o-iodo-benzoate and methyl 8-bromo-1-naphthoate were comparable in halogen reactivity, although Barnett (Thesis, Edin., 1932) suggested that the minimum temperature at which the iodo-benzoate was readily converted into diphenic ester was about 250°C., while the 8-bromo-naphthoate reacted at a lower temperature, 180°C. Nevertheless, Barnett carried out the reaction with a mixture of these esters at 190-200°. The above suggestion regarding the minimum temperature of reaction of iodobenzoic ester is based on the description of the formation of diphenic ester by Ullmann (Ann., 1904, 332, 70). While Ullmann's statement is not quite clear, it would seem to imply that the reaction proceeds very slowly at 200° and that a temperature of 240 - 250° is necessary to complete it. This, however, is not the case; a small-scale experiment (not described in the experimental section of this thesis) showed that the reaction set in vigorously at 150°C. The 8-bromo-naphthoate reacted at the same temperature, but more slowly. The conclusion that the two compounds are of similar activity would seem warranted, however, since the replacement of the iodobenzoate by the less reactive bromo- or chloro-ester enables the naphthoate to combine with itself to a greater extent, to the detriment of the yield of unsymmetrical product.

Pursell (Thesis, Edin., 1933) comments on "the remarkable variations caused by different samples of copper bronze" as employed in Ullmann reactions. In this connection Haldane (Thesis, Edin. 1934) has compared the effect of a number of different samples on the reaction between o-iodo-benzoic acid and sodium methoxide, the reaction being stimulated to widely varying degrees, as shown on the following page.

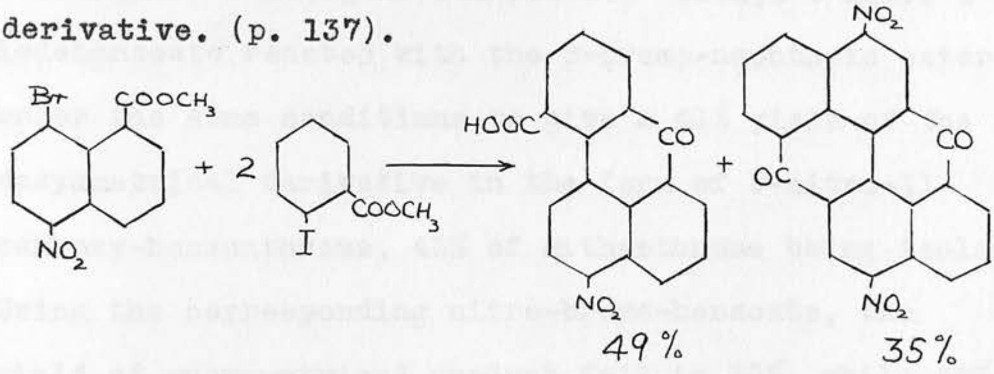
Sample of copper	A Gattermann's	B I.C.I.	C B.D.H.	E. B.D.H.	No catalyst present.
Velocity Constant (K_{50})	32·7	28·6	13·5	2·77	$3{\cdot}73 \times 10^{-4}$
Ratio	87,660	76,680	36,190	7,428	1

Three kinds of copper were employed in the Ullmann Reactions described in the present thesis. Copper bronze (A) is the sample B, referred to in the Table above and originally obtained from Imperial Chemical Industries, Limited; copper bronze (B) is a second sample from I.C.I., Ltd., and copper powder (Gattermann) is the metal prepared as given in Houben-Weyl (Die Methoden der org. Chem., 1922, Ed., II, 567) by precipitation from copper sulphate solution with zinc dust. The last-named product was filtered off, washed with dilute hydrochloric acid and distilled water and preserved under water. Before use it was filtered off and washed with alcohol and ether. Check determinations showed that these samples all had a very similar activity. A fourth sample (B.D.H.), however, proved to be practically uselsss. The active samples exhibited a red copper colour; the inactive specimen was of a brassy tint.

The Ullmann reaction was then applied to further substituted derivatives of the halogenated esters, and the results obtained when using methyl 5:8-dibromo- and 5-nitro-8-bromo-naphthoates are next dealt with. The former in reaction with two moles of o-iodo-benzoic ester at 180° gave a yield of 49% of unsymmetrical derivative, isolated in the form of 3-bromo-11-carboxy-benzanthrone, while the dinaphthyl product (4:9-dibrom-anthanthrone) amounted to 32%. (p.107).

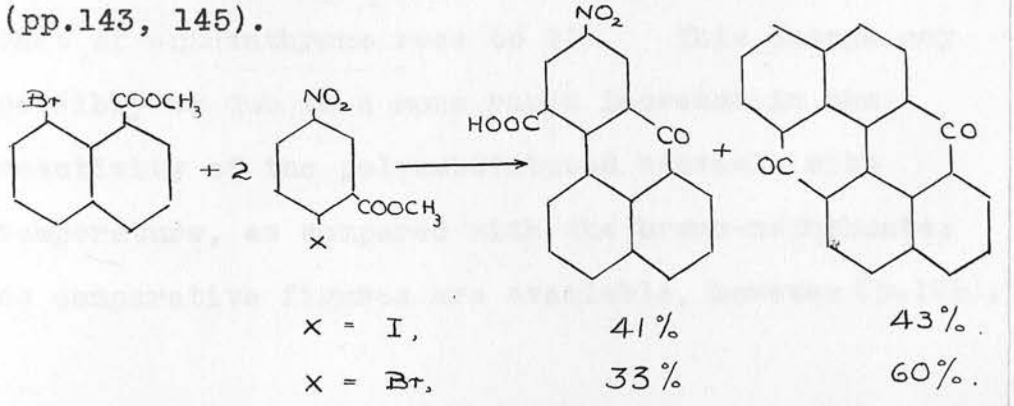


Under similar conditions, the 5-nitro-8-bromo-naphthoate gave 49% of the unsymmetrical derivative, 3-nitro-11-carboxy-benzanthrone, and 35% of dinaphthyl derivative. (p. 137).

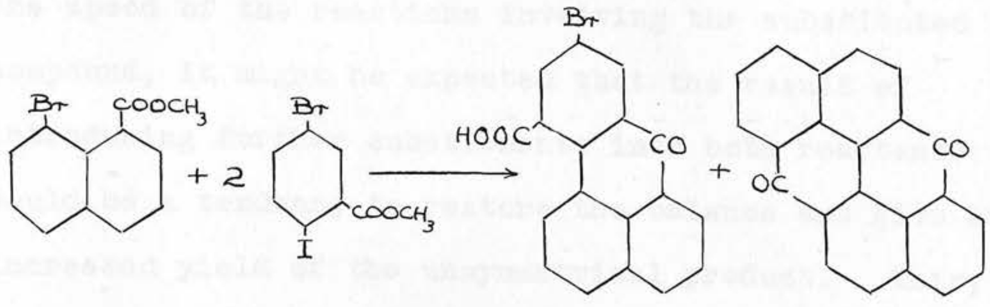


The introduction of a nitro-group in position 5 has previously been found to activate the halogen in 8-bromo-1-naphthoic acid and its methyl ester in the reaction with sodium methoxide (Haldane, Thesis, Edin., 1934) and the presence of substituent nitro-groups in certain positions has also been shown to affect the reactivity of halogen atoms in the reaction with copper bronze (Ullmann, loc. cit., p. 4). It appears likely, therefore, that the reduction in the yield of unsymmetrical product following on the introduction of substituents into the naphthoate molecule is due to the increased readiness with which the substituted naphthoate can react with itself to form a dinaphthyl dicarboxylic ester. The electro-negative substituent bromine in position 5 has exerted a similar effect to that of the nitro-group, the magnitude of which, surprisingly enough, is very similar. It is evident that the activation due to the presence of the carbomethoxy group is confined to the bromine atom in position 8, no evidence for the 5-bromine atom having reacted being obtained.

The reaction was next extended to the case of substituted o-halogeno-benzoates. Methyl 5-nitro-2-iodobenzoate reacted with the 8-bromo-naphthoic ester under the same conditions to give a 41% yield of the unsymmetrical derivative in the form of 9-nitro-11-carboxy-benzanthrone, 43% of an thanthrone being isolated. Using the corresponding nitro-bromo-benzoate, the yield of unsymmetrical product fell to 33%, while 60% of the naphthoate was accounted for as anthanthrone. (pp.143, 145).



In the case of the corresponding bromine-substituted ester, methyl 5-bromo-2-iodo-benzoate, an additional complication ensues, owing to the reactivity of the bromine atom. This was evident from the fact that an inseparable mixture of products was obtained by heating the ester itself with copper bronze. By maintaining the usual temperature conditions (180°) carefully, however, this activity was minimised and a 60% yield of the unsymmetrical product in the form of 9-bromo-11-carboxy-benzanthrone, was obtained, the anthanthrone amounting to 28%. The fact that the almost the whole of the iodine had reacted was checked in this and some other cases by analysing the copper halide residues for iodine (by the method described on p. 66), when it was found that about 90% of the iodine in the iodo-benzoate was accounted for. The results suggest that the effect of the bromine substituent in position 5 of the benzoate is similar to but less in magnitude than that of the nitro-group in the same position. At a temperature of 220°, the yield of unsymmetrical product had fallen considerably, amounting to 27%, whereas that of anthanthrone rose to 53%. This change may possibly be due to a more rapid increase in the reactivity of the polysubstituted benzoate with temperature, as compared with the bromo-naphthoate; no comparative figures are available, however (p.124).



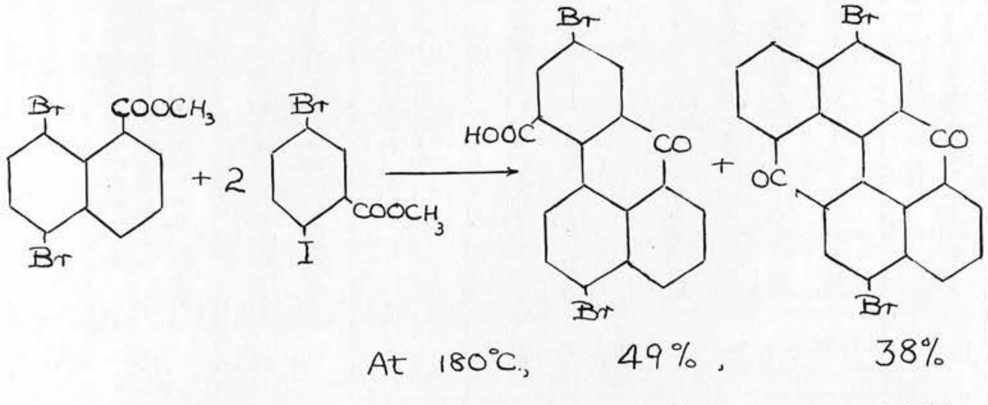
At 180°C., 60% 28%.

At 220°C., 27% 53%.

More pronounced difficulty was experienced when methyl 2:4-dibromo-benzoate was employed in reaction with the bromo-naphthoic ester at 220°, and in fact no unsymmetrical derivative was isolated in a pure state (p. 150). The yield of anthanthrone was 56%. As the bromine atoms are ortho and para to the activating carbomethoxy group, it was to be expected that the reaction would exhibit greater complexity.

Reactions carried out with methyl 4-nitro-2-iodo-benzoate and methyl 6-nitro-2-iodo-benzoate were unsatisfactory. In the former case, the yield of anthanthrone at 180° was 70%, and at 220°, 63%. The acidic products of the hydrolysis did not yield the expected 8-nitro-11-carboxy-benzanthrone. In the case of the latter reaction, due no doubt to steric hindrance, difficulty was experienced in purifying both fractions.

The reaction was also carried out with reactants, both of which contained additional substituents. If the effects of substitution were similar to those deduced above, viz., an increase in the speed of the reactions involving the substituted compound, it might be expected that the result of introducing further substituents into both reactants would be a tendency to restore the balance and give an increased yield of the unsymmetrical product. This, however, was not found to be the case. When methyl 5:8-dibromo-1-naphthoate and methyl 5-bromo-2-iodo-benzoate reacted at 180° the yield of unsymmetrical product isolated as 3:9-dibromo-11-carboxy-benzanthrone was 49%, dibrom-anthanthrone accounting for a further 38% of the naphthoate. A small amount of a second alkali-insoluble compound which had the properties of a brown vat-dye was also detected; it is suggested that this is produced by further reaction between the 5:5'-dibromo-dinaphthyl-dicarboxylic ester and the naphthoate. In this reaction, a rise of temperature to 220° did not produce a marked change in the yields; 41% of dibrom-anthanthrone was obtained and 36% of the benzanthrone-carboxylic acid. (p. 130).



At 180°C., 49%, 38%

At 220°C., 36%, 41%.

TABLE Of ULLMANN REACTIONS.

	Methyl 8-bromo-1-naphthoate in reaction with:	Temperature	% Yield of unsymmetrical product.	% Yield of dinaphthyl product (anthanthrone)
1	Methyl o-iodo-benzoate (2 mols)	180°	75	11
2	Methyl o-bromo-benzoate	"	41	44
3	Methyl o-chloro-benzoate	"	-	71
4	Methyl 5-bromo-2-iodo-benzoate	"	60	28
5	"	220°	27	53
6	Methyl 5-nitro-2-iodo-benzoate	180°	41	43
7	Methyl 5-nitro-2-bromo-benzoate	180°	33	60
	Methyl o-iodo-benzoate (2 mols) in reaction with:			
1	Methyl 5:8-dibromo-1-naphthoate	180°	49	32
2	Methyl 5-nitro-8-bromo-1-naphthoate	180°	49	35
1	Methyl 5:8-dibromo-1-naphthoate in reaction with methyl 5-bromo-2-iodo-benzoate (2 mols)	180°	49	38
2	do.	220°	36	41
3	Methyl 5-nitro-8-bromo-1-naphthoate in reaction with methyl 5-nitro-2-iodo-benzoate (2 mols)	180°	-	75%

Although the expected change in the sense of a larger yield of the unsymmetrical product has not been realised, the influence of substitution in both reactants appears to have maintained the equality of reactivity over a wider range of temperature than was observed when only one reactant is activated.

The reactions carried out with both compounds containing nitro-groups in the 5-positions was even less satisfactory than in the last case discussed above; the yield of dinaphthyl derivative at 180° amounted to 75%, but the acidic benzanthrone products, which must have been comparatively small in quantity, could not be purified. (p. 152).

The effects of substitution thus agree in some measure with the view that the reactivity of the halogen atom influences the success of the reaction in yielding the desired mixed product, although no explanation of the unexpectedly high yield in the case of the unsubstituted esters can be suggested. Attention was therefore turned to examples of similar reactions which have been recorded in the literature.

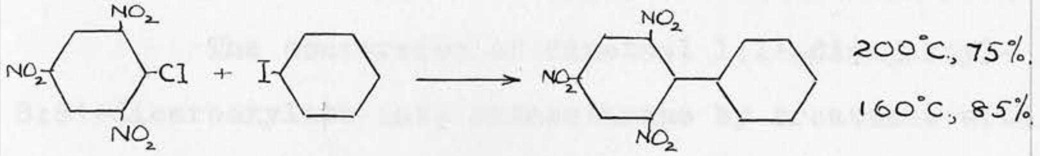
The most striking of these is undoubtedly the type of reaction discovered by Turner and co-workers (loc. cit., p. 7). The reaction between picryl chloride and iodobenzene (Gull and Turner, J., 1929, 491) attracted immediate notice and is therefore discussed in detail.

Iodobenzene, according to the experience of

Ullmann (Ann., 1904, 332, 38), did not react at its boiling-point with copper bronze to form diphenyl and it was necessary to heat the mixture to 230° under pressure. This was now verified in the present work and in addition it was found that even in solution in boiling nitrobenzene (temperature of mixture, 205°C.) no reaction took place. Picryl chloride, on the other hand, is so reactive that the mixture with copper bronze explodes at about 135°; in boiling nitrobenzene, the reaction proceeds smoothly with formation of hexanitro-diphenyl (Ullmann, loc. cit.).

Gull and Turner heated an equimolecular mixture of picryl chloride and iodobenzene at 200 - 205° with gradual addition of copper bronze, and obtained as the sole product, the unsymmetrical compound, 2:4:6-trinitro-diphenyl. As the solvent employed for extracting the mixture was alcohol, in which hexanitro-diphenyl is stated to be practically insoluble (Ullmann, loc. cit.) and, moreover, since no actual yield was quoted, some doubt attached to this result. In addition, the suggestion that the non-formation of hexanitro-diphenyl can be attributed to spatial effects appears inadequate in view of the disproportionate activities of the two reactants.

This experiment was therefore repeated (p. 148) and at 195 - 203° it was found that 2:4:6-trinitro-diphenyl was in fact the sole detectable product. The yield was 75%, decomposition probably accounting for the remaining 25%. As it was possible that the temperature in this experiment might have risen locally to a point where the iodobenzene would be normally reactive, the reaction was carried out at 160-65°. The yield of 2:4:6-trinitro-diphenyl was 85%.

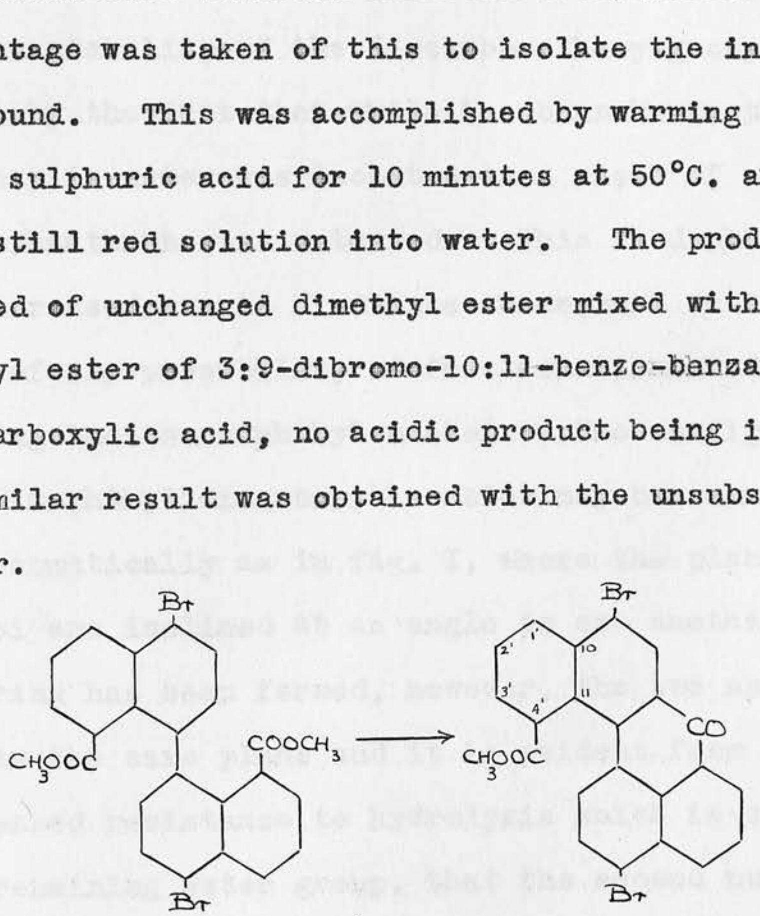


Another highly successful reaction of this type consists in the coupling of ethyl 2:4-dinitro-2-chloro-benzoate with aromatic iodo-compounds, when the sole product is said to consist of the unsymmetrical compound (Lesslie and Turner, J., 1930, 1758). Both picryl chloride and the dinitro-chloro-benzoate are compounds of quite exceptional reactivity; the lability of the chlorine atom in the former is well established and the ester has been shown to possess remarkable activity towards sodium methoxide (Haldane, Thesis, Edin. 1934). It almost appears that such compounds are able to induce some special form of activation in another halogenated compound in the presence of copper bronze.

Evidently the available data allow no parallel to be drawn between this type of reaction and that occurring between naphthoates and benzoates. The complexity of the governing factors, which may include steric hindrance, activation by substituents, the lability of the reacting halogen, and possibly some form of molecular association, renders any fruitful discussion impossible in the present state of our knowledge.

II. The Hydrolysis and Cyclisation of Dinaphthyl and Phenyl-naphthyl Dicarboxylic Esters: the Cyclisation of 11-Carboxy-benzanthrones.

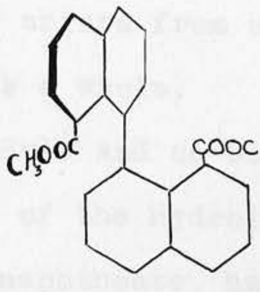
The conversion of dimethyl 1:1'-dinaphthyl-8:8'-dicarboxylate into anthanthrone by treatment with sulphuric acid (Kalb, Ber., 1914, 41, 1724) and the suggested explanation of the colour changes which occur have already been mentioned (p. 10). During the cyclisation of dimethyl 4:4'-dibromo-1:1'-dinaphthyl-8:8'-dicarboxylate to dibrom-anthanthrone (p. 100) it was noted that the intermediate red colouration of the sulphuric acid solution was relatively persistent and advantage was taken of this to isolate the intermediate compound. This was accomplished by warming the ester with sulphuric acid for 10 minutes at 50°C. and pouring the still red solution into water. The product consisted of unchanged dimethyl ester mixed with the methyl ester of 3:9-dibromo-10:11-benzo-benzanthrone-4'-carboxylic acid, no acidic product being isolated. A similar result was obtained with the unsubstituted ester.



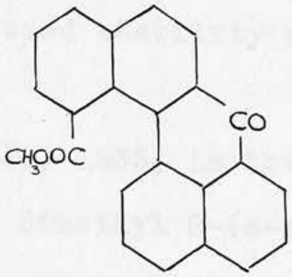
The comparative stability of the monomethyl ester formed under these conditions is evident. It gives a red solution in sulphuric acid (characteristic of a benzanthrone derivative) which is relatively stable under conditions of temperature and concentration in which the corresponding free acid rapidly gives the green colouration characteristic of anthanthrone formation. These results indicate that the free acid is the immediate precursor of the anthanthrone, but Kalb's assumption that the red intermediate solution corresponds to the existence of the free mono-carboxylic acid is not correct since, under the conditions employed, this will pass immediately into the anthanthrone.

The interesting point about this hydrolysis is the stability of the 4'-carbomethoxy group, which is shown by the fact that while the benzobenzanthrone carboxylic ester was isolated in a yield of about 50%, no anthanthrone was detected. This is doubtless due to increased steric hindrance consequent on the elimination of any possibility of free rotation about the bond joining the two naphthyl nuclei. The configuration of the dinaphthyl dicarboxylic ester may be represented diagrammatically as in fig. I, where the planar naphthyl nuclei are inclined at an angle to one another. After one ring has been formed, however, the two nuclei must lie in the same plane and it is evident from the increased resistance to hydrolysis which is offered to the remaining ester group, that the second nucleus is now closer and exerts a greater screening effect.

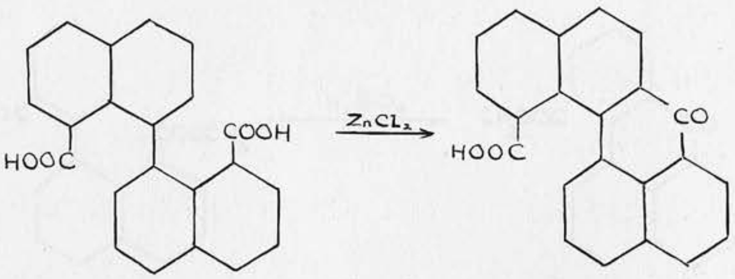
I



II



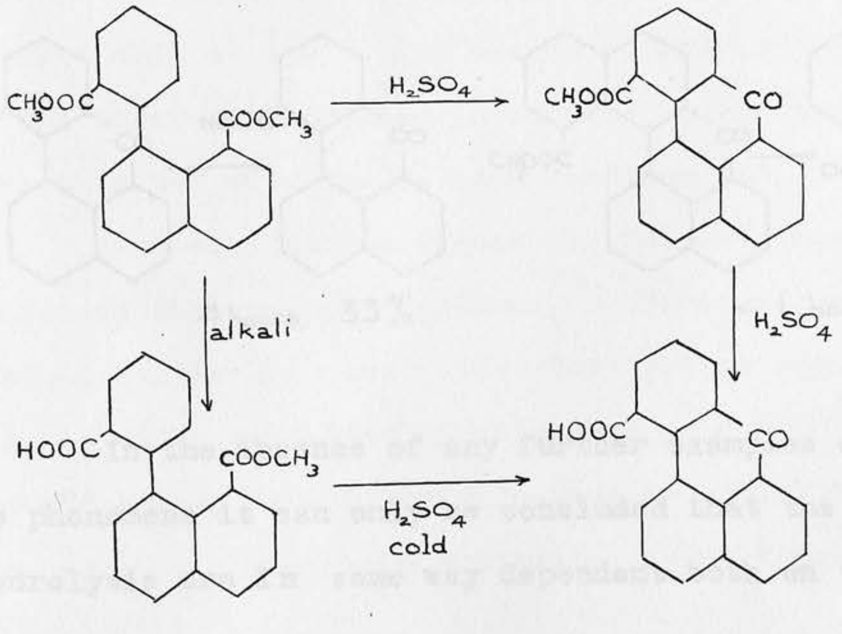
A similar stability can be traced in the fact that benzobenzanthrone-4'-carboxylic acid offers resistance to certain dehydrating agents (weaker than sulphuric acid) which are nevertheless able to bring about the closure of the first benzanthrone ring. Thus, while it would evidently be impossible to prepare the acid from 1:1'-dinaphthyl-8:8'-dicarboxylic acid by treatment with concentrated sulphuric acid, it can be prepared by the action of zinc chloride in acetic acid solution (Cassella G.m.b.h., C., 1928, I, 2311).



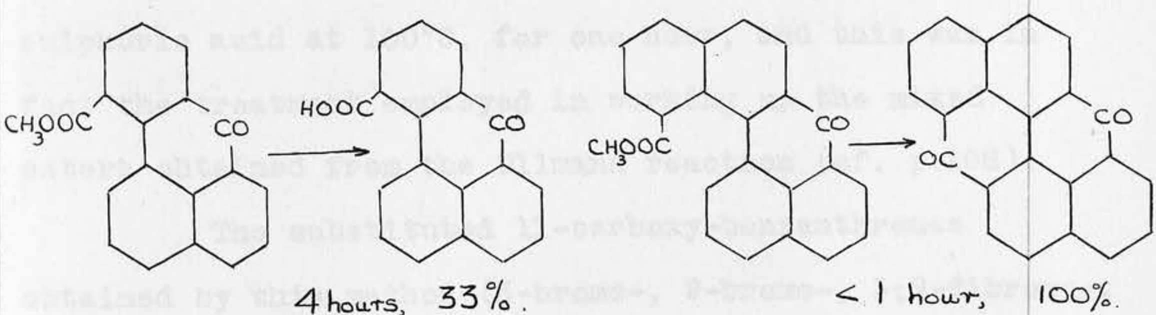
It was found also that the dibromo-dinaphthyl-dicarboxylic ester underwent ring-closure more slowly than the unsubstituted compound, the reaction requiring at least ten times as long at 50°C. to reach completion, as judged by the appearance of a pure green colouration.

Since there is no question of additional steric hindrance due to the bromine atoms, this effect apparently arises from an increased stability of the molecule as a whole.

Rule and co-workers (J., 1935, in the press) in a study of the hydrolysis of dimethyl 8-(o-carboxy-phenyl)-1-naphthoate, have shown that the primary product obtained by the action of concentrated sulphuric acid was 11-carbomethoxy-benzanthrone. From the alkaline hydrolysis of the dimethyl ester, an ester-acid was isolated to which the constitution of methyl 8-(o-carboxy-phenyl)-1-naphthoate could be assigned, since on treatment with sulphuric acid in the cold for a short period, it gave a quantitative yield of 11-carboxy-benzanthrone, a treatment which would have converted the isomeric carbomethoxy-phenyl-1-naphthoic acid into 11-carbomethoxy-benzanthrone.



Although this result is not commented on in the above papers, it may be noted that it presents an interesting anomaly. While the alkaline hydrolysis has taken the course to be expected on the usual ideas of steric hindrance, the ester-group attached to the phenyl nucleus being attacked prior to the peri-ester group, the acid hydrolysis has taken the opposite course. Indeed, the resistance offered by 11-carbomethoxy-benzanthrone is remarkable; for example, it is only hydrolysed to an extent of about 33% by treatment with sulphuric acid at 50°C. for four hours (p. 104). This contrasts not only with the ready hydrolysis and ring-closure of the ester-group in the peri-position in the same molecule, but also with the comparatively ready cyclisation of the carbomethoxy-group in the benzo-benzanthrone derivative discussed above, which is complete in less than an hour under the same conditions (p. 101).



In the absence of any further examples of these phenomena it can only be concluded that the rates of hydrolysis are in some way dependent both on the medium and on the general character of the reacting molecule; these effects appear to predominate, in the instance mentioned, over those to be expected on the usual grounds of steric hindrance due to adjacent groups.

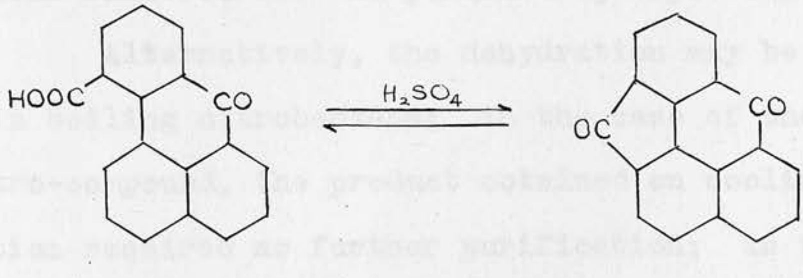
The hydrolysis of dimethyl 3-bromo-8-(o-carboxy-phenyl)-1-naphthoate by concentrated sulphuric acid was found in the present work to follow the same course as that of the unsubstituted ester, 3-bromo-11-carbomethoxy-benzanthrone being obtained in a yield of 75% by treatment at 50°C. for 3 hours, approximately the same rate of hydrolysis as in the case of the unsubstituted ester.(p. 110).

In the case of all the phenyl-naphthyl dicarboxylic esters dealt with, the closure of the benzanthrone ring and hydrolysis of the 11-carbomethoxy-group was complete after treatment with concentrated sulphuric acid at 100°C. for one hour, and this was in fact the treatment employed in working up the mixed esters obtained from the Ullmann reaction (cf. p.108).

The substituted 11-carboxy-benzanthrones obtained by this method (3-bromo-, 9-bromo-, 3:9-dibromo-, 3-nitro-, 9-nitro- ; see p.46a) were yellow crystalline compounds which dissolved in sulphuric acid with a blood-red colour, substitution having no apparent effect on the colour. The bromo carboxylic acids dissolved in alkali to give orange to red solutions with strong green fluorescence; the nitro-acids gave red, non-fluorescent solutions. The sodium salt of 3:9-dibromo-11-carboxy-benzanthrone was only sparingly soluble in water.

Cyclisation of 11-Carboxy-benzanthrones.

When this research was originally undertaken, it was hoped to investigate effects of substitution on the further cyclisation of these acids to 1:11-keto-benzanthrones, a novel type of derivative. This expectation was based on some work carried out by Pursell (Thesis, Edin., 1933) who had obtained a neutral product, believed to be the desired ketone, by the action of concentrated sulphuric acid on benzanthrone-11-carboxylic acid at high temperatures; moreover, it was then believed that an equilibrium of the following kind existed between the acid and the ketone in sulphuric acid solution:



The true nature of the neutral product obtained in this manner was established later by Rule and Bigelow (loc. cit.), who found that it consisted of a mixture of the ketone and benzanthrone, together with traces of the lactone of 1-hydroxy-11-carboxy-benzanthrone produced by oxidation. (Some sulphonation also occurred at high temperatures). Further, the formation of the ketone was not reversible in the presence of sulphuric acid.

A similar state of affairs was found in the present work on treating 3-bromo-11-carboxy-benzanthrone with concentrated sulphuric acid at 140° or 160°C. (p.120). 3-Bromo-benzanthrone, the 3-bromo-"lactone" and a third product (not purified but probably the ketone) were isolated. As this method was useless either as a preparative method or for any quantitative comparison, it was abandoned.

To prepare the 1:11-ketones, recourse was had to the method employed by Rule and Bigelow. This consists of the treatment of the acid, dissolved in molten phthalic anhydride at 200°C., with excess of phosphorus pentoxide over a period of two hours (cf., e.g., p. 115). The liquid is then poured into alkali and the insoluble diketone filtered off and purified by crystallisation.

Alternatively, the dehydration may be carried out in boiling nitrobenzene; in the case of the 9-nitro-compound, the product obtained on cooling the solution required no further purification; in the case of the 9-bromo-ketone, it was necessary first to remove a certain amount of alkali-insoluble material in order

TABLE of MELTING-POINTS Of SUBSTITUTED BENZANTHRONES, 11-CARBOXY-BENZANTHRONES And 1:11-KETO-BENZANTHRONES.

Substituent	Benzanthrone	11-Carboxy-Benzanthrone	1:11-Keto-Benzanthrone
-	171°C.	273°C.	328-9°C.
3-Bromo	178	315 - 316	326 - 8 (190±) [1]
9-Bromo	183	315 - 316	240
3:9-Dibromo	256	355 - 357 (d)	299 - 300
3-Nitro	248-9	310 (d)	282 - 283 (265)[1]
9-Nitro	291-2	287 (d)	316 - 317
3-Chloro	182	317 - 318 [2]	335 - 336 [2]

[1] Denotes sintering-point.

[2] J. L. Grieve, in these laboratories, unpublished.

to obtain a pure product. In phthalic anhydride solution, the dehydration appeared to be complete in every case, since no significant amount of acidic product was ever isolated from the alkaline filtrates; the yields of crude ketone amounted to 80 - 90%. No specific effects of substitution on the cyclisation were apparent. Unfortunately it did not prove possible to synthesise, by the method employed, 11-carboxy-benzanthrones containing substituents in positions 2 or 10, which might have exerted a considerable spatial effect on the cyclisation.

In this manner, 3-bromo-, 9-bromo-, 3:9-dibromo-, 3-nitro- and 9-nitro-1:11-ketobenzanthrones were prepared. They were brightly-coloured crystalline compounds, ranging in colour from orange to red, the 3-nitro-compound having the lightest colour and the dibromo-ketone the deepest. The mono-substituted derivatives dissolve in concentrated sulphuric acid to give purple solutions; a concentrated solution of the 3:9-dibromo-derivative was purple in colour with blue fluorescence, but on dilution, the solution became blue in colour with purple fluorescence.

The melting-points of these compounds present curious features (see Table opposite). While substitution by either bromine or a nitro-group raises the melting-point of benzanthrone or 11-carboxy-benzanthrone, the melting-point of the 1:11-ketone is lowered to a greater or less extent. This is particularly marked in the case of the 9-bromo-ketone which melts 88°C. lower than the unsubstituted compound. Similarly, the 3:9-dibromo-1:11-keto-benzanthrone melts 28° lower than the parent compound, although a rise of 82° was produced by the introduction of the two bromine atoms into 11-carboxy-benzanthrone. The effects of substitution can therefore only be described as irregular.

3-Bromo-1:11-keto-benzanthrone possesses a well-marked sintering-point, only removed by heat-treatment. In the crystalline form or in a finely-divided state as obtained by pouring its solution into water, it sinters sharply at a temperature varying between 180° and 200°, thereafter remaining unaltered till it melts at 326 - 8°C. A sample which has been heated to over 200° does not exhibit this behaviour but melts at 326 - 8° without previous change; after recrystallisation, however, the sintering-point is again observed. 3-Nitro-1:11-keto-benzanthrone shows the same effect but to a less marked extent. This point is discussed in further detail in the experimental section (p.116).

Benzanthrone itself is of no value as a vat-dyestuff, as it has only a weak affinity for the fibre. 1:11-Keto-benzanthrone is reduced by alkaline hydrosulphite and the solution re-oxidises in air, but this material is apparently of little value as a dye, since not only is the salt of the leuco-compound sparingly soluble in water, but the ketone is unstable to alkalis. The substituted ketones are open to the same objections, the insolubility of the leuco-compounds being particularly marked. 3-Nitro-benzanthrone is more readily reduced by alkaline hydrosulphite, a deep blue vat being formed from which the pink 3-amino-benzanthrone is deposited on oxidation. As this property receives no mention in the literature, it is probable that the dyeing properties are unsatisfactory. The nitro-keto-benzanthrones, however, vatted no more readily than the halogenated compounds, a suspension of purple material (amino-keto-benzanthrone ?) being formed in a weakly-coloured solution which only coloured cotton feebly. Methyl 3:9-dibromo-10:11-benzo-benzanthrone-4'-carboxylate (formula, p. 38), in contrast, vatted comparatively readily, giving a purple vat (resembling that of anthanthrone) which deposited the orange ester on re-oxidation.

The instability of the fluorenone ring in 1:11-keto-benzanthrone towards alkalis has been mentioned above. A small-scale experiment with 3-bromo-1:11-keto-benzanthrone showed that prolonged boiling with alkali opened the ring, with the production of a mixture of carboxylic acids, doubtless 1- and 11-carboxy-benzanthrones. The hydrolysis required considerably longer than that of the unsubstituted ketone, but this is probably due to the smaller solubility of the bromo-derivative.(p. 118).

11:11'-Dicarboxy-dibenzanthrone has been prepared (Rule and co-workers, loc. cit.) by the alkali fusion of 11-carboxy-benzanthrone and the product cyclised to a blue vat-dye, diketo-dibenzanthrone, by the action of phosphorus pentoxide in phthalic anhydride. Isodibenzanthrone may be prepared in good yield and high purity by the action of alcoholic alkali on the dibenzanthronyl selenide obtained by the action of selenium on 3-bromo-benzanthrone. The same reaction, the mechanism of which is somewhat obscure, has now been employed for the preparation of 11:11'-dicarboxy-isodibenzanthrone from 3-bromo-11-carboxy-benzanthrone (p.121).

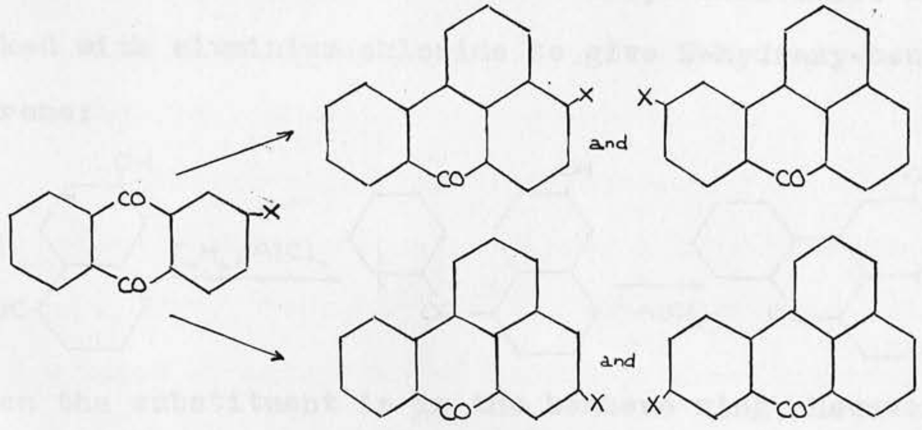
As in the case of dibenzanthrone-dicarboxylic acid, the dicarboxy-isodibenzanthrone exhibited somewhat greater stability towards dehydrating agents than the corresponding benzanthrone derivative. A neutral product was, however, obtained by more prolonged treatment with phosphorus pentoxide at a higher temperature, but it is somewhat doubtful whether this consisted entirely of the expected diketone, as although a portion behaved in the expected manner as a dyestuff, some material unaffected by hydrosulphite was also present (or was produced by reduction ?). Both fractions, nevertheless, dissolved in sulphuric acid with a green colour, characteristic of isodibenzanthrone.

A regularity can be traced in the stability and ease of formation of the five-membered ketone rings in the series fluorenone, keto-benzanthrone, diketodibenzanthrone, which holds also for the substituted derivatives. Fluorenone, fluorenone-carboxylic acids and benzo-fluorenone can be obtained by dehydration of the corresponding carboxy-acids by the action of concentrated sulphuric acid, zinc chloride, aluminium chloride, etc., under conditions which leave 11-carboxybenzanthrone unaffected (cf. Pursell, Thesis, Edin., 1933). The five-membered ring in fluorenone compounds is stable towards aqueous alkali, which is, however, able to attack the 1:11-ketone ring in keto-benzanthrones, owing no doubt to the greater molecular tension in the benzanthrone derivatives. "In fluorenone the strain in the five-membered ring may be relieved by a slight adjustment of the loose diphenyl system, a distortion which is not so readily tolerated by the more rigid benzanthrone molecule." (Rule and Bigelow, J., 1935, in the press). The resistance of dicarboxy-dibenzanthrone and -isodibenzanthrone towards dehydrating agents is in keeping with the still greater rigidity of its molecular structure. The resistance offered by diketodibenzanthrone to alkali can be attributed to its insolubility, a factor which also has an effect on the stability of substituted keto-benzanthrones.

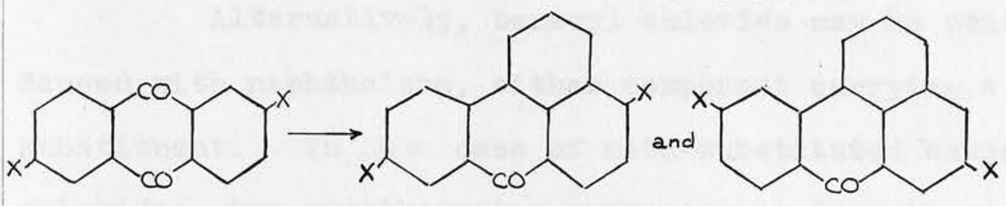
III. Orientation of Benzanthrone Derivatives.

Two methods are in general available for the orientation of derivatives obtained by substitution in a parent compound. These are (1) graduated synthesis, and (2) degradation to known products. Both these methods are applicable to a certain extent in the benzanthrone series and some discussion of them is given here in connection with the results described in the experimental section of this thesis.

The two methods commonly employed for the synthesis of benzanthrone, apart from that based on the Ullmann reaction employed in this thesis, are (1) the "Skraup synthesis" from anthraquinones or their reduction products, anthrones (p. 13), and (2) the synthesis of benzanthrones by "baking" α-benzoyl-naphthalenes with aluminium chloride, a process of dehydrogenation introduced by Scholl and Seer (p. 15). Of these, the former is of less interest in connection with the orientation of the products, since a number of possibilities arise, depending on the number and position of the substituents in the anthraquinone nucleus. For example, a 2-substituted-anthraquinone may theoretically give rise to four substituted benzanthrones on reduction and condensation with glycerol:

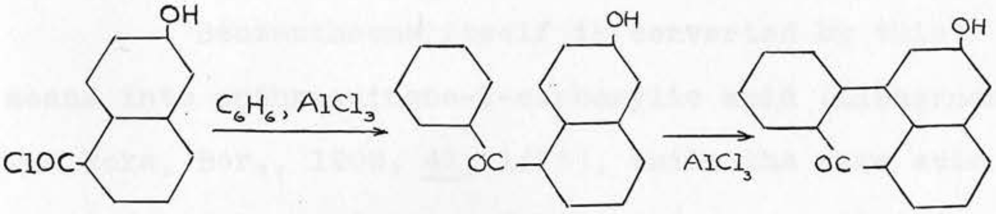


A 2:6-disubstituted anthraquinone can give rise to two isomeric benzanthrones, thus:



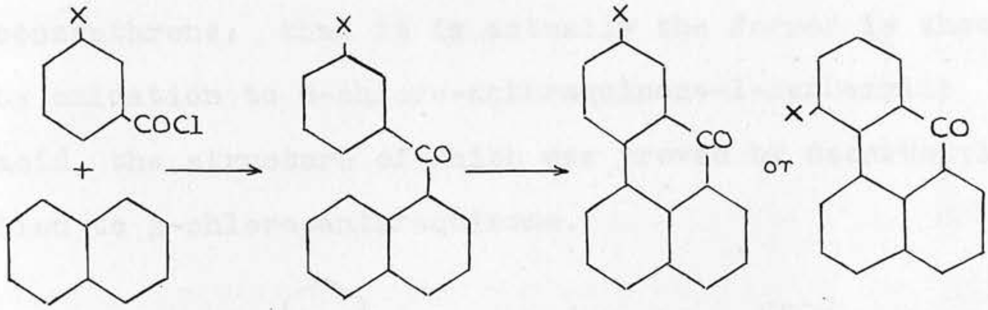
While it is of interest that in some cases only one of the possible isomers is formed, e.g. 4:9-dichloro-benzanthrone being obtained from 2:6-dichloro-anthraquinone (I.G., 1927, D.P. 450,445; Lüttringhaus and Neresheimer, Ann., 1929, 473,279 ; cf. also the analogous dibromo-compound, I.G., loc.cit.) the method possesses obvious disadvantages when applied to the determination of orientation.

The second method is, however, more adapted to this purpose since, in some cases at any rate, the position of the substituent is completely defined. As an example, the synthesis of 2-hydroxy-benzanthrone (M.L.B., 1923, D.P. 413738) may be given since this compound is mentioned later. 6-Hydroxy-1-naphthoÿl chloride is converted into the benzoyl derivative and the latter baked with aluminium chloride to give 2-hydroxy-benzanthrone:



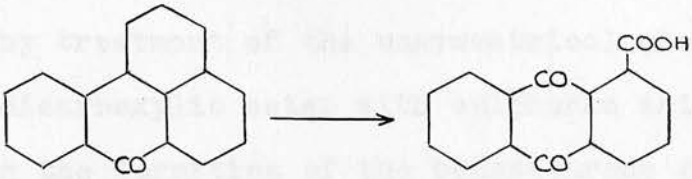
When the substituent is in the benzene ring, however, the orientation of the product obtained by this process cannot always be predicted.

Alternatively, benzoyl chloride may be condensed with naphthalene, either component carrying a substituent. In the case of meta-substituted benzoyl chlorides, two possibilities arise (apart from the possible formation of both α- and β-naphthyl-phenyl-ketones), as the benzanthrone derivative obtained by ring-closure of the α-naphthyl ketone may be either a 9- or an 11-substituted derivative:

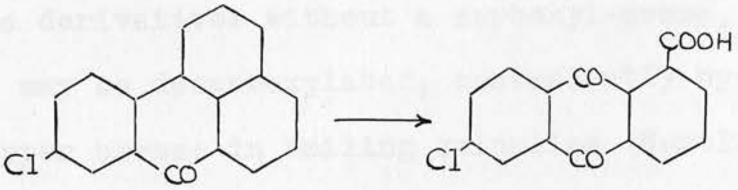


The degradation of benzanthrones to derivatives of anthraquinone by means of oxidation has proved very fruitful in establishing the constitution of substituted derivatives. Oxidation may be conveniently carried out with chromic acid, which converts the benzanthrone system into anthraquinone-1-carboxylic acid or a derivative thereof, many examples of which are known or can by synthesised.

Benzanthrone itself is converted by this means into anthraquinone-1-carboxylic acid (Liebermann and Roka, Ber., 1908, 41, 1425), while the same acid is produced by oxidation of benzanthrones containing substituents in the benz-nucleus (positions 1, 2 or 3).

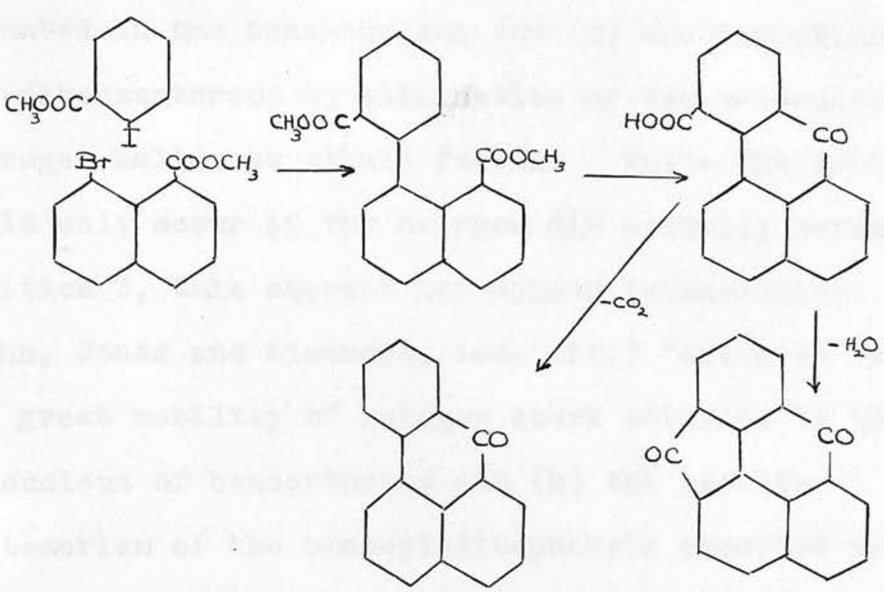


An example of the use of this method may be cited. A chloro-benzanthrone has been prepared by condensing m-chloro-benzoyl chloride with naphthalene and treating the product with aluminium chloride (Scholl and Seer, Ber., 1922, 55, 109). As previously indicated, the product might be either 9- or 11-chloro-benzanthrone; that it is actually the former is shown by oxidation to 6-chloro-anthraquinone-1-carboxylic acid, the structure of which was proved by decarboxylation to β-chloro-anthraquinone.



The mono-chlorination product of benzanthrone yields anthraquinone-1-carboxylic acid on oxidation, indicating that the substituent has entered the benz-nucleus; the dichlorination product of m.p. 267 - 268°C. yields 6-chloro-anthraquinone-1-carboxylic acid, indicating that the second chlorine atom has entered position 9 (Cahn, Jones and Simonsen, J., 1933, 444).

The synthetic method described in this thesis, viz., the coupling of a peri-halogeno-naphthoate and an o-halogeno-benzoate by means of the Ullmann reaction, followed by treatment of the unsymmetrical phenyl-naphthyl dicarboxylic ester with sulphuric acid, which results in the formation of the benzanthrone system containing the carboxyl group derived from the benzoate in position 11, is free from any of the uncertainty associated with the methods described above, and the constitution of the product may be deduced directly from that of the original reactants. The fact that the carboxyl-group is in position 11 is confirmed by the ring-closure which occurs, though with more difficulty than in the case of the six-membered ring, yielding 1:11-keto-benzanthrone (Rule and Bigelow, J., 1935, in the press). For the preparation of benzanthrone derivatives without a carboxyl-group, the above acids may be decarboxylated, conveniently by the action of copper bronze in boiling quinoline (Hurtley, J., 1929, 1870; Shephard, Winslaw and Johnson, J.A.C.S., 1930, 2084; Davies, Heilbron and Irving, J., 1932, 2715).



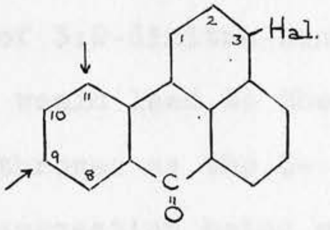
Though only a few compounds have so far been prepared by this method, they have served to give a definite proof, which has been hitherto lacking, of some of the positions in which substitution can take place in the benzanthrone nucleus.

Constitution of Some Halogenated Benzanthrones.

3-Bromo-benzanthrone, m.p. 176 - 7°C., prepared from methyl 5:8-dibromo-1-naphthoate and methyl o-iodo-benzoate by the above method, was identical with the product obtained by direct bromination of benzanthrone in acetic acid solution or aqueous suspension (p. 112). The proof of this orientation, which has been generally accepted, rested hitherto on (1) oxidation to a bromine-free anthraquinone-1-carboxylic acid, which established that the bromine was situated in the benz-nucleus and (2) the formation of iso-dibenzanthrone by elimination of two molecules of hydrogen halide on alkali fusion. While the latter could only occur if the halogen did actually occupy position 3, this argument may appear inconclusive (Cahn, Jones and Simonsen, loc. cit.) "owing to (a) the great mobility of halogen atoms attached to the Bz-nucleus of benzanthrone and (b) the peculiar tautomerism of the benzoyl-dinaphthyls reported by Lüttringhaus and Neresheimer (loc. cit.)."

In view of the confirmation supplied above, there now appears to be no reason for believing that any re-arrangement takes place at high temperatures or that position 3 is not that first attacked on bromination. While the analogous chloro-compound has not been synthesised by this method, a compound identical with the product obtained by direct chlorination of benzanthrone has been obtained in these laboratories (J. L. Grieve, unpublished) by chlorination of 11-carboxy-benzanthrone and subsequent decarboxylation. Since 11-carboxy-benzanthrone also brominates in position 3, there is no reason to doubt that halogenation of benzanthrone takes place primarily in position 3.

Further chlorination of benzanthrone has been shown (Cahn, Jones and Simonsen, loc. cit.) to result in the formation of a mixture of isomeric dichloro-benzanthrones (the proportions formed depending on conditions), to which the constitutions of 3:9- and 3:11-dichloro-benzanthrones can be assigned. Bromination, however, appears to give a homogeneous product (B.A.S.F., 1908, D.P. 193959), m.p. 256°C., which may be designated as 3:9-dibromo-benzanthrone, since the products obtained by decarboxylation of 3:9-dibromo-11-carboxy-benzanthrone and by bromination of 3-bromo-benzanthrone in aqueous suspension have proved to be identical (p. 135). It is evident, therefore, that the halogen atom in position 3 inhibits substitution in the benz-nucleus to a greater extent than the ketonic group inhibits substitution in the ring containing positions 8, 9, 10 and 11, since a second substituent enters the latter and not the former nucleus.



9-Bromo-benzanthrone was prepared by decarboxylation of 9-bromo-11-carboxy-benzanthrone. It possessed the same melting-point (183°C) as is recorded for the product obtained by reducing 4:9-dibromo-benzanthrone in alkaline medium (I.G.,1927,D.P. 450,445) (p. 127).

Constitution of Nitro-benzanthrones.
(cf. Martinet and Drobatscheff, Chem. et Ind., 1929, 21, 227).

When benzanthrone is nitrated in nitrobenzene solution at 40 - 50°C., a mono-nitro-benzanthrone of m.p. 248 - 9°C. is formed (B.A.S.F., Add$^{n.}$ No. 6435 to F.P. 349531). When benzanthrone is nitrated in boiling glacial acetic acid, the main product is stated to be an isomeric nitro-benzanthrone, m.p. 305 - 7°C. (B.A.S.F. loc. cit.) In sulphuric acid, a mixture of the two isomers is produced.

Martinet and Drobatscheff (loc. cit.) state that both these isomers on more energetic nitration give a dinitro-benzanthrone, m.p. 268°C., for which the constitution of 3:9-dinitro-benzanthrone is suggested. This would lead to the formulation of the mono-nitro-benzanthrones as the 3- and 9- nitro derivatives, the suggestion being made that the former is the lower melting isomer, which is produced under less vigorous conditions of nitration.

3-Nitro-benzanthrone, synthesised during the present investigation from methyl 5-nitro-8-bromo-1-naphthoate and methyl o-iodo-benzoate by the method described above, melted at 248 - 9°C. and was identical with the product obtained by nitration of benzanthrone in nitrobenzene (p.141). 9-Nitro-benzanthrone, prepared in the same way from methyl 8-bromo-1-naphthoate and methyl 5-nitro-2-iodo-benzoate, melted at 291 - 2°C. and depressed the melting-point of the second nitration product (m.p. 305 - 7°) obtainable from benzanthrone (p. 146).

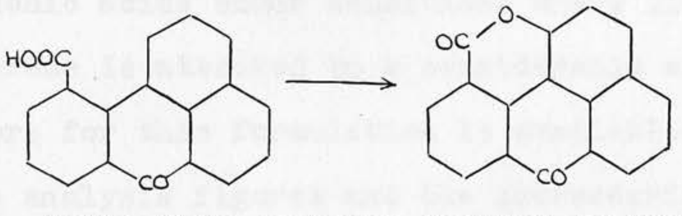
The statement that both the mono-nitro products of the direct nitration of benzanthrone give the same 3:9-dinitro-derivative is evidently erroneous. There is some ground for assuming dinitration to yield the 3:9-dinitro-derivative, since the 3-position is apparently the most readily attacked and, as in the case of the halogenated derivatives, the 9-position appears the most likely for further attack. Moreover, while the mono-nitro-derivatives obtained by direct nitration give orange non-fluorescent solutions in concentrated sulphuric acid, 9-nitro-benzanthrone gives a yellow solution with bright green fluorescence. Dinitro-benzanthrone is described as giving a similar fluorescence which may thus be characteristic of the nitro-group in position 9.

Unfortunately, this compound could not be synthesised, as it was not found possible to isolate the dinitro-carboxy acid from the products of the Ullmann reaction. For the same reason it was not possible to prepare 8- and 10-nitro-benzanthrones (p. 151).

Oxidation of Benzanthrones.

When benzanthrone is oxidised in sulphuric acid solution at 0° with manganese dioxide, 2-hydroxybenzanthrone is obtained (Scottish Dyes, E.P., 251313, 278112, 278496). When oxidation is carried out by means of aqueous potassium hydroxide and potassium chlorate, best in the presence of anthraquinone, at about 250°C., 4-hydroxy-benzanthrone is the main product (Perkin and Spencer, J., 1922, 121, 474).

It has been mentioned above that 11-carboxy-benzanthrone halogenates in position 3 and nitration has also been shown to occur in that position (J. L. Grieve, in these laboratories, unpublished). Oxidation of this compound appears to occur in a somewhat unexpected position, however, for Rule and Bigelow (J., 1935, in the press) conclude that the product obtained either by the action of concentrated sulphuric acid at high temperature or of chromic acid on an aqueous suspension of the acid, is the lactone of 1-hydroxy-11-carboxy-benzanthrone.



While this compound reacted in the expected manner with alkalies, it proved very resistant to methylation. Perkin and Bradshaw (J., 1922, 121, 911) record that difficulty was experienced in methylating the lactone of 4-hydroxy-3-carboxy-benzanthrone (prepared by the action of alkali and a sugar on 2-hydroxy-anthraquinone) and it seems that the 6-membered lactone ring is even more resistant to methylating agents. The presence of this ring also appears to stabilise the molecule towards oxidising agents, since under those conditions which lead to the oxidation of benzanthrones to anthraquinone-1-carboxylic acids, 11-carboxy-benzanthrone yields the "lactone", which does not yield an anthraquinone-carboxylic acid on further treatment (1:11-keto-benzanthrone is also highly resistant to oxidation).

A compound for which an analogous structure is suggested was obtained during the present work from 3-bromo-11-carboxy-benzanthrone by the action of chromic acid (p. 119) or (together with 3-bromo-benzanthrone and an unidentified neutral product, probably the 1:11-ketone) by the action of concentrated sulphuric acid at 140 - 160°C. (p. 120). (It may be noted that sulphonation appears to take place readily only in position 3, since 3-bromo-11-carboxy-benzanthrone gives no sulphonic acids under conditions where 11-carboxy-benzanthrone is attacked to a considerable extent). No support for this formulation is available, apart from the analysis figures and the characteristic lactone-like solubility in hot alkali, and the occurrence of oxidation in position 1 appears as a novel and somewhat unexpected phenomenon, of which additional confirmation is desirable. The orientation is the more unusual when it is remembered that the 2:2'-positions in the diphenyl system (corresponding to the 1:11-positions in benzanthrone) are considered to resemble ortho-positions most closely (Kenner and Turner, J., 1911, 99, 2101 ; Kenner, J., 1913, 103, 613), and that the presence of a carboxyl-group in position 11 would hardly be expected to favour attack on position 1.

III. EXPERIMENTAL SECTION.

The experimental work carried out is described in the following pages.

Yields are quoted as percentages of the theoretical amount obtainable. All melting-points are corrected, the thermometer used having been standardised against short-stemmed "standard thermometers". Analysis figures are given for all new compounds and the method of analysis noted.

Methods of Analysis.

Bromine was estimated by several methods. The method of Ter Meulen (Ter Meulen and Heslinga, Rec. Trav. Chim., 1923, 42, 1093), which consists of the hydrogenation of the compound in presence of ammonia and estimation of the ammonium halide by Volhard's volumetric method, proved satisfactory for compounds of comparatively low m.p. (below about 250°C.). For higher melting compoundsof the benzanthrone type, however, results were not sufficiently accurate, as the high temperature required to hydrogenate the compound resulted in the formation of a fog of ammonium halide which could not be trapped, leading to low results.

The method of Carius was resorted to, but in the case of bromo-1:11-keto-benzanthrones it was found that even treatment with fuming nitric acid at

300°C. for ten hours was insufficient to oxidise all the organic material. For this reason, C and H determinations (micro-determinations by Dr A. Schoeller, Berlin) are quoted for these compounds.

Later, a steel bomb (Parr, Pringsheim) was made available and sodium peroxide was found to be a satisfactory agent for the oxidation. The semi-micro method of Hein, Hoyer and Klar (Zeit. analyt. Chem., 1928, 75, 161) proved very satisfactory and as little as 20 - 30 mgm. was required for an analysis, the halide being estimated volumetrically by Volhard's method for bromine or Lang's cyanide method (below) for iodine.

Nitrogen was estimated by the micro-Dumas method. Difficulty was again experienced in the analysis of compounds of the benzanthrone type, especially nitro-11-carboxy-benzanthrones, and it was necessary to employ a silica tube and heat to as high a temperature as possible without causing the dissociation of carbon dioxide. Even so, low results were obtained; the constitution of these compounds was, however, confirmed by decarboxylation to the corresponding nitrobenzanthrones, which analysed correctly, within the limit of experimental error.

The estimation of cuprous iodide in the mixture of cuprous iodide and bromide formed in the Ullmann reactions was carried out by boiling the residue, after removal of organic material, with dilute sodium hydroxide solution, filtering the solution of sodium halides and making up to a known volume. In suitable portions, iodide was determined volumetrically by Lang's cyanide method (Lang, Z. anorg., 1922, 122, 332 ; Mitchell and Ward, Modern Methods of Quantitative Analysis, p. 6), by acidifying strongly with hydrochloric acid, adding potassium cyanide and starch solution and titrating with M/40 potassium iodate solution to decolourisation of the starch.

$$2CuI + 2NaOH \longrightarrow 2NaI + Cu_2O + H_2O$$

$$KIO_3 + 2I' + 3HCN \xrightarrow{3H^{\cdot}} 3ICN + 3H_2O + K^{\cdot}$$

PREPARATIONS.

8-Bromo-1-naphthoic acid.

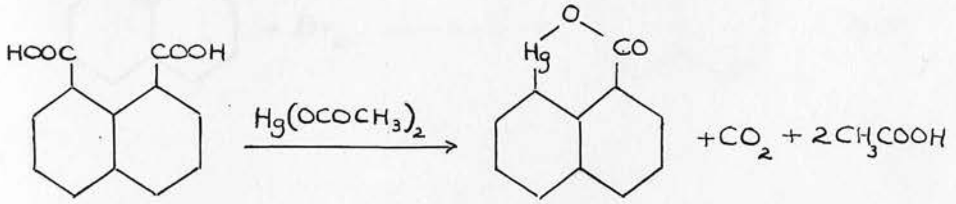
(Rule and co-workers, J.C.S., 1934, 170).

(a) Mercuration of naphthalic acid.

54 gm. naphthalic acid
21 gm. sodium hydroxide
55 gm. yellow mercuric oxide.

The sodium hydroxide and naphthalic acid were dissolved in 1200 ml. of water with heating. The solution was filtered and placed in a 2-litre flask fitted with a reflux condenser. The mercuric oxide was dissolved in a mixture of 40 c.c. glacial acetic acid and 150 c.c. water with heating, filtered and added to the flask. The contents were then made distinctly acid with acetic acid, when a light-coloured suspension formed. The mixture was boiled for 96 hours, after which a test portion (containing solid in suspension) was completely soluble in sodium hydroxide solution. The precipitate was filtered off, well washed with water and dried at 110°C.

Yield: 88 gm. = 97%.



(b) Bromination of mercury-compound.

80 gm. anhydro-8-hydroxy-mercuri-1-naphthoic acid.

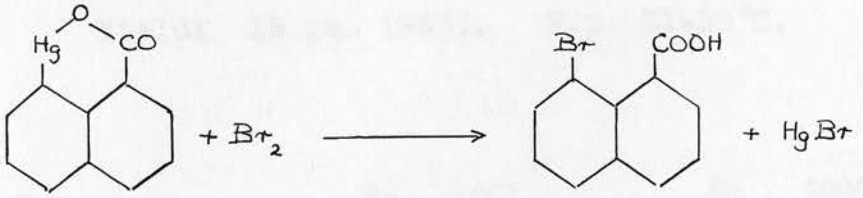
34 gm. bromine.

The mercury-compound was suspended in 300 c.c. of glacial acetic acid and 50 c.c. of water were added. The mixture was cooled in ice and water and efficiently stirred. Bromine, dissolved in 150 c.c. concentrated sodium bromide solution, was then added drop by drop over three hours, after which the mixture was warmed to 90°C. and the clear solution poured into 2 litres of cold water. After standing overnight, the crystalline solid was filtered off and extracted with 8-9 litres of boiling water. The crystals which deposited on cooling the filtrate were filtered off and dried.

Wt. 39 gm.   M.p. 160 - 170°C.

The crude acid was then recrystallised from benzene.

Yield: 33 gm. (57%).   M.p. 178°C.



Methyl 8-bromo-1-naphthoate.

(Rule and Barnett, J.C.S., 1932, 175).

15 gm. 8-bromo-1-naphthoic acid.

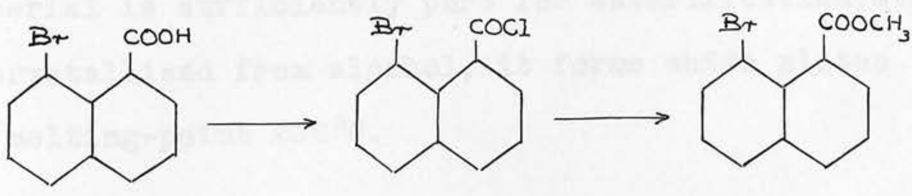
30 c.c. thionyl chloride (purified).

50 c.c. methyl alcohol (dry).

The acid and thionyl chloride were boiled under reflux on the water-bath until a clear solution was obtained and fumes ceased to be evolved. Excess thionyl chloride was distilled off on a boiling-water bath, and finally under reduced pressure. The acid chloride was allowed to cool and the methyl alcohol added in small quantities. Vigorous evolution of hydrochloric acid occurred and the reaction was then completed by boiling the mixture for half-an-hour.

Most of the alcohol was removed on the steam-bath and the liquid ester taken up in ether, washed with dilute sodium hydroxide and then with water. The ethereal solution was dried over calcium chloride and the ether removed in vacuo. The residual light-brown syrup solidified on standing or chilling to a cream-coloured solid.

Yield: 15 gm. (95%). M.p. 31-32°C.



5:8-Dibromo-1-naphthoic acid.

This acid was prepared by Rule, Pursell and Brown (l.c.) in 57% yield by the action of bromine in acetic acid solution on 8-bromo-1-naphthoic acid at 150°C. in a sealed tube. It is identical with that prepared by Goldstein and Francey (Helv., 1932, 15, 1362) from 5-brom-naphthastyril. Although Brown (Thesis, Edin., 1934) had investigated various other methods of bromination without success, the following simple method was found to give improved yields of a high quality of purity.

30 gm. 8-bromo-1-naphthoic acid.

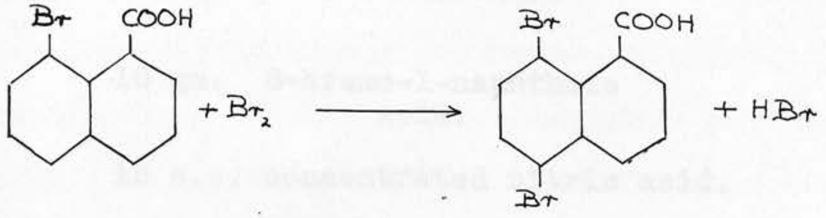
100 c.c. glacial acetic acid.

30 gm. bromine.

The above were placed in a 250 c.c. flask fitted with a ground-in water condenser and boiled gently for 4 to 5 hours, when hydrobromic acid fumes were no longer evolved. After cooling, the crystalline material was filtered off, washed with a little cold acetic acid and dried in the oven.

Yield: 34 gm. (86%). M.p. 230-32°C.

Though slightly brown in colour, this material is sufficiently pure for esterification, etc. Recrystallised from alcohol, it forms white plates of melting-point 232°C.



Methyl 5:8-dibromo-1-naphthoate.

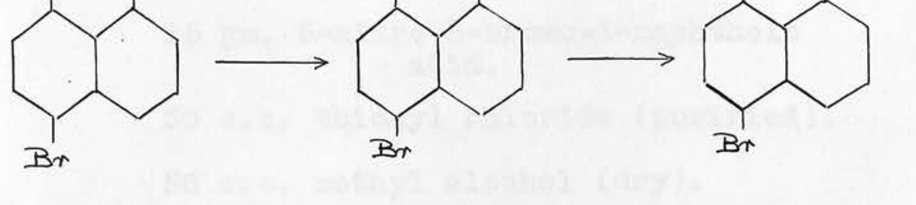
30 gm. 5:8-dibromo-1-naphthoic acid.

60 c.c. thionyl chloride (purified).

100 c.c. methyl alcohol (dry).

The acid chloride was formed as described in the preparation of the 8-bromo-naphthoate (p.69). After treatment with methyl alcohol, the ester was extracted as before, washed with dilute alkali and water, and the ether evaporated off. The semi-solid ester was then recrystallised from 50% alcohol.

Yield: 30 gm. (96%). M.p. 73°C.



5-Nitro-8-bromo-1-naphthoic acid.

(Rule and co-workers, J., 1934, 170).

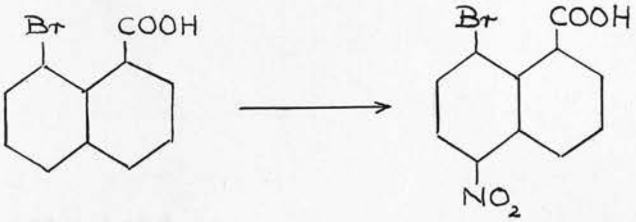
10 gm. 8-bromo-1-naphthoic acid.

15 c.c. concentrated nitric acid.

The above were mixed to a paste in a 250 c.c. flask and heated on a water-bath at 65°C. for two hours with occasional stirring. After cooling, the mixture was poured into 50 c.c. of water, allowed to settle and filtered off. The yellow powder (10 gms.) was boiled with 50 c.c. of alcohol, allowed to cool and filtered.

Yield: 7·5 gm. (64%). M.p. 242-3°C.

Recrystallised from aqueous alcohol, it forms yellow needles, M.p. 245°C.



Methyl 5-nitro-8-bromo-1-naphthoate.

(Rule and co-workers, loc. cit.).

15 gm. 5-nitro-8-bromo-1-naphthoic acid.

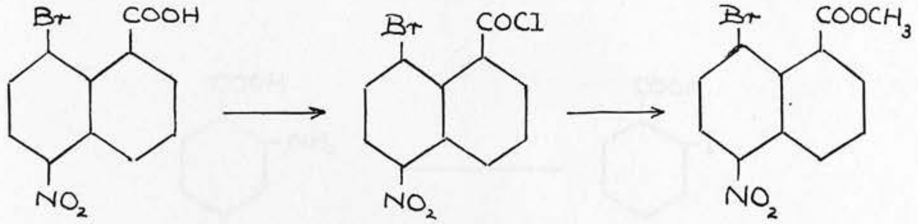
30 c.c. thionyl chloride (purified).

50 c.c. methyl alcohol (dry).

The acid chloride was formed as usual and after treatment with methyl alcohol, the dark solution was poured into dilute sodium carbonate solution. After standing some time, the cream-coloured solid was filtered off, washed with water and dried in the air. Weight, 15 gm. The crude ester was recrystallised from methyl alcohol as pale yellow needles.

Yield: 12·5 gm. (80%). M.p. 102-3°C.

The above authors quote m.p. 97°C. That this is in error was shown by a determination with their sample, which gave 103-4°C.



o-Iodo benzoic acid.

(Cohen and Raper, J., 1904, 1272)

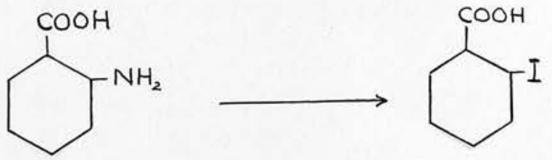
16 gm. anthranilic acid.

8 gm. sodium nitrite in 20 c.c. water.

20 gm. potassium iodide in 50 c.c. water.

The acid was dissolved in dilute sulphuric acid (25 c.c. concentrated acid in 125 c.c. water) and cooled in ice to 0°C. The sodium nitrite solution was added slowly with stirring until excess was present, the temperature being maintained at 0°. The potassium iodide solution was then added slowly with stirring and the mixture allowed to stand at room temperature overnight. It was then warmed on the steam-bath till effervescence ceased. After cooling, free iodine was removed with sodium bisulphite, and the buff-coloured solid filtered off and washed with water. It was then recrystallised from dilute acetic acid.

Yield: 22 gm. (76%). M.p. 160°C.



Methyl o-iodo-benzoate.

(Cohen and Raper, loc. cit.).

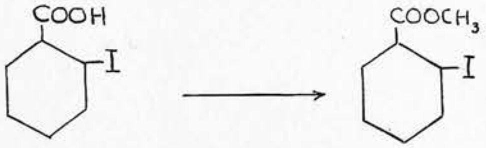
50 gm. o-iodo benzoic acid

200 gm. methyl alcohol.

20 gm. concentrated sulphuric acid

The above were boiled together under reflux for 15 hours. Most of the excess alcohol was then boiled off and the liquid poured into water and neutralised with solid sodium carbonate. The ester was extracted with ether and the extract shaken with dilute alkali and water. After drying, the ether was removed and the crude ester distilled under reduced pressure.

Yield: 45 gm. (85%). B.p. 145°C./15 mm.

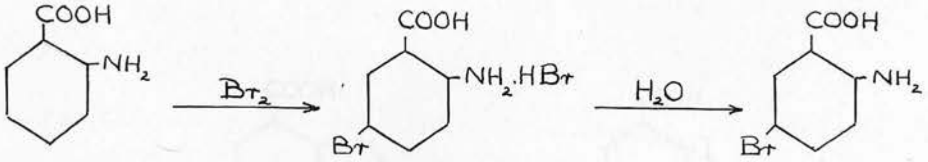


5-Bromo-anthranilic acid.

(cf. Wheeler, J.A.C.S., 1909, 31, 566).

Anthranilic acid, 50 gm., was dissolved in 500 c.c. of glacial acetic acid and cooled to 15°C. Bromine, 60 gm., was dropped in with mechanical stirring at such a rate that the temperature was maintained at 15-16°C. The white solid was filtered off and extracted with about 8 litres of boiling water. After cooling, the crystals from the filtrate were filtered off and dried.

Yield: 50 gm. (63%). M.p. 210°C.



5-Bromo-2-iodo benzoic acid.

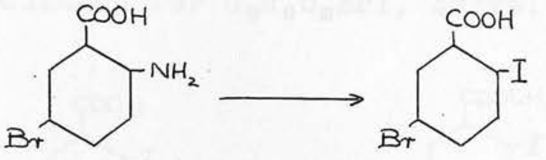
43 gm. 5-bromo-anthranilic acid.

14 gm. sodium nitrite in 30 c.c. water.

34 gm. potassium iodide in 70 c.c. water.

The finely-powdered acid was suspended in a solution of 50 c.c. of concentrated sulphuric acid in 300 c.c. of water, cooled to 0° and diazotised with the sodium nitrite. The potassium iodide solution was then added with stirring and the mixture allowed to stand overnight. After warming on the steam-bath till effervescence ceased and removing free iodine with sodium bisulphite, the mixture was allowed to cool and the solid filtered off and washed with water. The crude acid was then recrystallised from dilute acetic acid.

Yield: 50 gm. (73%). M.p. 158-9°C.



Methyl 5-bromo-2-iodo-benzoate.

50 gm. 5-bromo-2-iodo benzoic acid.

200 gm. methyl alcohol.

20 gm. concentrated sulphuric acid.

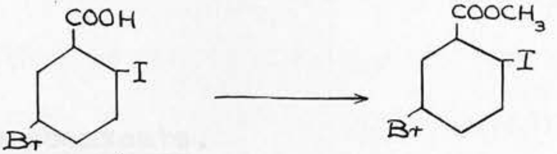
The above were boiled under reflux for 15 hours, excess alcohol removed and the ester extracted with ether. The extract was shaken with water, dilute alkali and water again. After drying, ether was removed and the syrupy ester recrystallised from methyl alcohol, part solidifying from an oil and part forming white needles.

Yield: 40 gm. (77%). M.p. 45-46°C.

Analysis (sodium peroxide method):-

found: I, 37·0% ;

calculated for $C_8H_6O_2BrI$, 37·2%.



o-Chlorobenzoic acid.

(Graebe, Ann., 1893, 276, 54).

13·7 gm.	anthranilic acid.
30 c.c.	concentrated hydrochloric acid in 75 c.c. of water.
7·0 gm.	sodium nitrite in 20 c.c. water.

The anthranilic acid was diazotised at 0°C. in the usual way and the diazo-solution added slowly with stirring to an ice-cold solution of cuprous chloride, made by boiling 7 gm. of cupric chloride in a solution of 50 c.c. of concentrated hydrochloric acid in 15 c.c. of water with 4 gm. of copper powder.

The solid product was filtered off, washed and recrystallised from dilute alcohol with addition of animal charcoal.

Yield: 11 gm. (70%). M.p. 138°C.

Methyl o-chlorobenzoate.

10 gm. o-chlorobenzoic acid.

40 gm. methyl alcohol.

5 gm. concentrated sulphuric acid.

The procedure was the same as in the case of the analogous o-iodo-acid (p. 74).

Yield: 10 gm. (92%). B.p. 120°/20 mm.

o-Bromobenzoic acid.

(Holleman and De Bruyn, Rec. trav. chim., 1901, 20, 210).

50 gm. anthranilic acid.

115 c.c. hydrobromic acid (S.G. 1·49).

31·25 gm. copper sulphate ($CuSO_4.5H_2O$).

25·75 gm. sodium bromide.

147·5 gm. hydrobromic acid (S.G. 1·49)

16·45 gm. copper filings.

50 gm. sodium nitrite in 250 c.c. water.

A solution of cuprous bromide was made by boiling together copper sulphate, sodium bromide, hydrobromic acid and copper filings until decolourised and added to a solution of the anthranilic acid made by boiling with 115 c.c. hydrobromic acid and 900 c.c. of water. To the warm mixture (30-40°C.) the sodium nitrite solution was slowly added with stirring, and after cooling the crude bromo-acid was filtered off and recrystallised from water.

Yield: 65 gm. (88%). M.p. 149°C.

Methyl o-bromo-benzoate.

10 gm. o-bromobenzoic acid.

40 gm. methyl alcohol.

5 gm. concentrated sulphuric acid.

The method was the same as for the iodo- and chloro-acids. (p. 74).

Yield: 10 gm. (93%). B.p. 130°C./15 mm.

5-Nitro-2-bromo-benzoic acid.

(Holleman and de Bruyn, Rec. Trav. Chim., 1901, 20, 211).

15 gm. o-bromo-benzoic acid.
60 gm. fuming nitric acid (S.G. 1·52).

The o-bromo-benzoic acid was added in small portions to the nitric acid contained in a small flask. The solution was stirred with a thermometer after each addition and the temperature kept between 20° and 25°, the flask being cooled in ice-water if necessary. After complete addition, the solution was allowed to stand for half-an-hour and then poured on to 500 gm. of ice and water. The white precipitate was filtered off, washed with cold water and recrystallised from about 400 c.c. of water as colourless needles.

Yield: 16 gm. (85%). M.p. 178-9°C.

(The pure compound melts at 180°).

Methyl 5-nitro-2-bromo-benzoate.

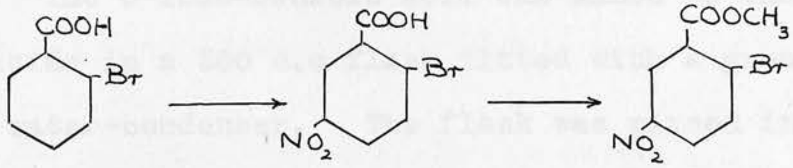
(Ullmann and Bielecki, Ber., 1901, 34, 21).

15 gm. 5-nitro-2-bromo-benzoic acid.
50 c.c. methyl alcohol.
5 gm. concentrated sulphuric acid.

The above were boiled under reflux for

18 hours, the solution allowed to cool and diluted with water. The precipitated solid was filtered off, washed with sodium carbonate solution and water and dried in the air. The crude ester (15 gm.) was recrystallised from about 40 c.c. of methyl alcohol, forming long colourless needles.

Yield: 13 gm. (82%). M.p. 81 - 82°C.



5-Nitro-2-iodo-benzoic acid.

(cf. Gumbel, Ber., 1893, 26, 2474).

The action of nitric acid on o-iodo-benzoic acid leads first to the formation of o-iodoso-benzoic acid, then to a nitro-iodoso-benzoic acid and finally, at high temperatures, to the nitro-o-iodo-benzoic acid of m.p. 193°C. The orientation of the compound is not given in Beilstein. On the usual considerations, the nitro-group will enter either the 5- or the 3-position; that the 5-position is the one actually attacked has been shown by the graduated synthesis of 3-nitro-2-iodo-benzoic acid, m.p. 206°C. (James, Kenner and Stubbing, J., 1920, 773). The series of mono-nitro-o-iodo-benzoic acids has been completed by the preparation of the previously unknown 6-nitro-2-iodo-benzoic acid (p. 85).

20 gm. o-iodo-benzoic acid.
300 gm. concentrated sulphuric acid.
100 gm. fuming nitric acid.

The o-iodo-benzoic acid was added to the mixed acids in a 500 c.c flask fitted with a ground-in reflux water-condenser. The flask was placed in an oil-bath, the temperature of which was slowly raised to 175-180°C. and maintained there for five hours. After cooling, the colourless solution was poured on to 1000 gm. of ice and water and the white solid which deposited was filtered off.

In order to convert any o-iodoso-acid to the o-iodo-acid, the solid was suspended in 500 c.c. of boiling water and 10 gm. of potassium iodide added. Free iodine was removed by addition of solid sodium bisulphite and then sufficient glacial acetic acid was added to bring the solid into solution. On cooling, fine colourless needles were formed.

Yield: 15 gm. (64%). M.p. 192-3°C.

Methyl 5-nitro-2-iodo-benzoate.

This compound can be prepared according to Reverdin (Ber., 1897, 30, 3002) by heating methyl o-iodo-benzoate with fuming nitric acid "until the reaction slackens somewhat." This method proved unreliable in practice and a considerable amount of the o-iodo-benzoic acid is formed by hydrolysis. It is therefore preferable to nitrate o-iodo-benzoic acid as described and esterify the product in the usual way.

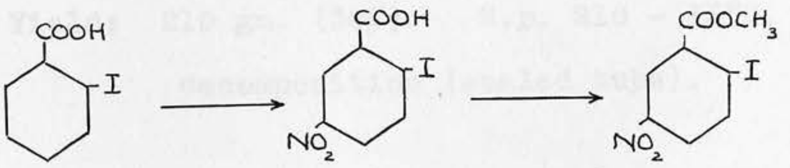
15 gm. 5-nitro-2-iodo-benzoic acid.

100 gm. methyl alcohol.

10 gm. concentrated sulphuric acid.

The above were boiled under reflux for 15 hours and allowed to cool. The crystalline deposit was filtered off, washed with dilute sodium carbonate and water, and dried in the air.

Yield: 12·5 gm. (80%). M.p. 122-3°C.



6-Nitro-2-iodo-benzoic acid.

(a) 3-Nitro-phthalic acid.

(Organic Syntheses, 7, 70).

Phthalic anhydride, 500 gm., was dissolved in 650 c.c. of concentrated sulphuric acid in a 2 litre beaker and mechanically stirred. The beaker was placed in a large jar and heated to 80° by passing steam into the jar. The steam was then shut off and 210 c.c. of fuming nitric acid added at such a rate as to maintain the temperature at 100 - 110° (about 2 hours). 900 c.c. of concentrated nitric acid were then added and steam passed for 2 hours longer. After standing overnight, the mixture was added to 1·5 litres of iced water and filtered repeatedly through a Buchner funnel without paper until the filtrate was clear. The moist solid was returned to the beaker and well stirred with 200 c.c. of water to remove 4-nitrophthalic acid. The undissolved solid was filtered off and recrystallised from about 300 c.c. of water.

Yield: 210 gm. (30%). M.p. 210 - 15°C. with decomposition (sealed tube).

(b) 3-Nitro-phthalamide.

(Bogert and Boroschek, J.A.C.S., 1901, 23, 747).

The imide of 3-nitro-phthalic acid is best prepared by the action of heat on the acid ammonium salt.

3-Nitro-phthalic acid, 100 gm., was dissolved in 200 c.c. of hot water and the solution made alkaline with concentrated ammonia. Excess ammonia was boiled off and 100 gm. of finely-powdered 3-nitro-phthalic acid added with stirring. On cooling, the acid ammonium phthalate separated and was filtered off and dried. Wt. 200 gm.

The acid salt was placed in a wide-necked flask and the flask immersed in an oil-bath maintained at 225° until the whole was in a state of quiet fusion (2 - 3 hours). The liquid was then poured into a mortar and, after solidifying, finely powdered.

Yield: 160 gm. of pale yellow powder.
M.p. 214 - 16°.
(88% of theory, based on 3-nitro-phthalic acid.).

(c) 6-Nitro-phthalamic acid.
(Kahn, Ber., 1902, 35, 3863).

Finely-powdered 3-nitro-phthalimide, 140 gm., was added to 2920 c.c. of N/2 potassium hydroxide solution and mechanically stirred at room temperature until solution was complete (3 hours). The solution was then acidified with 730 c.c. of 2 N. hydrochloric acid and after standing for some time the white crystals of 6-nitro-phthalamic acid were filtered off and dried.

Yield: 110 gm. (72%). Decomposes at 150-5°
to give the imide, M.p. 214 - 16°C.

(d) 6-Nitro-anthranilic acid.

(cf. Haldane, Thesis, Edin. 1934).

A standard hypochlorite solution containing 47 gm. of sodium hypochlorite and 50 gm. of sodium hydroxide per litre was prepared by passing chlorine into a solution of 100·5 gm. of sodium hydroxide in 400 c.c. of water and 400 gm. of ice until the increase in weight was 44·8 gm. The volume was then made up to 1 litre.

A Hofmann Reaction was carried out as follows:

50 gm. 6-nitro-phthalamic acid.
375 c.c. standard hypochlorite solution.
20 gm. sodium hydroxide in 50 c.c. water.
150 c.c. concentrated hydrochloric acid.

The hypochlorite solution was cooled to 0° and mechanically stirred. The finely-powdered 6-nitro-phthalamic acid was added in portions, the temperature being maintained between 0° and 5°. The sodium hydroxide was then added and the yellow solution heated on a water-bath to 80° and maintained there for ten minutes. The now dark red solution was then cooled in ice and acidified slowly and with stirring with the hydrochloric acid. The yellow crystalline precipitate was filtered off, washed with water and dried.

Yield: 40 gm. (92%). M.p. 187-8° with decomp.

Crystallisation from water gives the acid in the form of yellow needles, m.p. 189°C. (decomp.). Kahn (loc. cit.) describes this compound as yellow plates of melting-point 180°C. (decomp.). Bogert and Chambers (J.A.C.S., 1905, 27, 649) describes it as yellow needles but quote no melting-point.

Analysis (micro-Dumas):- found: N, 15·6% ;
calculated for $C_7H_6O_4N_2$, 15·3%.

(e) 6-Nitro-2-iodo-benzoic acid.

Witt's method of diazotisation yielded a much purer product than could be obtained by diazotisation with sulphuric acid and sodium nitrite.

20 gm.	6-nitro-anthranilic acid.
12·5 gm.	potassium metabisulphite ($K_2S_2O_5$)
45 c.c.	fuming nitric acid.
17 gm.	iodine.
33 gm.	potassium iodide in minimum quantity of water.

The nitric acid was stirred and cooled to 0°. The 6-nitro-anthranilic acid and metabisulphite were finely ground together in a mortar and added in portions, the temperature being kept below 5°. The viscous liquid was poured on to 220 gm. of crushed ice and the solution of the iodine in the potassium iodide added with stirring. Vigorous effervescence occurred and black solid separated. After standing for half-an-hour, free iodine was removed by the addition of sodium bisulphite and the orange solid filtered off, washed with water and dried.

Yield: 25 gm. (77% of theory). M.p. 185-7°C.

Recrystallised from water it forms pale yellow needles of melting-point 188-9°C.

Analysis:- found: N , 5·05 % ; calculated for $C_7H_4O_4NI$, 4·8 %.

Methyl 6-nitro-2-iodo-benzoate.

The first attempt to prepare the methyl ester from 6-nitro-2-iodo-benzoic acid by the usual method, employing thionyl chloride and methyl alcohol, resulted in the production of a dark-coloured tar. (Decomposition seemed to occur during the removal of thionyl chloride in vacuo on a boiling water-bath). The tar was dissolved in hot benzene and petroleum-ether (B.p. 60° - 80°) added. Some dark tar was first deposited; when signs of crystallisation appeared, the liquid was decanted and chilled. The crystalline product was filtered off and, as it was dark in colour, recrystallised from methyl alcohol, when it formed buff-coloured needles of melting-point 93 - 94°C. The yield was only 5 gm. from 15 gm. of acid.

The ester can be satisfactorily prepared by way of the silver salt.

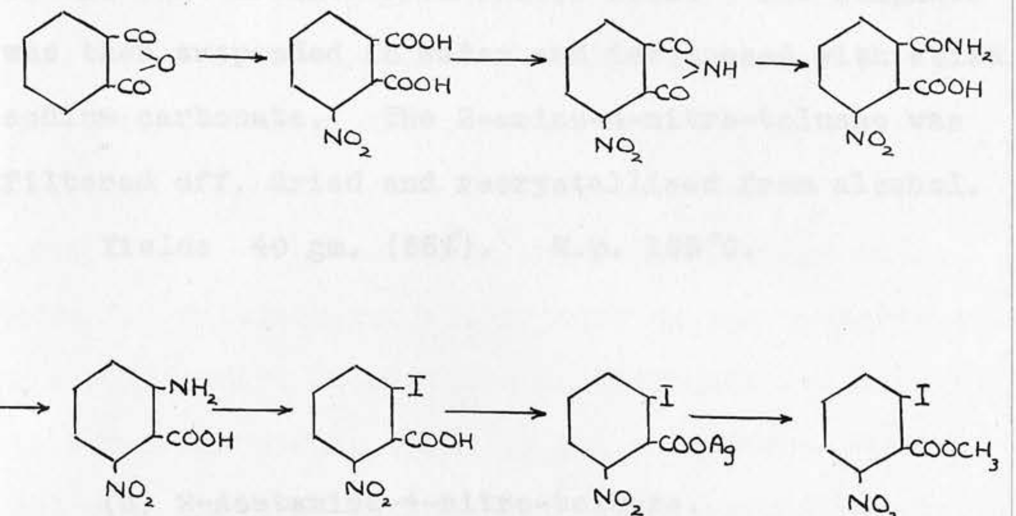
6-Nitro-2-iodo-benzoic acid, 12 gm., was dissolved in dilute ammonia solution and excess ammonia boiled off; silver nitrate, 7 gm., dissolved in 30 c.c. of water was then added and the mixture cooled. The silver salt separated as a buff-coloured crystalline deposit, which was filtered off and dried. Weight, 16 gm. The silver salt was boiled under reflux with 50 gm. of methyl iodide for 3 hours. The mixture was then extracted with three 100 c.c. portions of methyl alcohol, the filtrates reduced in volume and the crystalline ester filtered off after cooling.

Yield: 10 gm. (80%). M.p. 93 - 94°C.

After a second recrystallisation from methyl alcohol, the ester melted sharply at 94°C.

Analysis:- found: N, 4·7%; calculated for $C_8H_6O_4NI$, 4·6%.

<u>Note</u>. It is essential to adhere throughout to the conditions stated above. Even slight variations result in the production of highly impure products.



2-Iodo-4-nitro-benzoic acid.

(a) **2-Amino-4-nitro-toluene.**

(Cohen and Dakin, J., 1902, 81, 1333).

50 gm. o-toluidine

500 gm. concentrated sulphuric acid.

50 gm. potassium nitrate.

10 c.c. fuming nitric acid.

The o-toluidine dissolved in the sulphuric acid was cooled to 0°C. and the potassium nitrate, finely powdered, gradually added with stirring, so that the temperature rose to 10°. Finally, the fuming nitric acid was added. The mixture was poured on to a small quantity of ice and the solid sulphate of the base drained from excess acid. The sulphate was then suspended in water and decomposed with solid sodium carbonate. The 2-amino-4-nitro-toluene was filtered off, dried and recrystallised from alcohol.

Yield: 40 gm. (56%). M.p. 106°C.

(b) <u>2-Acetamino-4-nitro-toluene.</u>

(Noelting and Collin, Ber., 1884, <u>17</u>, 269).

50 gm. 2-amino-4-nitro-toluene.

75 gm. acetic anhydride.

The above were boiled together under reflux for ten minutes, cooled and poured into water. The solid was filtered off and recrystallised from dilute alcohol as light yellow needles.

Yield: 58 gm. (90%). M.p. 150 - 151°C.

(c) <u>2-Amino-4-nitro-benzoic acid.</u>

(Wheeler and Johns, Amer. Chem. J., 1910, <u>44</u>, 445).

35 gm. 2-acetamino-4-nitro-toluene.

90 gm. crystallised magnesium sulphate.

90 gm. potassium permanganate.

The nitro-toluene was suspended in one litre of hot water and the magnesium sulphate added. Steam was passed in and the permanganate, dissolved in two litres of water, added in portions at intervals. After three hours, the contents of the flask were filtered hot and the filtrate evaporated to a volume of 500 c.c. The solution was made alkaline with ammonia, filtered and acidified with hydrochloric acid. The bulky white precipitate of the acetamino acid was filtered off and dried. It was then dissolved in 200 c.c. of alcohol containing 15 c.c. of concentrated sulphuric acid and digested for an hour on the steam-bath. The orange crystalline precipitate of the amino acid was filtered off, washed with water and dried. A further quantity was obtained by diluting the filtrate and recrystallising the solid from alcohol.

Yield: 25 gm. (76%). M.p. 263°C.

(d) 2-Iodo-4-nitro-benzoic acid.

(Wheeler and Johns, loc. cit.)

34 gm. 2-amino-4-nitro-benzoic acid.

300 c.c. of 40% sulphuric acid.

12 gm. sodium nitrite in minimum amount of water.

30 gm. potassium iodide in 50 c.c. water.

The finely-powdered amino acid was suspended in the sulphuric acid, cooled to 0 - 5°C. and stirred for two hours with gradual addition of the sodium nitrite. The mixture was then poured on to ice (300 gm.) and treated with the potassium iodide. Free iodine was removed with solid sodium bisulphite and the solid recrystallised from water as long yellow prisms.

Yield: 40 gm. (73%). M.p. 141 - 2°C.

Methyl 2-iodo-4-nitro-benzoate.

(Willgerodt and Gartner, Ber., 1908, 41, 2817).

25 gm. 2-iodo-4-nitro-benzoic acid.

150 gm. methyl alcohol.

15 gm. concentrated sulphuric acid.

The above were boiled under reflux for 18 hours and allowed to cool. The crystalline deposit was filtered off, washed with water and recrystallised from methyl alcohol as buff-coloured needles.

Yield: 18 gm. (69%). M.p. 87 - 88°C.

Attempted Preparation of 4-Bromo-2-iodo-benzoic Acid.

The essential intermediate for this preparation, 4-bromo-anthranilic acid, has been prepared by a tedious process of many stages from p-bromaniline (Claus and Scheulen, J. prakt., 1891, [2] , 43, 204). No yields and few details are given. It was hoped to prepare it by another method recorded by Waldmann (J. prakt., 1930, 126, 60). This consisted of the bromination of phthalic anhydride in alkaline solution to give 4-bromo-phthalic acid, which was converted to the anhydride by distillation, the latter forming the imide on fusion with urea. The imide was then converted to the 4-bromo-anthranilic acid by the Hofmann Reaction. No yield was quoted, however, and it was found that while 4-bromo-phthalimide may be readily prepared as described, the action of sodium hypochlorite gave an inseparable mixture of isomeric acids. This preparation was therefore abandoned.

2:4-Dibromo-benzoic acid.

The corresponding dibromo-acid was, however, readily prepared by a simpler method than those previously recorded.

(a) 2:4-Dibromo-toluene.

(cf. Erdmann, Ber., 1891, 24, 2769, for the corresponding chloro-compound).

40 gm.	m-toluylene-diamine
300 c.c.	hydrobromic acid (S.G. 1·49)
83 gm.	copper sulphate ($CuSO_4.5H_2O$)
21 gm.	copper powder
69 gm.	sodium bromide
400 c.c.	hydrobromic acid (S.G. 1·49)
100 gm.	sodium nitrite in 1 litre of water

The base (B.D.H. product, recrystallised from water) was dissolved in 300 c.c. of hydrobromic acid and 100 c.c. of water and added to a solution of cuprous bromide made by boiling copper sulphate, sodium bromide and copper powder with 400 c.c. of hydrobromic acid till decolourised. The mixture was warmed to 60 - 70°C. and the sodium nitrite solution was added with shaking through a tap-funnel which delivered below the surface of the liquid. After heating on the steam-bath for an hour, the supernatant liquid was decanted and the residual oil distilled in steam, taken up in ether and washed with alkali and water. The ethereal solution was dried over calcium chloride and the ether evaporated off, leaving a yellow oil which did not solidify.

Yield: 48 gm. (58%).

(b) 2:4-Dibromo-benzoic acid.

(Miller, J., 1892, 61, 1033).

2:4-Dibromo-toluene, 48 gm., was boiled under reflux for several days with 1·5 l. of dilute nitric acid (1 volume of acid of density 1·42 to 3½ volumes of water) until most of the oil had disappeared. The solid which separated on cooling was filtered off, taken up in sodium carbonate solution and extracted with ether. The dibromo-benzoic acid obtained on acidification was recrystallised as white needles from dilute nitric acid.

Yield: 20 gm. (37%). M.p. 169°C.

(c) Methyl 2:4-Dibromo-benzoate.

20 gm. 2:4-dibromo-benzoic acid

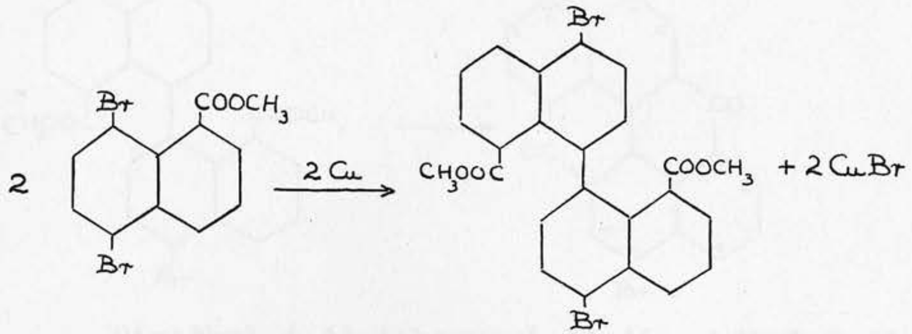
100 gm. methyl alcohol

10 gm. concentrated sulphuric acid.

The esterification was carried out in the usual way and the product recrystallised from methyl alcohol.

Yield: 17 gm. (81%). M.p. 33-34°C.

Dimethyl 4:4'-Dibromo-1:1'-dinaphthyl-8:8'-dicarboxylate.



6 gm. methyl 5:8-dibromo-1-naphthoate.

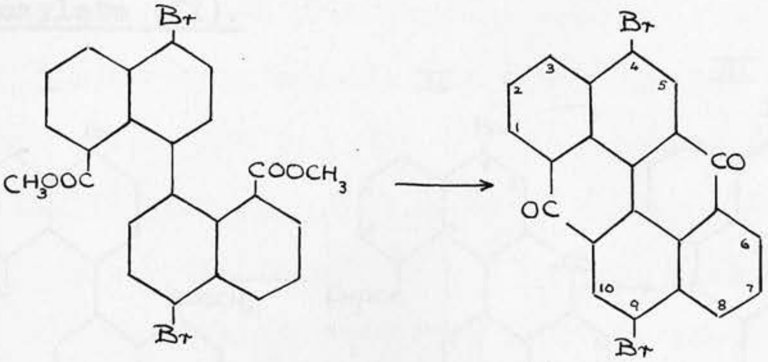
4 gm. copper bronze.

The ester was placed in a small flask fitted with stirring apparatus and heated in an oil-bath at 210 - 220°C. The copper bronze was added in small quantities and the resulting paste stirred at the above temperature for two hours longer. After cooling, the solid was broken up and extracted repeatedly with acetone. The extract was evaporated down till crystallisation set in and, after cooling, the colourless plates formed were filtered off and dried.

Yield: 2·5 gm. (55%). M.p. 205°C.

Corbellini and Barbaro (G. chim. ind. appl., 1933, 15, 335) quote the m.p. of this ester as 204·5 - 205°C.

4:9-Dibrom-anthanthrone.



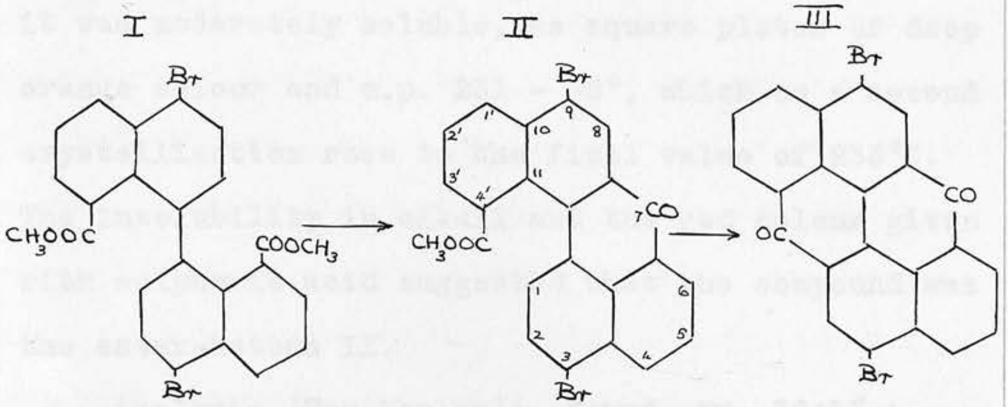
Dimethyl 4:4'-dibromo-1:1'-dinaphthyl-8:8'-dicarboxylate, 2·5 gm., was placed in 40 c.c. of concentrated sulphuric acid and heated at 100° on a boiling water-bath for an hour. The orange solution rapidly became dark red in colour, with a green fluorescence, and changed slowly to a deep green. After cooling, the solution was poured into 400 c.c. of water and the red flocculent precipitate filtered off, washed with water and dried.

Yield: 2·3 gm. (quantitative), M.p. > 360°C.

The red powder may be obtained in the form of fine red needles by recrystallisation from nitrobenzene, with practically no loss of material. It dissolves readily in warm alkaline sodium hydrosulphite solution to give a deep violet-coloured vat. Cotton immersed in the vat, washed and dried, is dyed a fast shade of orange or red.

The same compound has been prepared by Corbellini and Barbaro (loc. cit.) by the action of sulphuric acid in the cold on the corresponding dicarboxylic acid (see p. 12).

Methyl 3:9-Dibromo-10:11-benzobenzanthrone-4'-carboxylate (II).

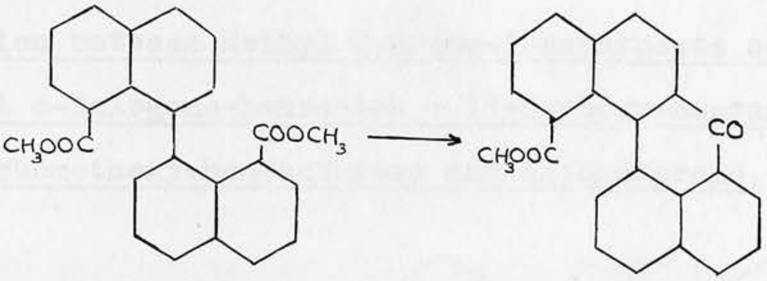


During the ring-closure of the dibromo-dinaphthyl-dicarboxylic ester (I) to dibromanthanthrone (III) by heating in sulphuric acid solution, it was observed that the intermediate red colouration was relatively persistent. This suggested that it might be possible to isolate the intermediate compound in which the ring-closure was only complete on one half of the molecule. This was accomplished as described below.

Dimethyl 4:4'-dibromo-1:1'-dinaphthyl-8:8'-dicarboxylate, 1·5 gm., was warmed with 25 c.c. of concentrated sulphuric acid at 50°C. for ten minutes. The red solution was poured into 200 c.c. of water and the orange precipitate filtered off. The solid was warmed with dilute alkali to remove any acidic component, but the filtrate was not coloured and deposited no solid on acidification. The residue was dried and extracted with 30 c.c. of hot acetone to remove any unchanged dimethyl ester. The orange residue (0·75 gm.) was recrystallised from glacial acetic acid, in which it was moderately soluble, as square plates of deep orange colour and m.p. 231 - 32°, which on a second crystallisation rose to the final value of 233°C. The insolubility in alkali and the red colour given with sulphuric acid suggested that the compound was the ester-ketone II.

Analysis (Ter Meulen): found, Br, 32·3% ;
calculated for $C_{23}H_{12}O_3Br_2$, 32·2%.

Methyl 10:11-Benzobenzanthrone-4'-carboxylate.



In view of the above result, it seemed of interest to examine the case of the unsubstituted dinaphthyl-dicarboxylic ester. A qualitative test showed that anthanthrone formation took place more rapidly than in the case of the dibromo-ester, the colour of the sulphuric acid solution becoming pure green in less than an hour at 50°C., while nearly twelve hours was required for the change to occur with the substituted ester.

The following procedure was adopted:

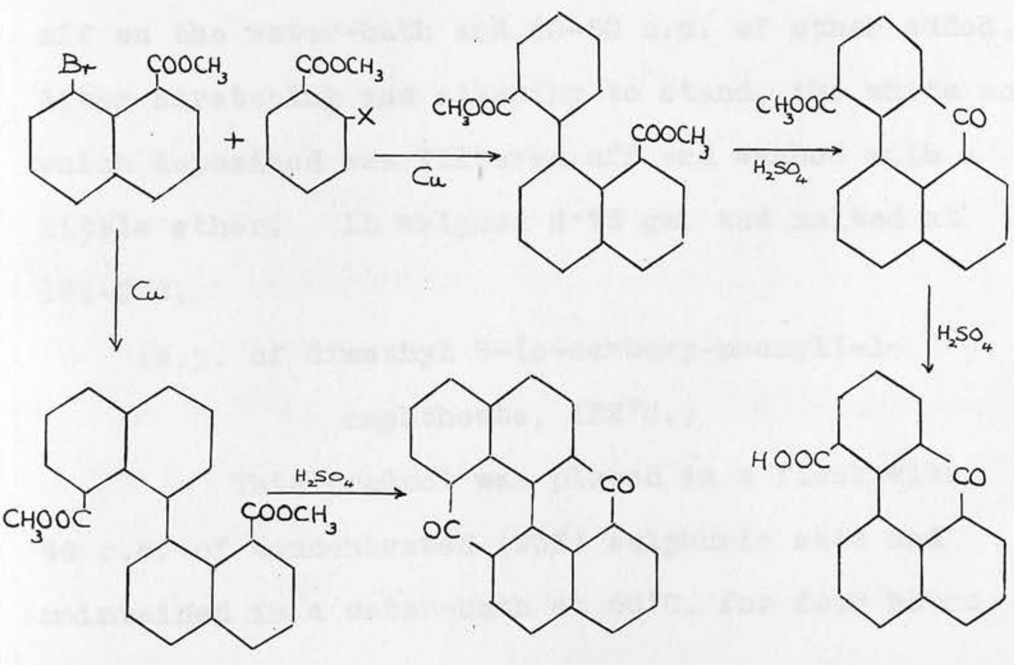
1 gm. of dimethyl 1:1'dinaphthyl-8:8'-dicarboxylate (m.p. 142°C.) was placed in 15 c.c. of concentrated sulphuric acid at 50° for three minutes. The reddish-brown solution was poured into 100 c.c. of water and the yellow product filtered off. It was completely insoluble in alkali and after two recrystallisations from alcohol, there was obtained 0·4 gm. of stout yellow needles of m.p. 154°C.

Analysis: found, C. 81·4% ; H, 4·16%.

Calculated for $C_{23}H_{14}O_3$, C, 81·7% ;

H, 4·16%.

Reaction between Methyl 8-Bromo-1-naphthoate and Methyl o-Halogeno-benzoates : 11-Carboxy-benzanthrone, 11-Carbomethoxy-benzanthrone and Anthanthrone.



The first experiment describes in detail the method adopted for carrying out the Ullmann reaction and working up the products.

1) 4 gm. methyl 8-bromo-1-naphthoate.

8 gm. methyl o-iodo-benzoate (2 molecular proportions).

4 gm. copper bronze A (4 molecular proportions).

The esters were melted together in a small stoppered flask fitted with an efficient stirrer and heated in an oil-bath at 180°C. Copper was added in small portions through an inlet-tube over about half-an-hour and the resulting paste stirred at 180° for a further half-hour. The temperature was then raised to 215 - 220° for four hours. After cooling, the mixture was extracted by boiling with four successive 50 c.c. portions of acetone under reflux and filtering from copper and cuprous halide. Acetone was evaporated off on the water-bath and 40-50 c.c. of ether added. After scratching and allowing to stand, the white solid which deposited was filtered off and washed with a little ether. It weighed 2·75 gm. and melted at 131-2°C.

(M.p. of dimethyl 8-(o-carboxy-phenyl)-1-naphthoate, 132°C.)

This product was placed in a flask with 40 c.c. of concentrated (93%) sulphuric acid and maintained in a water-bath at 50°C. for four hours.

After cooling, the blood-red solution was poured into 400 c.c. of water and the yellow solid filtered off. The solid was then warmed with dilute sodium hydroxide and the undissolved yellow solid (11-carbomethoxy-benzanthrone) filtered off and dried. Weight, 1·63 gm. M.p., 158-9°. Recrystallised from alcohol, it melted at 160°.

The orange alkaline filtrate, which had a strong green fluorescence, was acidified with dilute sulphuric acid and the yellow precipitate of 11-carboxy-benzanthrone was filtered off and dried. Weight, 0·8 gm. M.p., 270 - 72°. These weights of benzanthrone derivatives correspond to 2·75 gm. of the phenyl-naphthyl dicarboxylic ester, which was therefore obtained directly in a yield of 57%. (All %age yields in these reactions are based on the original weight of naphthoate used, the benzoate being generally present in excess).

The ethereal filtrate from the ester was freed from solvent and treated with 100 c.c. of 93% sulphuric acid at 50° for four hours, after which the alkali-insoluble fraction (anthanthrone + 11-carbomethoxy-benzanthrone) was separated. It weighed 0·91 gm. and on extraction with alcohol yielded a residue of 0·25 gm. of anthanthrone (an orange powder giving a green solution in sulphuric acid and a violet hydrosulphite vat. The alcoholic filtrate on evaporation gave 0·66 gm. of 11-carbomethoxy-benzanthrone (m.p. 157 - 9°). Purification of the acidic residual products containing iodo-benzoic and diphenic acids in addition to the benzanthrone-carboxy acid is impracticable in the case of the easily soluble unsubstituted compound.

The yield of anthanthrone corresponds to 11% of theory and the benzanthrone derivatives isolated correspond to a 75% yield of the unsymmetrical phenyl-naphthyl compound. The 14% of bromo-naphthoate unaccounted for is present (in part, at any rate) as 11-carboxy-benzanthrone in the acidic residue.

2) 4 gm. methyl 8-bromo-1-naphthoate.
4 gm. methyl o-iodo-benzoate.
4 gm. copper bronze A.

This reaction, using equimolecular proportions of the esters, was carried out under the same conditions as described above. The esters obtained from the ether solution weighed 2·75 gm. and on sulphuric acid treatment gave 0·47 gm. of anthanthrone, 0·52 gm. of 11-carboxy-benzanthrone and 1·31 gm. of 11-carbomethoxy-benzanthrone. The residue yielded 0·25 gm. of anthanthrone and 0·3 gm. of 11-carbomethoxy-benzanthrone. The yield of dinaphthyl derivative from the Ullmann reaction was therefore 31% and that of the unsymmetrical phenyl-naphthyl compound was 54%.

3) The above proportions were again employed but the temperature was maintained at 200 - 206° instead of 180°C. 2·9 gm. of mixed esters were obtained which on treatment with sulphuric acid at 100° gave 0·5 gm. (22%) of anthanthrone and 1·95 gm. (47%) of 11-carboxy-benzanthrone. The residue was not worked up, but the yield had evidently not altered greatly from the previous case in which the yields of dinaphthyl and phenyl-naphthyl compounds from the esters were 20% and 43% respectively.

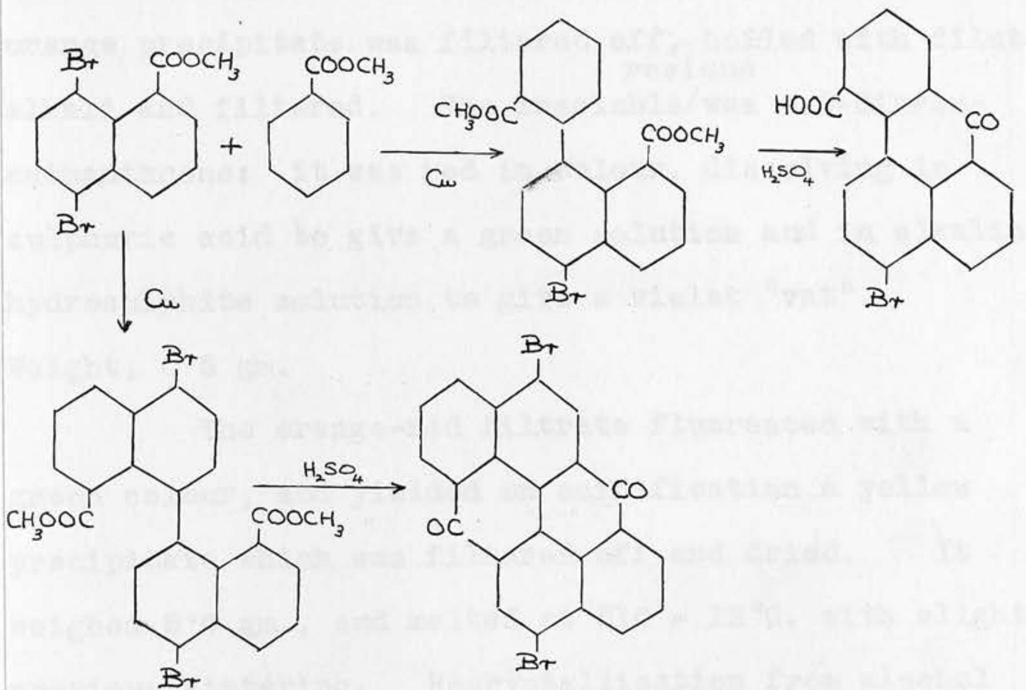
4) 4 gm. methyl 8-bromo-1-naphthoate.
7·1 gm. methyl o-bromo-benzoate.
4 gm. copper bronze A.

This reaction, using two molecular proportions of the o-bromobenzoic ester, was carried out at 180°C. The yield of anthanthrone was 44%, whilst 2 gm. (41%) of pure phenyl-naphthyl ester was obtained. The results are therefore less satisfactory than those obtained using methyl o-iodo-benzoate.

5) 4 gm methyl 8-bromo-1-naphthoate.
5·3 gm. methyl o-chloro-benzoate.
4 gm. copper bronze A.

Employing two molecular proportions of the o-chloro-benzoic ester under the same conditions, the yield of the symmetrical dinaphthyl derivative rose to 70%. No unsymmetrical product was isolated.

Reaction between Methyl 5:8-Dibromo-1-naphthoate and Methyl o-Iodo-benzoate : 3-Bromo-11-carboxy-benzanthrone and 4:9-Dibrom-anthanthrone.



10 gm. methyl 5:8-dibromo-1-naphthoate.

16 gm. methyl o-iodo-benzoate (2 molecular proportions).

10 gm. copper powder (Gattermann).

The esters were melted and stirred at 180° (oil-bath temperature) and the copper added in portions over half-an-hour. The paste was stirred at 180° for a further half-hour and then at 215 - 220° for four hours longer. After extraction with acetone and removal of the solvent, the addition of ether precipitated a white solid, which was filtered off, washed with ether and dried. It weighed 6·4 gm. and consisted of mixed phenyl-naphthyl and dinaphthyl dicarboxylic esters.

The mixed product was heated with 100 c.c. of concentrated sulphuric acid on a boiling water-bath for one hour, cooled and poured into water. The orange precipitate was filtered off, boiled with dilute alkali and filtered. The insoluble residue was 4:9-dibromanthanthrone: it was red in colour, dissolving in sulphuric acid to give a green solution and in alkaline hydrosulphite solution to give a violet "vat". Weight, 0·5 gm.

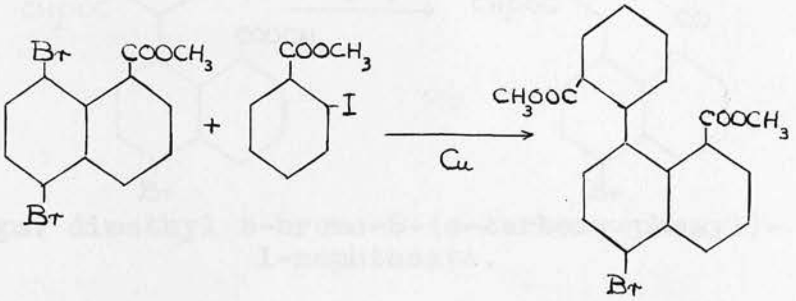
The orange-red filtrate fluoresced with a green colour, and yielded on acidification a yellow precipitate which was filtered off and dried. It weighed 5·0 gm., and melted at 310 - 12°C. with slight previous sintering. Recrystallisation from alcohol (250 c.c. per gm.) gave fine yellow needles of m.p. 314 - 15°, raised to 315 - 16° by crystallisation from nitrobenzene (10 c.c. per gm.).

Analysis (Carius): found, Br. 22·3%; calculated for 3-bromo-11-carboxy-benzanthrone, $C_{18}H_9O_3Br$, 22·6%.

The ethereal filtrate from the esters was evaporated to dryness and similarly treated with 150 c.c. of concentrated sulphuric acid and worked up as usual. The alkali-insoluble residue (dibrom-anthanthrone) weighed 1·65 gm. Only a small amount of 3-bromo-11-carboxy-benzanthrone (m.p. 312 - 15°) was obtained by recrystallising the acidic compounds from alcohol.

The total yield of dibrom-anthanthrone (2·15 gm.) corresponds to 32% of theory; the yield of 3-bromo-11-carboxy-benzanthrone (5·0 gm.) corresponds to 49%.

Dimethyl 5-Bromo-8-(o-carboxy-phenyl)-1-naphthoate.



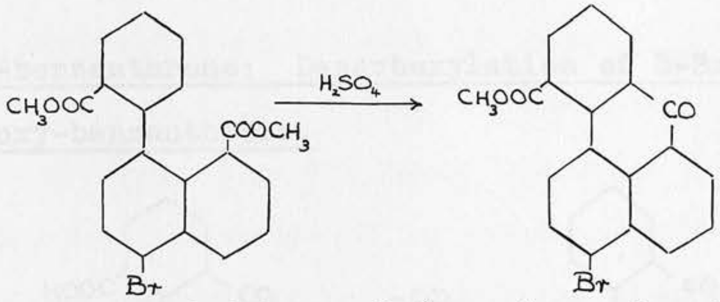
5 gm. methyl 5:8-dibromo-1-naphthoate.
8 gm. methyl o-iodo-benzoate.
4 gm. copper bronze A.

The Ullmann coupling was carried out as before and the acetone extract treated with ether. The white crystalline precipitate was filtered off and washed with a little cold ether. It weighed 2·55 gm. and melted at 152 - 4°C. Recrystallisation from ligroin yielded 2·4 gm. of colourless needles of m.p. 155°C.

Analysis (Ter Meulen); found, Br 19·9% ; calculated for $C_{20}H_{15}O_4Br$, 20·0%.

The yield amounts to 44% of theory and hence the use of a different sample of copper bronze has not greatly altered the yield of unsymmetrical phenyl-naphthyl compound from that quoted in the first case (49%).

3-Bromo-11-carbomethoxy-benzanthrone.



1 gm. dimethyl 5-bromo-8-(o-carboxy-phenyl)-1-naphthoate.

15 c.c. concentrated (93%) sulphuric acid.

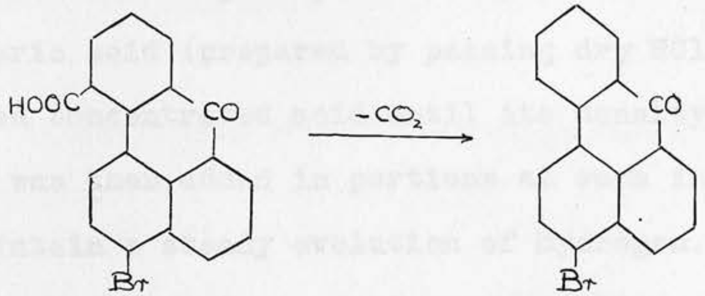
The above were placed in a flask and heated on a water-bath at 50°C. for three hours. The blood-red solution was cooled and poured into 150 c.c. of water. A yellow-brown precipitate was formed which was filtered off, boiled with dilute alkali and filtered from insoluble material. The latter was a light yellow powder, weighing 0·68 gm. and melting at 191-2°.

Recrystallised from alcohol, the methyl 3-bromo-benzanthrone-11-carboxylate formed pale yellow needles of m.p. 193 - 4°, raised to 194° on further crystallisation. The yield is 74%.

Analysis (Ter Meulen): found, Br 21·6%; calculated for $C_{19}H_{11}O_3Br$, 21·8%

The alkaline filtrate on acidification yielded 0·2 gm. (24%) of 3-bromo-11-carboxy-benzanthrone. The hydrolysis of the methyl ester can be completed by prolonging the treatment at 50° or raising the temperature to 100° for one hour.

3-Bromo-benzanthrone: Decarboxylation of 3-Bromo-11-carboxy-benzanthrone.



3-Bromo-11-carboxy-benzanthrone, 1 gm., was dissolved in 5 c.c. of boiling quinoline and 0·3 gm. of copper bronze added in small portions. Effervescence occurred and boiling was continued for 15 minutes. After cooling somewhat, the solution was filtered and the copper residue washed with ether. The filtrate was poured into dilute hydrochloric acid to dissolve the quinoline and the brown solid filtered off, washed with warm sodium carbonate solution and water, and dried. Weight, 0·6 gm. M.p., 166 - 7°C.

After several crystallisations from chlorobenzene and alcohol, it was obtained in the form of yellow plates of m.p. 176 - 7°C., which was not depressed by admixture with the product obtained by the direct bromination of benzanthrone.

Anthranol.

(Liebermann and Gimbel, Ber., 1887, 20, 1854).

Anthraquinone, 20 gms., was dissolved in 800 gm. of glacial acetic acid by warming. Tin, 50 gm., and a crystal of copper sulphate were added and the solution was boiled gently under reflux. Fuming hydrochloric acid (prepared by passing dry HCl gas into the cooled concentrated acid until its density was 1·5), 90 c,c., was then added in portions at such intervals as to maintain a steady evolution of hydrogen. At the end of two hours, a test portion, on cooling, deposited no anthraquinone. The liquid was then poured into four litres of cold water, 200 c.c. of concentrated hydrochloric acid added and the white solid filtered off and dried.

Yield: 18 gm. (90%). M.p., 165 - 170°C.

Benzanthrone.

(Bally and Scholl, Ber., 1911, 44, 1656).

18 gm. anthanthrol.
270 gm. 82% sulphuric acid.
18 gm. glycerol.

The above were mixed and heated cautiously to 120° in an oil-bath for four hours. After cooling, the liquid was poured into three litres of cold water and the greenish solid filtered off. It was then boiled with 200 c.c. of 1% sodium hydroxide solution, filtered, washed with water and dried. The crude benzanthrone was recrystallised from alcohol with the addition of animal charcoal.

Yield: 12 gm. (56%). M.p., 168 - 169°C.

A portion was sublimed and again crystallised from alcohol, forming pale yellow needles of m.p. 171 - 2°C.

(An improved preparation of benzanthrone is given in Organic Syntheses XIV, p. 4).

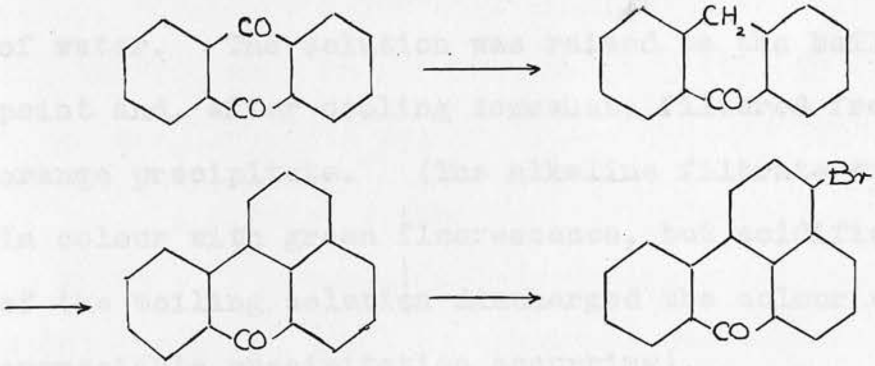
3-Bromo-benzanthrone.

(B.A.S.F., D.P. 193959 ; C., 1908, I, 1112).

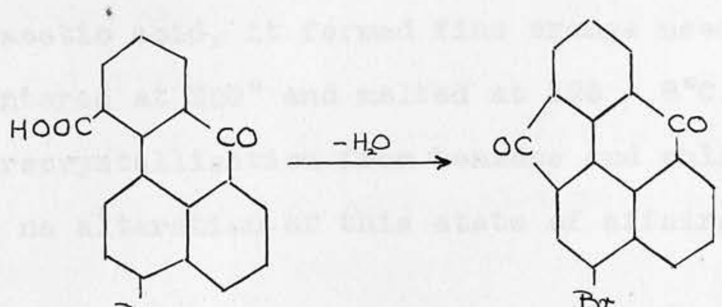
2·5 gm. benzanthrone.
1·75 gm. bromine.

The above were placed in 50 c.c. of glacial acetic acid in a flask with ground-in reflux condenser and heated on the boiling water-bath for an hour. After cooling, the crystalline material was filtered off. It weighed 2·5 gm. and melted about 150°C. After recrystallisation from alcohol and chlorobenzene (twice) there was obtained 1 gm. of pale yellow plates, m.p. 172 - 3° (mixed m.p. with benzanthrone, 135 - 40°).

Sublimation, followed by a further crystallisation from alcohol, raised the melting-point to 176 - 7°. Lüttringhaus and Neresheimer (Ann., 1929, 473, 259) by repeated crystallisation of the commercial product from chlorobenzene, raised the m.p. to 178°C.



3-Bromo-1 : 11-keto-benzanthrone.



1 gm. 3-bromo-11-carboxy-
benzanthrone.

30 gm. phthalic anhydride.

1 gm. phosphorus pentoxide.

The carboxy-acid was placed in a small flask and the phthalic anhydride added. The stoppered flask was heated in an oil-bath at 200°C. and when complete solution had occurred, half of the phosphorus pentoxide was dusted in rapidly. The yellow solution became darker and after half-an-hour, the remainder of the pentoxide was added. The now dark-red solution was heated for one and a half hours further, cooled somewhat and the liquid poured out with stirring into a hot solution of 16 gm. of sodium hydroxide in 300 c.c. of water. The solution was raised to the boiling-point and, after cooling somewhat, filtered from a pale orange precipitate. (The alkaline filtrate was red in colour with green fluorescence, but acidification of the boiling solution discharged the colour without appreciable precipitation occurring).

<u>Alkali-insoluble fraction.</u> The insoluble residue weighed 0·8 gm. (84%) and melted at about 320°C. after sintering at 190 - 200°. Recrystallised from glacial acetic acid, it formed fine orange needles which sintered at 200° and melted at 326 - 8°C. Further recrystallisation from benzene and chlorobenzene effected no alteration of this state of affairs.

As some doubt as to the purity of this product was entertained, its further examination is detailed below. The substance is insoluble in hot strong alkalis and only partly soluble in a hot alkaline hydrosulphite vat, forming a yellow suspension in a greenish-brown liquid. It is readily soluble in concentrated sulphuric acid to give a purple-red solution from which it is recovered unchanged on pouring into water. It may be recrystallised from boiling glacial acetic acid, benzene, chlorobenzene or nitrobenzene, in which it is fairly soluble, or from a large volume of absolute alcohol. From all of these solvents, it forms fine orange-red needles, which shrink together at about 200°C., forming a solid mass which remains unaltered till 325°C., when it softens, melting finally at 326 - 8°C. On cooling, crystals appear in the melt at 326°C.

A bromine estimation (Ter Meulen; found, Br. 24·3% ; 3-bromo-1:11-keto-benzanthrone requires 23·9%) indicated that the substance was certainly a dehydration product of the carboxy-acid. Molecular weight estimations in benzene solution (Menzies-Wright method) gave the values 332, 335, 336 (Theory, 335) and thus eliminated the possibility that a dimolecular anhydride was present.

In an attempt to prepare a sample which did not sinter before melting, sublimation was resorted to. By sublimation under reduced pressure at 230 - 240°C., a yellow sublimate was obtained on a water-cooled tube. This possessed no crystalline form under the microscope, sintered at 180°, forming a solid orange mass which melted at 325 - 7°C. By continuing the sublimation at 300 - 310°, orange needles were formed to the lower ends of which were attached small red lumps of roughly cubical shape. The needles and lumps were separated under the lens; the former sintered and melted as before, the latter did not sinter, but melted at 326 - 8°, solidifying at 326° and remelting at 325 - 7°C. Finally, a crystalline sample which sintered at 200° was melted and allowed to solidify. The red mass when powdered was orange in colour; it did not sinter but melted sharply at 325 - 7°. Recrystallised from glacial acetic acid, it formed orange needles which sintered at 195° and melted at 326 - 8°C.

Analysis: found, C,64·2% ; H, 2·0%.

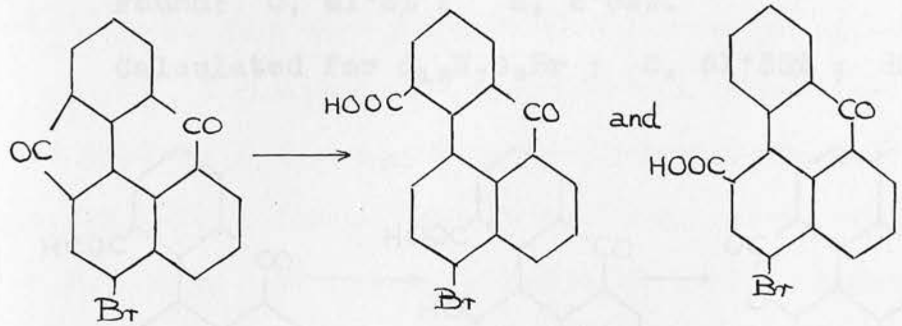
Calculated for $C_{18}H_7O_2Br$; H, 2·1%; C, 64·5%.

The above evidence indicates that sintering at about 200°C. is characteristic of 3-bromo-1:11-keto-benzanthrone in the crystalline or micro-crystalline form and is confirmed by the preparation of a compound showing exactly similar effects (alone or mixed with the above), obtained by brominating 1:11-keto-benzanthrone (J. L. Grieve, in these laboratories, unpublished).

Treatment of 3-bromo-1:11-keto-benzanthrone with alkali.

The cyclised product (0·5 gm.)was boiled under reflux with 25 c.c. of approximately 10% sodium hydroxide solution for 48 hours. The alkali-insoluble material was filtered off and dried. It weighed 0·2 gm. and consisted of unchanged diketone. The alkaline filtrate was deep-red in colour with intense green fluorescence and gave on acidification 0·3 gm. of yellow powder, m.p. 255 - 275°, sintering at 230°. This was dissolved in boiling alcohol and,on cooling, the solution deposited 0·17 gm of yellow powder, m.p. 275 - 85°, sintering at 260°. Addition of water to the filtrate gave 0·1 gm. of similar material, m.p. 250 - 57°, sintering at 235°.

No further separation was effected, but it appears probable that the acidic product of the hydrolysis of the diketone is a mixture of the 11-carboxy-acid and an isomer of lower melting point, 3-bromo-1-carboxy-benzanthrone.



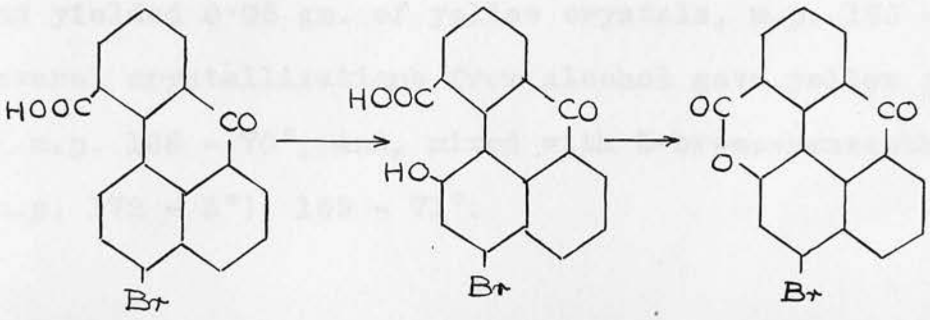
Lactone of 3-Bromo-1-hydroxy-11-carboxy-benzanthrone: Oxidation of 3-Bromo-11-carboxy-benzanthrone.

3-Bromo-11-carboxy-benzanthrone, 0·8 gm., was dissolved in 8 c.c. of concentrated sulphuric acid. The red solution was diluted with 60 c.c. of water, giving a yellow suspension of the acid in a finely divided state. Chromic acid, 3·2 gm., was then added and the mixture stirred at its boiling-point for 12 hours, cooled, diluted with water and filtered. The recovered pale-yellow solid weighed 0·5 gm. and melted at 315 - 20°. Crystallisation from chlorobenzene gave 0·42 gm. (53%) of pale-yellow needles, m.p. 321 - 3°C., unaltered by further crystallisation.

The substance is insoluble in cold alkali and dissolves slowly on heating to give a purple solution with red fluorescence. The original material is recovered on acidification. By analogy with the compound obtained by Rule and Bigelow, this compound is assigned the structure of the lactone of the 1-hydroxy-acid, in agreement with the analysis figures given below.

Found: C, 61·3% ; H, 2·03%.

Calculated for $C_{18}H_7O_3Br$: C, 61·55% ; H, 2·0%.



Treatment of 3-Bromo-11-carboxy-benzanthrone with Sulphuric Acid.

(1) 3-Bromo-11-carboxy-benzanthrone, 0·8 gm., was heated with 12 c.c. of concentrated (93%) sulphuric acid at 140 - 145°C. for one hour. The red solution was poured into water, yielding a yellow precipitate, which was filtered off, boiled for a short time with dilute sodium hydroxide and filtered. The yellow insoluble residue weighed 0·21 gm. and melted over a wide range. Recrystallisation from alcohol gave 0·11 gm. of yellow powder, m.p. 180 - 240° (see below). The purple alkaline solution gave on acidification, 0·56 gm. of yellow powder, m.p. 270 - 310°.

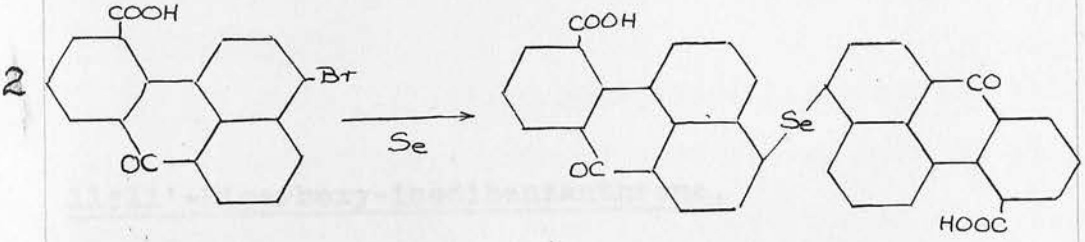
(2) 3-Bromo-11-carboxy-benzanthrone, 1 gm., was heated with 20 c.c. of 93% sulphuric acid at 160° for an hour. The alkali-insoluble fraction weighed 0·25 gm. and on crystallisation from alcohol gave 0·15 gm. of yellow material, m.p. 180 - 240°. This was combined with the similar fraction from (1) and repeatedly crystallised from alcohol and chlorobenzene. Complete purification, however, could not be effected and the final m.p. was over a range at 305 - 10°.

The alcoholic filtrate was evaporated down and yielded 0·06 gm. of yellow crystals, m.p. 160 - 163°. Several crystallisations from alcohol gave yellow plates of m.p. 168 - 70°, and, mixed with 3-bromo-benzanthrone (m.p. 172 - 3°), 169 - 71°.

The purple alkaline filtrate gave on acidification 0·7 gm. of yellow powder. This was boiled out with alcohol, in which it was sparingly soluble, and recrystallised from chlorobenzene as yellow needles, m.p. 319 - 321° and, in admixture with the lactone of 3-bromo-1-hydroxy-11-carboxy-benzanthrone, 320 - 322°C.

The occurrence of decarboxylation and oxidation in this reaction is thus established: it is probable that the second neutral product is 3-bromo-1:11-keto-benzanthrone.

<u>11:11'-Dicarboxy-3:3'-dibenzanthronyl selenide.</u>
(cf. B.P. 367,462; C., 1932, II, 2544).



2 gm. 3-bromo-11-carboxy-benzanthrone.

2 gm. selenium, finely powdered.

0·5 gm. fused sodium acetate.

100 c.c. tetralin.

The above were boiled under reflux for two hours. The carboxy-acid dissolved to form a clear orange solution; after an hour, an orange deposit began to form. After cooling, the solid was filtered off and washed free from tetralin with alcohol. The solid was then dissolved in hot dilute sodium hydroxide, filtered hot from excess selenium and the purple solution (which deposited the sparingly soluble sodium salt on cooling) acidified with hydrochloric acid. The orange-yellow precipitate of dicarboxy-dibenzanthronyl-selenide was filtered off, washed with water and dried.

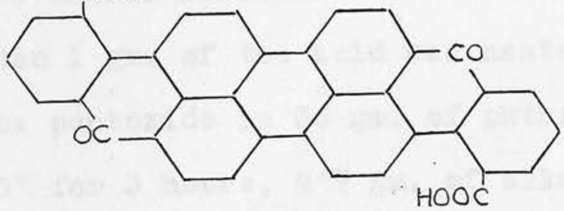
Yield: 1·75 gm. (98%). M.p. > 360°.

Selenium Analysis. The compound was heated with sodium peroxide in a steel bomb, the sodium selenate formed reduced with sulphur dioxide in hydrochloric acid solution and the precipitated selenium filtered off and weighed.

0·2985 gm. of compound gave 0·0361 gm. of selenium.

Found: Se, 12·4% ; calculated for $C_{40}H_{18}O_6Se$, 12·8%.

11:11'-Dicarboxy-isodibenzanthrone.



1·4 gm. 11:11'-dicarboxy-3:3'-dibenzanthronyl selenide.

6 gm. potassium hydroxide

12 c.c. absolute alcohol.

The above were stirred together in a nickel tube and gradually heated to 150° in an oil-bath. The mixture frothed and became dark blue in colour. Heating and stirring were continued for half-an-hour and the melt was boiled out with water. The dark blue alkaline solution was filtered and acidified. The dark blue flocculent precipitate of 11:11'-dicarboxy-isodibenzanthrone was filtered off, washed and dried.

Yield: 1·18 gm. (97%). M.p. > 360°C.
The compound is soluble in alkali and concentrated sulphuric acid with dark blue colour but practically insoluble in all organic solvents.

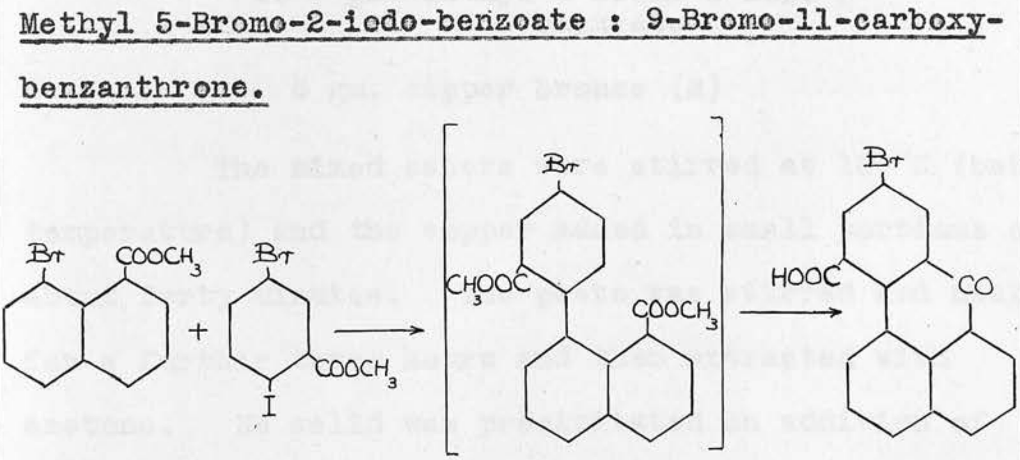
Attempted Preparation of 1:11:1':11'-Diketo-iso-dibenzanthrone.

When 11:11'-dicarboxy-isodibenzanthrone was heated with sulphuric acid at 140° for an hour or with phosphorus pentoxide in phthalic anhydride at 200° for two hours, no alkali-insoluble residue was detected.

When 1 gm. of the acid was heated with 1 gm. of phosphorus pentoxide in 30 gm. of phthalic anhydride at 220 - 230° for 3 hours, 0·7 gm. of alkali-insoluble material was obtained. (The alkaline filtrate was deep purplish-red in colour). The insoluble substance was soluble in concentrated sulphuric acid with a deep green colour (iso-dibenzanthrone dissolves in sulphuric acid with bright green colour), and soluble to some extent with a violet colour in hot alkaline hydrosulphite solution. Cotton immersed in the vat and allowed to oxidise in air was dyed purple, resembling that given by isodibenzanthrone, though not so vivid. The non-vattable residue was black in colour, dissolving in concentrated sulphuric acid with a dirty green colour, but even after reprecipitation with water, it was not affected by hydrosulphite.

It may be noted that 1:11-keto-benzanthrones give an insoluble residue on treatment with alkaline hydrosulphite, but in the absence of any convenient method of purifying such high-molecular products as dibenzanthrones and consequent difficulty of proving homogeneity, it is not easy to determine whether the expected ring-closure has taken place.

Reaction between Methyl 8-Bromo-1-naphthoate and Methyl 5-Bromo-2-iodo-benzoate : 9-Bromo-11-carboxy-benzanthrone.



In some early attempts to carry through this reaction, in which the coupling was carried out at 180° and the reaction completed at 220°, difficulty was experienced in purifying the products. Ullmann (Ann., 1904, 332, 56) records difficulty in obtaining homogeneous products from reactions with bromo-iodo-benzenes, and it was found in the present work that no pure diphenic ester derivative could be obtained by heating methyl 5-bromo-2-iodo-benzoate with copper bronze at 190 - 200°. The bromine atom in position 5 evidently possesses considerable reactivity; but by carefully maintaining the temperature at 180°, a good yield of the unsymmetrical product was obtained in the reaction with 8-bromo-naphthoic ester. Homogeneous products could also be isolated by working at 220° throughout, but the yield of unsymmetrical product was considerably smaller .

4 gm. methyl 8-bromo-1-naphthoate
10·3 gm. methyl 5-bromo-2-iodo-benzoate
6 gm. copper bronze (B)

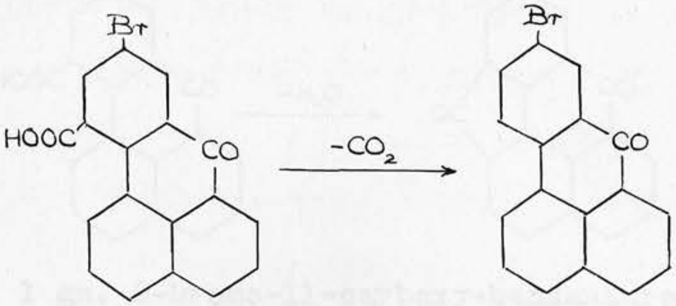
The mixed esters were stirred at 180°C. (bath temperature) and the copper added in small portions over about forty minutes. The paste was stirred and heated for a further three hours and then extracted with acetone. No solid was precipitated on addition of ether to the extract and, after removal of solvent, the syrupy esters were treated with 100 c.c. of

concentrated sulphuric acid at 100° for an hour and separated with alkali in the usual way. The insoluble residue of anthanthrone weighed 0·65 gm. (28%) and gave the correct colour reactions. The alkaline filtrate was red in colour with strong green fluorescence and gave a yellow precipitate on acidification. This was filtered off, dried and recrystallised from nitrobenzene (20 c.c.), yielding 3·23 gm. of yellow needles, m.p. 312 - 314°C. Recrystallisation from alcohol (100 c.c. per gm.) or nitrobenzene raised the m.p. to 315 - 316°C., unaltered on further crystallisation. The yield is 60% of theory.
Analysis. - Found: Br, 22·7% ; calculated for $C_{18}H_8O_3Br$, 22·6%.

A repetition, using the same quantities but carried out at 220° for four hours, gave 1·22 gm. (53%) of anthanthrone and 1·45 gm. (27%) of 9-bromo-11-carboxy-benzanthrone, m.p. 315 - 16°C.

An earlier experiment, in which 7·7 gm. of methyl 8-bromo-1-naphthoate, 15 gm. (1½ molecular proportions, instead of two) of methyl 5-bromo-2-iodobenzoate, and 10 gm. of copper powder (Gattermann) were used, gave at 215 - 220°, 71% of anthanthrone and 22% of 9-bromo-11-carboxy-benzanthrone, m.p. 312 - 15°.

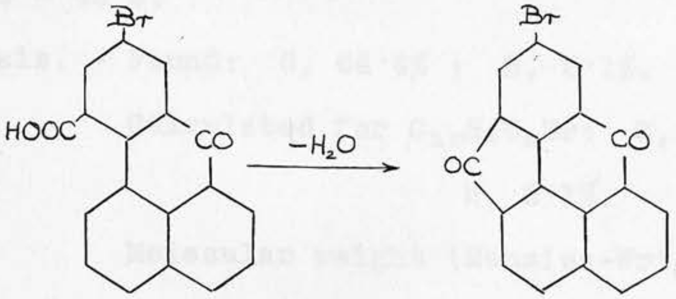
9-Bromo-benzanthrone : Decarboxylation of 9-Bromo-11-carboxy-benzanthrone.



9-Bromo-11-carboxy-benzanthrone, 0·5 gm., was dissolved in 3 c.c. of boiling quinoline and 0·2 gm. of copper bronze added in portions. After cooling, the mixture was poured into dilute hydrochloric acid and the brownish solid (mixed with copper bronze) filtered off and washed with warm alkali and water. After drying, the compound was dissolved in boiling chlorobenzene, filtered from the copper and allowed to crystallise. Yield: 0·25 gm. M.p. 180 - 182°C.

Recrystallisation from alcohol and chlorobenzene gave yellow plates of m.p. 182 - 183°C. The melting-point of 9-bromo-benzanthrone, obtained by the reduction of 4:9-dibromo-benzanthrone in alkaline medium, is given in G.P. 450,445 (I.G.) as 183°C.

9-Bromo-1:11-keto-benzanthrone.



1 gm. 9-bromo-11-carboxy-benzanthrone.

1·5 gm. phosphorus pentoxide.

30 gm. phthalic anhydride.

The acid and anhydride were heated together in an oil-bath at 200°C. To the yellow solution 0·75 gm. of phosphorus pentoxide was added. The solution darkened and half-an-hour later the remainder of the phosphorus pentoxide was added. The solution was heated for one and a half hours more, cooled somewhat and poured into a hot solution of 16 gm. of sodium hydroxide in 300 c.c. of water. The mixture was raised to the boiling-point and the yellow precipitate filtered off and dried. Weight: 0·8 gm. (84%). M.p. 230 - 235°C. with previous sintering.

The alkaline filtrate was somewhat red in colour, with green fluorescence, but acidification of the hot solution discharged the colour without any appreciable precipitation occurring. Recrystallisation of the alkali-insoluble compound from benzene (80 c.c.) yielded 0·7 gm. of orange needles, m.p. 237 - 9°, sintering at 230°C. Crystallisation from glacial acetic acid raised the melting-point to the final value of 239 - 40°C.

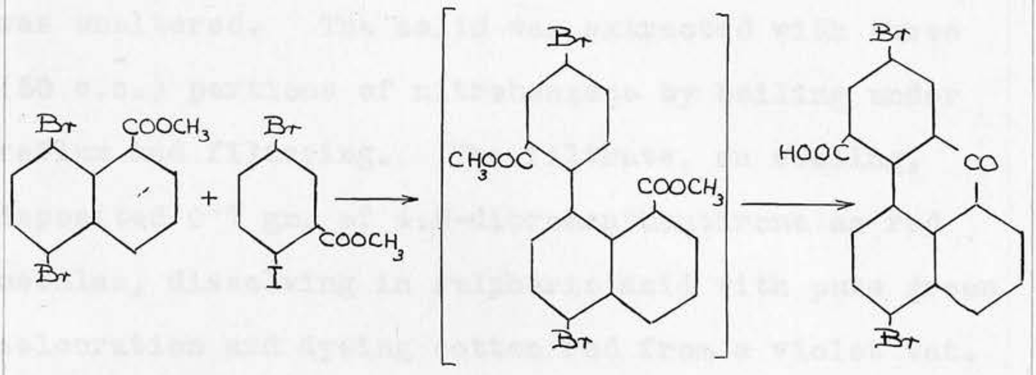
Analysis. - Found: C, 64·4% ; H, 2·1%.

Calculated for $C_{18}H_7O_2Br$: C, 64·5% ;
H, 2·1%.

Molecular weight (Menzies-Wright method):
found: 329, 331, 336; theory, 335.

An alternative method of cyclisation was tried, but proved more troublesome. 9-Bromo-11-carboxybenzanthrone, 1 gm., was dissolved in 10 c.c. of boiling nitrobenzene, 1·5 gm. of phosphorus pentoxide added in two portions and the mixture boiled for two hours. After cooling, the deposited solid was filtered off, washed with alcohol and boiled with alkali. The insoluble diketone was filtered off, dried and recrystallised from chlorobenzene. Yield, 0·6 gm. (63%). M.p. 238 - 9°C. The alkaline filtrate, which was purple in colour, gave on acidification a yellow precipitate (0·2 gm.), m.p. 305 - 310°C.

Reaction between Methyl 5:8-Dibromo-1-naphthoate and Methyl 5-bromo-2-iodo-benzoate : 3:9-Dibromo-11-carboxy-benzanthrone.



5 gm. methyl 5:8-dibromo-1-naphthoate.
10 gm. methyl 5-bromo-2-iodo-benzoate.
10 gm. copper bronze (B).

The mixture of esters was stirred at 180° (bath temperature) and the copper bronze added slowly over a period of 45 minutes. Heating was continued for three hours and the cooled mixture then extracted with acetone. The syrupy esters failed to solidify on addition of ether and, after removal of solvent, were treated with 150 c.c. of concentrated sulphuric acid at 100° for an hour. The purple-red solution gave an orange precipitate on pouring into water, which was filtered off and extracted with alkali. The red insoluble residue (1·71 gm.) gave a purple colouration with sulphuric acid and was again treated with sulphuric acid (30 c.c.) and separated with alkali.

Alkali-insoluble fraction. The residue (1·27 gm.) was red in colour, but gave a purple solution in sulphuric acid, which became greenish-violet on warming. Further treatment with sulphuric acid produced no appreciable change and the colour reaction was unaltered. The solid was extracted with three (50 c.c.) portions of nitrobenzene by boiling under reflux and filtering. The filtrate, on cooling, deposited 0·7 gm. of 4:9-dibromanthanthrone as red needles, dissolving in sulphuric acid with pure green colouration and dyeing cotton red from a violet vat. The residue (0·45 gm.) was brown in colour, dissolving with purplish-green colour in sulphuric acid. From this, 0·35 gm. of dibromanthanthrone was obtained by further treatment, the residue (0.06 gm.) consisting of a brown powder, acting as a brown vat dye. Since the bromine atom in methyl 5-bromo-2-iodo-benzoate is reactive, it is possible that further coupling could occur with the 5:8-dibromo-naphthoate, with production of the compound (I), which on treatment with sulphuric acid would yield an alkali-insoluble compound (II) which would also function as a vat dye.

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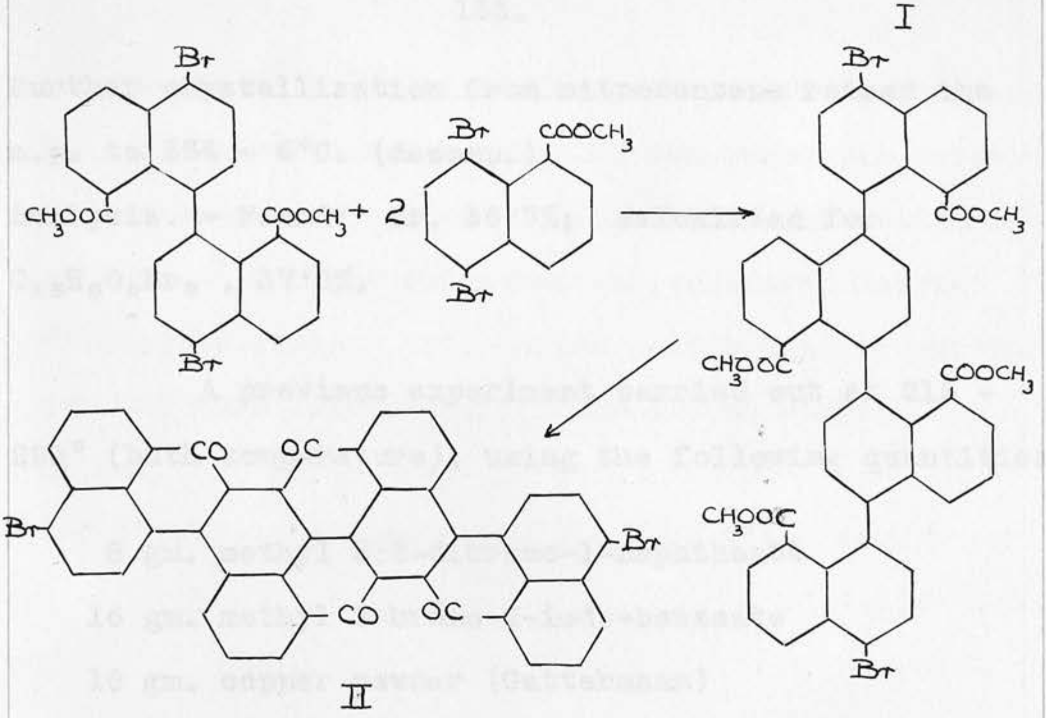


This may be the impurity present in the dibrom-anthanthrone which obscures the green colour-reaction with sulphuric acid. As only a small quantity is present, and the effect on the calculation of the yield of anthanthrone small, the yield (1·27 gm.) of product derived solely from the naphthoate may be accepted as 38%.

3:9-Dibromo-11-carboxy-benzanthrone.

The red alkaline filtrates, with green fluorescence, which deposited the sparingly soluble sodium salt of 3:9-dibromo-11-carboxy-benzanthrone on cooling, were acidified and the yellow precipitate filtered off, washed, dried and recrystallised from nitrobenzene (100 c.c.). The yellow needles were filtered off, washed with alcohol and dried. Yield, 3·06 gm. (49%). M.p. 352 - 4°C. (decomp.).

Further crystallisation from nitrobenzene raised the m.p. to 354 - 6°C. (decomp.).

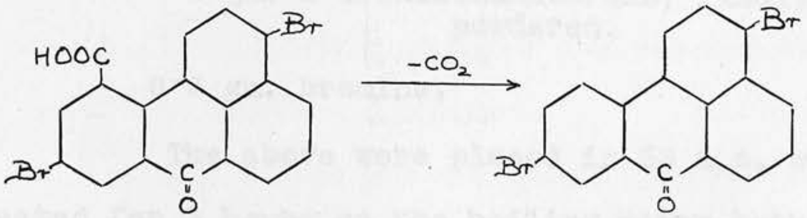
Analysis. - Found: Br, 36·7%; calculated for $C_{18}H_8O_3Br_2$, 37·0%.

A previous experiment carried out at 215 - 220° (bath temperature), using the following quantities:

8 gm. methyl 5:8-dibromo-1-naphthoate
16 gm. methyl 5-bromo-2-iodo-benzoate
10 gm. copper powder (Gattermann)

yielded 23 gm. (41%) of alkali-insoluble material and 3·65 gm. (36%) of 3:9-dibromo-11-carboxy-benzanthrone.

3:9-Dibromo-benzanthrone; Decarboxylation of 3:9-Dibromo-11-carboxy-benzanthrone.



3:9-Dibromo-11-carboxy-benzanthrone, 1 gm., was dissolved in 10 c.c. of quinoline maintained at its boiling-point in an oil-bath. Copper bronze, 0·3 gm., was added in small portions, when effervescence occurred and the solution darkened. After 15 minutes, the solution was cooled and poured into dilute hydrochloric acid. The resulting brown solid was filtered off, washed with water, warm sodium carbonate solution and water again. After drying, it was dissolved in 30 c.c. of boiling chlorobenzene, filtered hot and allowed to cool. Long golden-yellow needles crystallised out and were filtered off, washed with alcohol and dried.

Yield: 0·45 gm. (50%). M.p. 255 - 6°C.

3:9-Dibromo-benzanthrone.

(D.P. 193959, C. 1908, I, 1112).

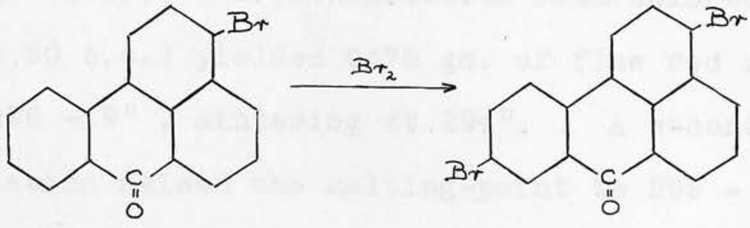
A first experiment, in which 0·5 gm 3-bromobenzanthrone was boiled under reflux in 15 c.c. glacial acetic acid with 0·26 gm. bromine for two hours, resulted in the recovery of the material unchanged.

1 gm. 3-bromobenzanthrone, finely powdered.

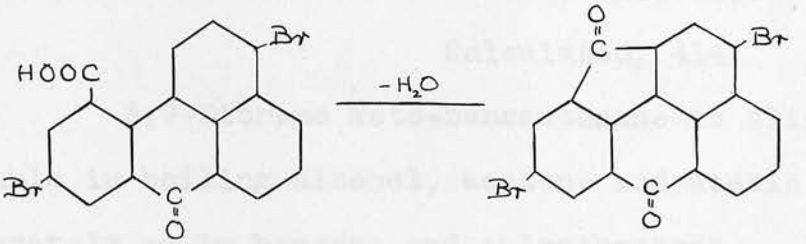
0·6 gm. bromine.

The above were placed in 50 c.c. water and heated for 3 hours on the boiling water-bath under reflux. After cooling, the fine suspension was poured off (m.p. of solid recovered, 165 - 70°C.) and a quantity of darker-coloured material which remained on the foot of the flask was removed and dried. On recrystallisation from chlorobenzene, this yielded

0·3 gm. of fine yellow needles of melting-point 255 - 6°C., and giving no depression when mixed with a sample of 3:9-dibromo-benzanthrone (p. 133) of m.p. 255 - 6°C.



3:9-Dibromo-1:11-keto-benzanthrone.



1 gm. 3:9-dibromo-11-carboxy-benzanthrone.
30 gm. phthalic anhydride.
1·5 gm. phosphorus pentoxide (in two portions).

The acid and anhydride were heated together in an oil-bath at 200°C; complete solution was not attained. Half of the phosphorus pentoxide was then added, when the solution darkened and all the solid dissolved. After half-an-hour, the remainder of the dehydrating agent was added and the heating continued for 1½ hours. After cooling somewhat, the liquid was poured into a hot solution of 16 gm. of sodium hydroxide in 300 c.c. of water. The solution was raised to the boiling-point and the flocculent red precipitate filtered off, washed with water and dried. Weight, 0·85 gm. (90%). Crystallisation from chlorobenzene (about 50 c.c.) yielded 0·75 gm. of fine red needles, m.p. 298 - 9°, sintering at 294°. A second recrystallisation raised the melting-point to 299 - 300°C. with sintering at 297°, unaltered by sublimation or further crystallisation.

Analysis. - Found: C, 52·2%; H, 1·45%.

Calculated for $C_{18}H_6O_2Br_2$: C, 52·2%;

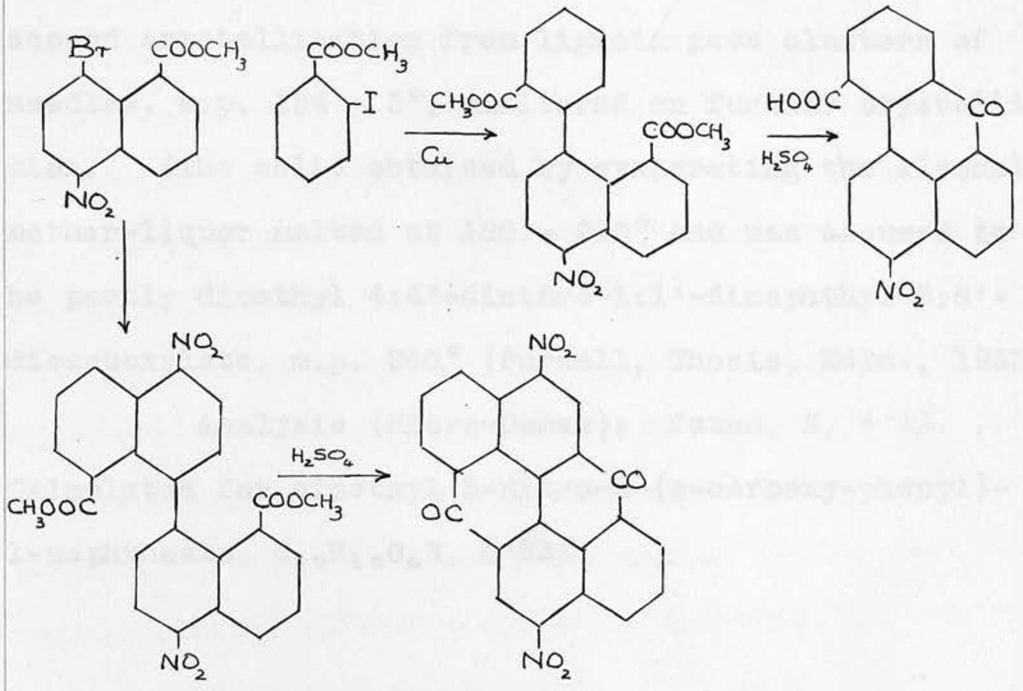
H, 1·60%.

Molecular Wt.: Found, 420, 423.

Calculated, 414.

3:9-Dibromo keto-benzanthrone is slightly soluble in boiling alcohol, acetone and acetic acid, moderately so in benzene and chlorobenzene. It dissolves readily in cold concentrated sulphuric acid, to give a purple-red solution with blue fluorescence, which on dilution becomes violet-blue with purple fluorescence. On pouring into water, the ketone is recovered unchanged. On treatment with alkaline sodium hydrosulphite, a yellow suspension in a brown liquid is formed. Cotton placed in the vat is only feebly coloured.

Reaction between Methyl 5-Nitro-8-bromo-1-naphthoate and Methyl o-Iodo-benzoate: Dimethyl 5-Nitro-8-(o-carboxy-phenyl)-1-naphthoate, 3-Nitro-11-carboxy-benzanthrone and 4:9-Dinitro-anthanthrone.



6·2 gm.	methyl 5-nitro-8-bromo-1-naphthoate.
10·5 gm.	methyl o-iodo-benzoate.
6·4 gm.	copper bronze A.

The esters were mixed and stirred at 180° (oil-bath temperature) and the copper added over twenty minutes. The heating and stirring of the resulting paste were continued for a further two hours, after which the solid was extracted with four (50 c.c.) portions of boiling acetone, the acetone evaporated off and ether added. A pale yellow powder separated slowly and was filtered off, washed with ether and dried.

Weight, 5 gm. M.p., 150 - 152°C.

Of these mixed esters, 2 gm. were reserved for sulphuric acid treatment (see below). The remaining 3 gm. were recrystallised from alcohol, giving 2·25 gm. of pale yellow needles, m.p. 152 - 4°. A second crystallisation from ligroin gave clusters of needles, m.p. 154 - 5°, unaltered on further crystallisation. (The solid obtained by evaporating the alcoholic mother-liquor melted at 180 - 210° and was assumed to be partly dimethyl 4:4'-dinitro-1:1'-dinaphthyl-8:8'-dicarboxylate, m.p. 240° (Pursell, Thesis, Edin., 1933).

Analysis (Micro-Dumas): found, N, 4·1%. Calculated for dimethyl 5-nitro-8-(o-carboxy-phenyl)-1-naphthoate, $C_{20}H_{15}O_{6}N$, 3·83%.

3-Nitro-11-carboxy-benzanthrone.

2 gm. of the above mixed esters (m.p. 150 - 152°C.) were treated with 30 c.c. of concentrated sulphuric acid on a boiling water-bath for one hour. The yellow solution rapidly became blood-red and, after cooling, was poured into 300 c.c. of water. A brown-yellow precipitate formed and was filtered off and heated for a short time with dilute sodium hydroxide solution. The insoluble material was filtered off, washed and dried. It weighed 0·45 gm., was greenish-brown in colour, dissolving in sulphuric acid with

blood-red colour and forming a violet vat with hydrosulphite which dyed cotton blue. This was assumed to be 4:9-dinitro-anthanthrone.

The alkaline filtrate (red-brown in colour, without any fluorescence) was allowed to cool and acidified with dilute hydrochloric acid (acidification of the hot solution caused tarring). The yellow flocculent precipitate was filtered off and dried. Weight, 1·25 gm. M.p. 300 - 303° with decomposition. Recrystallisation from alcohol (200 c.c.) gave 1·15 gm. of purplish-brown cubical crystals of m.p. 308 - 9° (decomp.). On powdering, or dissolving in alkali and reprecipitating, a yellow powder of the same m.p. was obtained. Further recrystallisation from glacial acetic acid or nitrobenzene gave golden-yellow needles of m.p. 310° (decomp.).

Analysis (Micro-Dumas): found, N, 3·8%. Calculated for 3-nitro-11-carboxy-benzanthrone, $C_{18}H_9O_5N$, 4·39%.

The residue obtained from the Ullmann reaction after filtering off the esters was freed from ether and treated with 100 c.c. of sulphuric acid at 100° for an hour. From this treatment, 0·27 gm. of dinitro-anthanthrone was isolated. A simple calculation, based on the weights obtained from 2 gm. of the mixed esters, shows that the yield of dinitro-anthanthrone and therefore of dinaphthyl dicarboxylic ester is 35%. The amount of 3-nitro-11-carboxybenzanthrone corresponds to a yield of the unsymmetrical product of 49%.

A repetition was carried out with another sample of copper bronze (B).

5·25 gm. methyl 5-nitro-8-bromo-1-naphthoate.

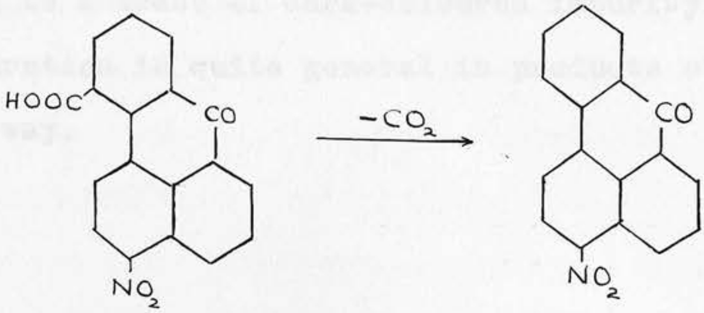
8·9 gm. methyl o-iodo-benzoate.

5·3 gm. copper bronze B.

The solid esters obtained weighed 3·95 gm. and melted at 149 - 52°. On treatment with sulphuric acid they yielded 0·95 gm. of dinitro-anthanthrone and 2·45 gm. of 3-nitro-11-carboxy-benzanthrone (m.p. 305-6°). Recrystallisation from nitro-benzene gave 2·15 gm. of yellow needles, m.p. 309 - 10° (decomp.). (These weights correspond to 3·90 gm. of esters).

The residue after removal of ether was similarly treated and gave 0·27 gm. of dinitro-anthanthrone. The yield of dinaphthyl derivative was therefore 36% of theory, and 45% of the theoretical yield of the unsymmetrical product is accounted for as 3-nitro-11-carboxy-benzanthrone. These figures agree well with those in the previous case.

3-Nitro-benzanthrone: Decarboxylation of 3-nitro-11-carboxy-benzanthrone.

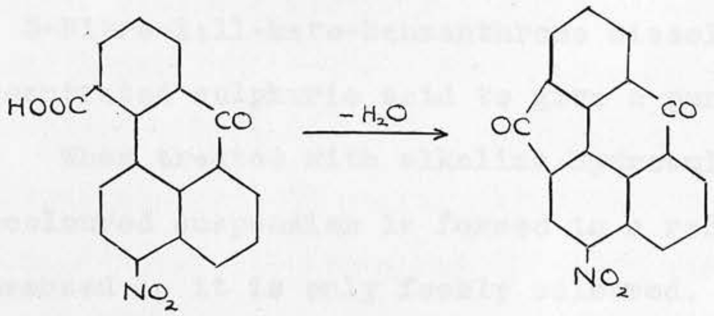


0·24 gm.	3-nitro-11-carboxy-benzanthrone.
0·1 gm.	copper bronze.
3 c.c.	quinoline.

The carboxy acid was dissolved in the boiling quinoline and the copper added in small portions. Effervescence occurred and boiling was continued for two minutes longer. (Further boiling was found to give a product which could only be purified with difficulty). The cooled mixture was treated with hydrochloric acid to dissolve the quinoline and filtered. The residue was washed with warm dilute alkali and water and dried. The brown solid was dissolved in boiling acetic acid, filtered from the copper and cooled. Brown crystals were formed, m.p. 246 - 7°; recrystallisation from toluene yielded brown needles, m.p. 248 - 9°. Yield: 0·08 gm.

The product obtained by nitrating benzanthrone in nitrobenzene solution forms yellow needles of m.p. 248 - 9°. A mixed melting-point with the above compound was unchanged at 248 - 9°; the brown colour of the specimen of 3-nitro-benzanthrone must be ascribed to a trace of dark-coloured impurity: this discolouration is quite general in products obtained in this way.

3-Nitro-1:11-keto-benzanthrone.



1·5 gm. 3-nitro-11-carboxy-benzanthrone.

45 gm. phthalic anhydride.

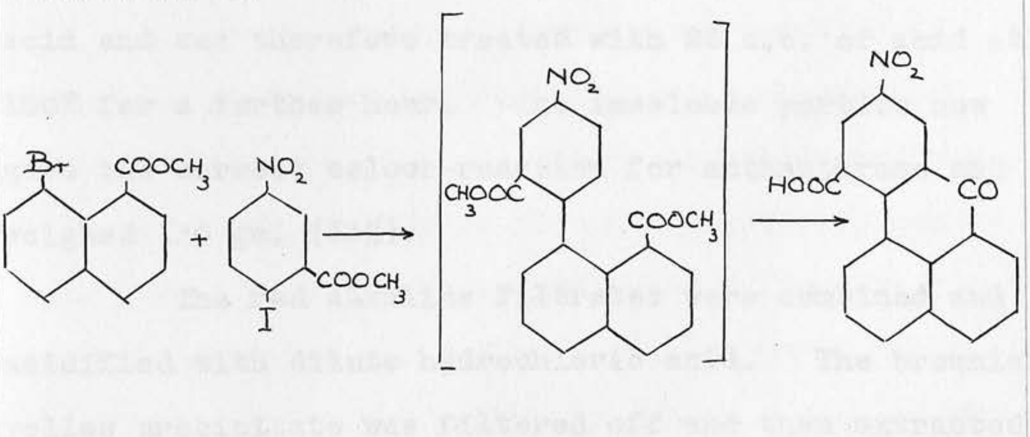
2 gm. phosphorus pentoxide.

The carboxy acid was dissolved in the molten anhydride with stirring at 200° (oil-bath). The phosphorus pentoxide was added in two portions at intervals of half-an-hour. The solution darkened and after two hours heating was cooled somewhat and poured into a solution of 24 gm. of sodium hydroxide in 400 c.c. water. The mixture was raised to the boiling point and the yellow insoluble precipitate filtered off. Weight, 1·2 gm. (85%). The filtrate was brown in colour with green fluorescence, but on acidification a negligible amount of material was precipitated. The cyclised product was recrystallised from benzene as orange needles (1·05 gm.) with a metallic lustre. M.p., 280 - 81°, sintering at 260°C. Further crystallisation from chlorobenzene or nitrobenzene raised the melting point to 282 - 83° with sintering at 265°C.

Analysis (Micro-Dumas): found, N. 4·45%. theory, 4·65%.

3-Nitro-1:11-keto-benzanthrone dissolves in cold, concentrated sulphuric acid to give a purple-red solution. When treated with alkaline hydrosulphite, a violet-coloured suspension is formed in a red liquid; cotton immersed in it is only feebly coloured.

Reaction between Methyl 8-Bromo-1-naphthoate and Methyl 5-Nitro-2-iodo-benzoate : 9-Nitro-11-carboxy-benzanthrone.



4 gm. methyl 8-bromo-1-naphthoate.
9 gm. methyl 5-nitro-2-iodo-benzoate.
4 gm. copper bronze (B).

The mixed esters were stirred at 180° (bath temperature) and the copper added over a period of twenty minutes. After two hours, the mixture was extracted with acetone, the solvent removed and ether added. After standing overnight, small clusters of crystals had separated. These were filtered off and dried. Weight, 0·82 gm. Recrystallisation from methyl alcohol yielded 0·7 gm. of colourless rhomboidal plates, m.p. 177°C., not depressed by admixture with authentic dimethyl 4:4'-dinitro-diphenate.

The product from the ethereal filtrate, after removal of solvent, was treated with 120 c.c. of concentrated sulphuric acid at 100° for an hour. The alkali-insoluble residue (1·66 gm.) from this treatment did not give a pure green colouration with sulphuric acid and was therefore treated with 25 c.c. of acid at 100° for a further hour. The insoluble portion now gave the correct colour-reaction for anthanthrone and weighed 1·0 gm. (43%).

The red alkaline filtrates were combined and acidified with dilute hydrochloric acid. The brownish-yellow precipitate was filtered off and then extracted with 400 c.c. of boiling water to remove the soluble 4:4'-dinitro-diphenic acid. The yellow residue of

9-nitro-11-carboxy-benzanthrone weighed 2·25 gm. (41%) and melted at 280 - 283°C. with decomposition. Recrystallisation from nitrobenzene (10 - 12 c.c.) gave 2·05 gm. of yellow leaflets of m.p. 286 - 287°C. (decomp.), unaltered by further recrystallisation from glacial acetic acid (100 c.c.).

Analysis (Micro-Dumas):-

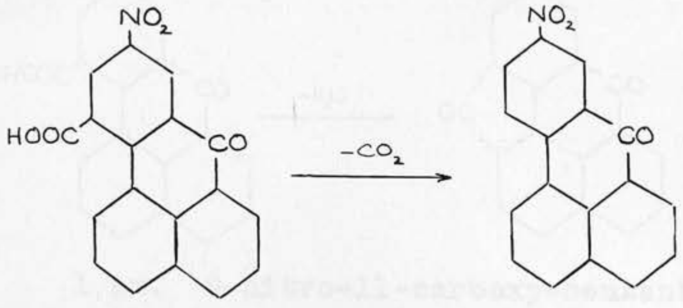
Found: N, 3·9%; calculated for $C_{18}H_9O_5N$, 4·4%.

Reaction between Methyl 8-Bromo-1-naphthoate and Methyl 5-nitro-2-bromo-benzoate.

5 gm. methyl 8-bromo-1-naphthoate.
10 gm. methyl 5-nitro-2-bromo-benzoate.
6 gm. copper bronze (B).

The reaction was carried out exactly as described above and yielded 2·5 gm. of dimethyl dinitro-diphenate, 1·72 gm. (60%) of anthanthrone and 1·97 gm. (33%) of 9-nitro-11-carboxy-benzanthrone, m.p. 279 - 282°, raised to 285 - 286°C. (decomp.) on recrystallisation.

9-Nitro-benzanthrone : Decarboxylation of 9-Nitro-11-carboxy-benzanthrone.



0·5 gm. 9-nitro-11-carboxy-benzanthrone.

0·2 gm. copper bronze.

5 c.c. quinoline.

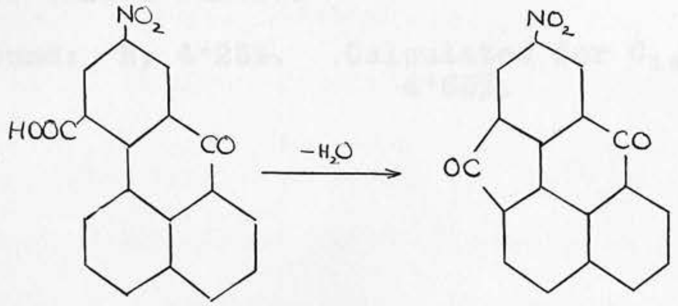
The decarboxylation was carried out as in the case of the 3-nitro-compound (p.141). Addition of water to the acetic acid filtrate threw out a brownish-yellow precipitate (0·3 gm.) which was twice crystallised from glacial acetic acid, forming clusters of brown needles, m.p. 291 - 2 °C., which dissolved in sulphuric acid to give a yellow solution with bright green fluorescence.

Analysis (Micro-Dumas):-

Found: N, 4·8%; calculated for $C_{18}H_{9}O_{3}N$, 5·1%.

The second nitration product of benzanthrone (see p. 59) melts at 305 - 7°C.; mixed with 9-nitro-benzanthrone, the melting-point ranged from 255 to 285°C.

9-Nitro-1:11-keto-benzanthrone.



1 gm. 9-nitro-11-carboxy-benzanthrone.

1 gm. phosphorus pentoxide.

30 gm. phthalic anhydride.

The cyclisation of the acid was carried out as described before (p. 142). The orange alkali-insoluble material weighed 0·55 gm. (58%) and on recrystallisation from chlorobenzene (25 c.c.) gave 0·5 gm. of deep orange needles of m.p. 315 - 316°, raised to 316 - 317°C. on further crystallisation. The yield quoted is smaller than usual in these reactions, but a large lump of black material had formed on the foot of the flask and probably occluded some of the organic compounds.

An alternative method of cyclisation which proved more successful was carried out as follows; (cf. p. 129): 0·8 gm. of 9-nitro-11-carboxy-benzanthrone was dissolved in 10 c.c. of boiling nitrobenzene and 0·8 gm. of phosphorus pentoxide added in two portions. After two hours boiling, the liquid was poured off and allowed to cool. The deposited orange needles were filtered off, washed with alcohol and dried.

Yield, 0·6 gm. (79%). M.p. 315 - 316°C.

Analysis (Micro-Dumas):-

Found: N, 4·25%. Calculated for $C_{18}H_7O_4N$, 4·65%.

Picryl Chloride.

(Jackson and Gazzolo, Amer. Chem. J., 1900, 23, 384).

25 gm. picric acid.

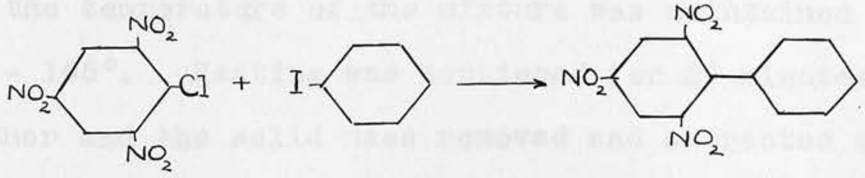
50 gm. phosphorus pentachloride.

The above were mixed in a large flask fitted with an air-condenser and gently warmed on the steam-bath until the vigorous reaction had ceased and the contents formed a dark red liquid. The flask was cooled in ice and ice-water gradually added. The solid was filtered off, dried, washed with ether and crystallised from alcohol as yellow plates.

Yield; 14 gm. (52%). M.p. 83°C.

2:4:6-Trinitro-diphenyl.

(Gull and Turner, J., 1929, 491).



20 gm. picryl chloride.
20 gm. iodo-benzene.
20 gm. copper bronze (B).

The picryl chloride and iodo-benzene were mixed in a small flask in an oil-bath at 195°C. and stirred with a thermometer. The copper was added in small portions over a period of 45 minutes, the mixture being stirred after each addition and the temperature maintained between 195° and 203° by removing the flask occasionally from the bath. The mixture was heated for a further 15 minutes and extracted with alcohol (250 c.c.). On cooling, 2:4:6-trinitro-diphenyl separated and was filtered off. Weight, 14 gms. M.p. 129 - 130°C. The filtrate on evaporation yielded a further 3·5 gm., m.p. 127 - 9°. Total yield, 75%.

The residue was extracted with acetone, but the product obtained on evaporation of the extract yielded black, tarry material from which no pure compound was isolated.

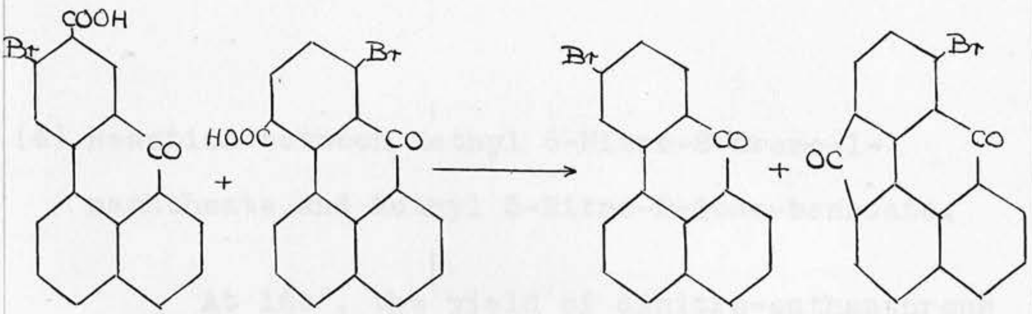
The reaction was repeated, using 14 gm. of each of the reactants and maintaining the oil-bath at 155-160°. The addition of copper occupied 40 minutes, and the temperature of the mixture was maintained at 160 - 165°. Heating was continued for 20 minutes further and the solid mass removed and extracted with alcohol (200 c.c.) by suspending the solid in a paper thimble (Soxhlet) below a reflux condenser attached to the flask containing the boiling alcohol (15 hours). The alcoholic extract on cooling deposited 11·95 gm. of trinitro-diphenyl in the form of square golden-yellow plates, m.p. 129 - 130°, a further 1·25 gm. being obtained on evaporation of the filtrate. Total yield: 85%.

Further Attempted Synthesis by the Ullmann Reaction.

As no homogeneous unsymmetrical products were isolated from the following Ullmann reactions, they are only briefly described.

(1) Reaction between Methyl 8-Bromo-1-naphthoate (1 mol.) and Methyl 2:4-Dibromo-benzoate (2 mols.).

The mixture at 215 - 220° gave 56% of anthanthrone. The mixed acids obtained after hydrolysis could not be purified by crystallisation, nor could the alkali-insoluble material obtained from them by treatment with phosphorus pentoxide in phthalic anhydride at 200° be separated by repeated crystallisation. It is possible that both bromine atoms of the benzoate reacted with that of the naphthoate. The formation of a mixture of neutral products may then be due to the decarboxylation of the 9-carboxybenzanthrone, and, in fact, evolution of gas was observed during the treatment at 200°.



(2) Reaction between Methyl 8-Bromo-1-naphthoate and Methyl 4-nitro-2-iodo-benzoate (2 mols.).

At 180° the yield of anthanthrone was 70%. The alkali-soluble material formed a brown amorphous powder which could not be crystallised and which did not melt below 360°C. At 215 - 220°, the yield of anthanthrone was 63% and the acidic product was similar to that obtained from treatment at 180°.

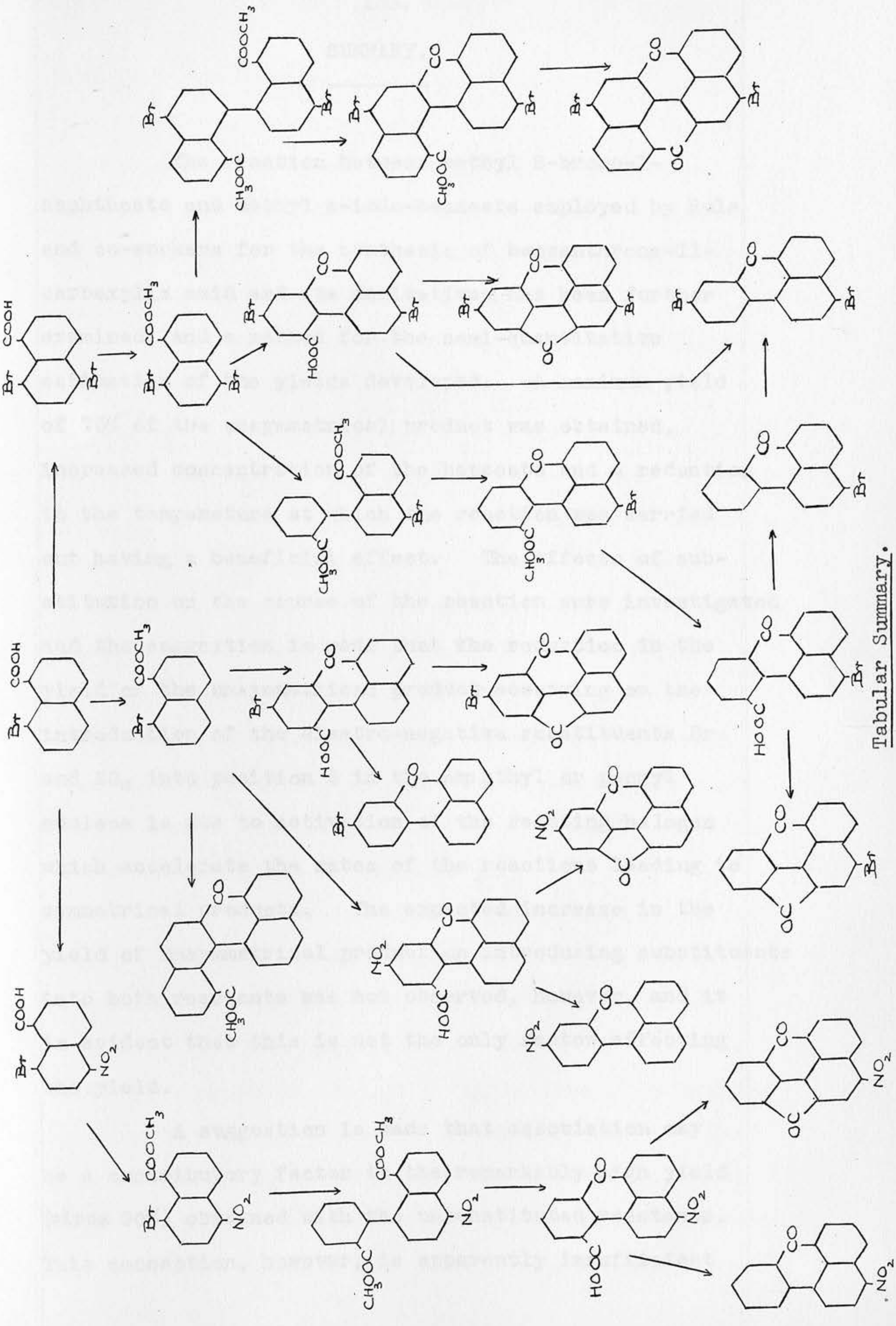
(3) Reaction between Methyl 8-bromo-1-naphthoate and Methyl 6-nitro-2-iodo-benzoate.

The reaction was carried out at 180°. The alkali-insoluble material after three successive treatments with concentrated sulphuric acid at 100° for an hour amounted to about 50%, but was apparently not quite pure anthanthrone. The acidic products were black and uncrystallisable, decomposing at about 200°C.

(4) Reaction between Methyl 5-Nitro-8-bromo-1-naphthoate and Methyl 5-Nitro-2-iodo-benzoate.

At 180°, the yield of dinitro-anthanthrone amounted to 75%. The alkaline filtrates yielded tarry material on acidification, which could not be purified.

(5) No pure products were obtained from the reaction between methyl 4:5-dinitro-8-bromo-1-naphthoate and methyl o-iodo-benzoate at 180°.



Tabular Summary.

SUMMARY.

The reaction between methyl 8-bromo-1-naphthoate and methyl o-iodo-benzoate employed by Rule and co-workers for the synthesis of benzanthrone-11-carboxylic acid and its derivatives has been further examined, and a method for the semi-quantitative estimation of the yields developed. A maximum yield of 75% of the unsymmetrical product was obtained, increased concentration of the benzoate and a reduction in the temperature at which the reaction was carried out having a beneficial effect. The effects of substitution on the course of the reaction were investigated and the suggestion is made that the reduction in the yield of the unsymmetrical product occurring on the introduction of the electro-negative substituents Br and NO_2 into position 5 in the naphthyl or phenyl nucleus is due to activation of the reacting halogen which accelerate the rates of the reactions leading to symmetrical products. The expected increase in the yield of unsymmetrical product on introducing substituents into both reactants was not observed, however, and it is evident that this is not the only factor affecting the yield.

A suggestion is made that association may be a contributory factor to the remarkably high yield (circa 90%) obtained with the unsubstituted reactants. This conception, however, is apparently insufficient

to explain the success of the reaction between picryl chloride and iodobenzene under temperature conditions under which the iodobenzene is normally unreactive towards copper bronze. This reaction was re-examined and concluded to involve, apparently, some novel form of "activation" of the iodine atom.

The hydrolysis and cyclisation of the phenyl-naphthyl and dinaphthyl dicarboxylic esters obtained by this reaction were studied. The most noteworthy feature emerging is the comparative stability of the ester group attached to the 4' peri-position in benzo-benzanthrone carboxylic ester. This can be attributed to increased steric hindrance produced when the free rotation of the naphthyl nuclei is prevented by the benzanthrone ring-closure. The different courses taken by the alkaline and acid hydrolysis of dimethyl 8-(o-carboxy-phenyl)-1-naphthoate are pointed out and the unexpected stability of the ester group in 11-carbomethoxy-benzanthrone is emphasised.

The cyclisation of some substituted 11-carboxy-benzanthrones to 1:11-keto-benzanthrones by means of phosphorus pentoxide in phthalic anhydride or nitro-benzene at 200° was carried out. The products, whose melting-points show curious irregularities, are highly coloured but devoid of useful dyeing properties. The greater difficulty of formation, due apparently to the higher tension of the five-membered ring in benzanthrone-1:11-ketone as compared with fluorenone, is noted.

The decarboxylation of substituted 11-carboxybenzanthrones has enabled it to be definitely established that halogenation of benzanthrone occurs primarily in position 3. Further bromination takes place in position 9. The mono-nitration product of benzanthrone of m.p. 248 - 9°C. was proved to be the 3-nitro-derivative. The second mono-nitration product of benzanthrone, m.p. 305 - 7°C., described in the literature is not the 9-nitro-derivative which has now been obtained by synthesis.

In conclusion, the author wishes to express his indebtedness to Dr H. G. Rule for valuable advice and helpful encouragement throughout the course of this work, and to make grateful acknowledgment to the Carnegie Trust for the Universities of Scotland for a Scholarship held during 1933 - 1935, and to Imperial Chemical Industries Limited for materials.