MECHANISM OF FORMATION OF HETERO CYCLIC COMPOUNDS
BY FRACTION OF HYDRAZOIC ACID WITH CYCLIC CONTAINERS.

SYNTHESIS OF BENZOXAZINES.

being a Thesis submitted to the
University of London
for the degree of
Doctor of Philosophy in the Faculty of Science

by

Robert Edward Marks, B.Sc. (Lond.)

Battersea Polytechnic. February 1957.
Abstract of Thesis.

2-α-Naphthoyl-, 2-α-methoxybenzoyl-, 2-α-chlorobenzoyl-, 2-α-nitrobenezoyl-, 2-α-mesityloyl-, 2-α-phenylacetyl-, and 2-α-butyryl-benzoic acids, and benzylidene- and propylidene-phthalalides have been subjected to the conditions of the Schmidt reaction to yield, principally, 2-substituted-6-oxo-4:5-benz-1:3-oxazines. Where the substituent is aryl the oxazine can be isolated under the conditions employed; 2-α-methoxyphenyl-, 2-α-chlorophenyl-, 2-α-nitrophenyl-, 2-α-naphthyl, and 2-α-mesityl-6-oxo-4:5-benz-1:3-oxazines were so obtained. Where the substituent is alkyl or aralkyl the hydrolysis product, an N-substituted-anthranilic acid, is isolated; N-phenylacetyl- and N-butyryl-anthranilic acids were obtained. The mechanism of this reaction, believed to proceed via a cyclic ion, is discussed. Evidence for the existence of a counter-rearrangement, which leads, not to a 2-substituted-6-oxo-4:5-benz-1:3-oxazine or an N-substituted-anthranilic acid, but ultimately, to a primary amine, is given, and the mechanism of the counter-rearrangement is discussed.

Experiments concerning the Schmidt reaction of 1:2-benzofluorenone are described. The preparation of 1:2- and 7:8-benzophenanthridines from 9-azido-1:2-benzofluorene is recorded; the ratio of isomers, 2:9 : 1, is shown to be in accord with views based on earlier work in the field. A novel method for the preparation of certain 9-azidofluorenes
is described. New observations on the acid-catalysed
decomposition and the pyrolysis of 9-azido-fluorenes,
together with data in the literature, lead to the
conclusion that acid-catalysed decomposition of secondary
and tertiary azides, also pyrolysis of the latter, yield
substituted phenanthridines, but that pyrolysis of
secondary azides yields ketimines.

The preparation of 2:4-dihydroxyquinoline from
1:3-diketohydrindene, via the Schmidt reaction, has been
verified.
The investigations described in this Thesis were effected in the Organic Chemistry Research Laboratories of Battersea Polytechnic, under the direction of Dr. F.R. Goss, to whom the author expresses his thanks for his interest in the work.

To Dr. C.L. Arcus the author expresses his grateful appreciation of encouragement and valued advice.

Thanks are also due to the Governing Body of the Battersea Polytechnic for the award of an Edward Tate and Holf Scholarship.
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(i) Sulphuric acid

(ii) Trichloroacetic acid

(iii) Polyphosphoric acid

The Interaction Between 1:2-Benzofluoren-9-ol and Hydrazoic Acid in the Presence of Strong Acids

1:2-Benzofluoren-9-ol

9-Acetoxy-1:2-benzofluorene

4-Chrysenequinone

The Behaviour of 1:2-Benzofluorenone with Hydrazoic Acid in the Presence of Strong Acids

(i) Sulphuric acid

(ii) Trichloroacetic acid

(iii) Polyphosphoric acid

9-Chlorophenyl-6-oxo-5-ENZ-15 2-oxazine

M-Nitrophenylphthalamic acid

2-Butyrylbenzoic acid
PART I

THE HISTORICAL INTRODUCTION.
HISTORICAL INTRODUCTION.

The Schmidt reaction, Introductory:

The reaction between equimolar quantities of hydrazoic acid and carbonyl compounds in the presence of strong acids is known as the Schmidt reaction; aldehydes yield nitriles and formyl derivatives of amines, ketones yield amides:

\[ R.\text{CHO} + \text{IN}_3 \xrightarrow{\text{H}_2\text{SO}_4} R.\text{CN} \text{ and } R.\text{NH} \cdot \text{CHO} \ ( + N_2) \]

\[ R.\text{CO} \cdot \text{R} + \text{IN}_3 \xrightarrow{\text{H}_2\text{SO}_4} R.\text{NH} \cdot \text{CO} \cdot \text{R} + N_2 \]

With an excess of hydrazoic acid, aldehydes and ketones yield 1:5-substituted tetrazoles.

\[ R.\text{CO} \cdot \text{R} + 2\text{IN}_3 \rightarrow R-\text{C}-\text{N} \cdot \text{R} + \text{H}_2\text{O} + N_2 \]

It has been found that, under similar reaction conditions to the above, carboxylic acids react with hydrazoic acid to give primary amines, this offers a route to the preparation of amines which is alternative to the Hofmann and Curtius degradations of carboxylic acids. Further, it is a one stage synthesis.

Similar to the Schmidt reaction is the formation of ketimines by the interaction of hydrazoic acid and certain alcohols and olefins in the presence of strong acids.

\[ \text{H}_2\text{SO}_4 \]

\[ R.\text{CH} \cdot \text{OH} \cdot \text{R} + \text{IN}_3 \rightarrow R.\text{CH} = \text{N} \cdot \text{R} + \text{H}_2\text{O} + N_2 \]
The reaction of carbonyl compounds with hydrazoic acid was first reported by K.F. Schmidt (1) in 1924. In his study of the decomposition of hydrazoic acid in the presence of sulphuric acid, he found that the major product was hydroxylamine. When benzene was added to hydrazoic acid and sulphuric acid at room temperature, gas was evolved for several days, and hydrazine was the major product. Small quantities of hydroxylamine and aniline were also obtained. At 60-70°C, with stirring, the major product was aniline; only a small quantity of hydrazine was formed. If benzophenone was added, a vigorous reaction ensued with the formation of a quantitative yield of benzanilide. The reaction with m-nitrobenzaldehyde gave 5/6 of the theoretical quantity of m-nitrocyanobenzene, and 1/6 of the theoretical quantity of m-nitroaniline.

To account for these results, following a suggestion by Rolle, whom he acknowledges in a footnote, Schmidt (1) postulated the cleavage of the hydrazoic acid molecule in sulphuric acid to give the imine radical (NH) and nitrogen, the former reacted further as follows:
To account for the formation of benzamidide from benzophenone, and of m-nitroacetylbenzene and m-nitroaniline from m-nitrobenzaldehyde, he suggested that the imine radical added to the carbonyl group followed either by a direct rearrangement (1, 3), or the Beckmann rearrangement of a hypothetical oxime (2).

\[
\begin{align*}
H_2SO_4 &\quad HN_3 \rightarrow N_2 + (NH) \\
H_2O + (NH) &\rightarrow H_2O \quad OH \\
4(NH) &\rightarrow 2(NH;NH) \rightarrow N_2H_4 + N_2 \\
C_6H_5 + (NH) &\rightarrow C_6H_5\cdotNH_2
\end{align*}
\]

When \( R' = H \), loss of water from the intermediate would give the nitrile, and rearrangement would give the formyl derivative of an amine.

There is evidence that the imine radical does exist in certain circumstances and that it does play a part in certain reactions. Tolmachev (4) has identified bands corresponding to (NH) in the spectra of exploding hydrazoic acid. Oliveri-Mandala (5) suggested that it might be formed in the decompositions of hydrazoic acid in aqueous solution in the presence of platinum black. Cleu (6) has found that
hydroxylamine is formed when aqueous hydrazoic acid is irradiated with ultra-violet light. Hydroxylamine-0-sulphonic acid has been prepared by Specht et al. (7) from hydrazoic acid and fuming sulphuric acid, and they assumed that the protonated radical (NH₂)⁺ played a part. The amination of aromatic nuclei by both hydrazoic acid and hydroxylamine-0-sulphonic acid has been demonstrated by Keller and Smith (8), who assumed the formation of (NH) or (NH₂)⁺ depending on the conditions of the reaction. However, many carbonyl compounds yield oximes when treated with hydroxylamine-0-sulphonic acid (9) whereas with hydrazoic acid they yield amides. Thus Keller and Smith (8) demonstrated that hydroxylamine-0-sulphonic acid was not an intermediate in the Schmidt reaction as had been suggested by Sanford et al. (9). Keller and Smith also pointed out that the amination of aromatic nuclei only takes place under conditions under which hydrazoic acid is known to decompose, whereas the Schmidt reaction of ketones is vigorous, in many cases, at 0°C. The postulate of Schmidt that an oxime be formed as an intermediate is also rendered improbable since the oxime of α-hydrindone is stable in concentrated sulphuric acid at 100°C (10), whereas the ketone undergoes the Schmidt reaction at 40°C (11). Thus subsequent evidence bears out Schmidt's theory for the direct amination of aromatic nuclei, while his theory with regard to the ketone reaction is not justified.

Schmidt's reaction mechanism was first criticised in 1925 by Oliveri-Mandala (12), who suggested that the first
stage in the reaction was the addition of the hydrazoic acid molecule to the carbonyl group. Loss of nitrogen from the resultant azide, and subsequent rearrangement of the intermediate gave the final product.

\[
\begin{align*}
\text{R} & \quad \text{HN} \quad \text{N} \quad \text{R} \\
\text{\text{C=O}} & \quad \rightarrow & \quad \text{\text{C}} \quad \text{\text{O}} \quad \text{\text{H}} \quad \text{\text{N}} \quad \text{\text{R}} \\
\text{N}_{3} \quad \rightarrow & \quad \text{\text{C}} \quad \text{\text{O}} \quad \text{\text{H}} \quad \text{\text{N}} \quad \text{\text{R}} \\
\text{OH} & \quad \rightarrow & \quad \text{\text{R}} \quad \text{\text{C=N}} \quad \text{\text{R}} \\
\end{align*}
\]

This mechanism was further developed by Hurd (13), and by Briggs and Lyttleton (14). The new mechanism was based on the linear formulation of hydrazoic acid as a resonance hybrid of the three forms below, I being regarded as the most stable form, and II and III the active forms.

\[
\begin{align*}
\text{I} & \quad \text{II} & \quad \text{III} \\
\text{H} \quad \text{N} & \quad \text{N} \quad \text{=} & \quad \text{H} \quad \text{N} \quad \text{N} \quad \text{=} \\
\text{I} & \quad \text{II} & \quad \text{III} \\
\end{align*}
\]

Briggs and Lyttleton considered II to be involved in the Schmidt reaction and suggested the following:–

\[
\begin{align*}
\text{R}' \quad \text{R} \quad \text{C} \quad \text{N} \quad \text{O} \quad \text{H} \\
& \quad \rightarrow & \quad \text{R} \quad \text{C} \quad \text{N} \quad \text{N} \quad \text{N} \quad \text{O} \quad \text{H} \\
& \quad \rightarrow & \quad \text{R} \quad \text{C} \quad \text{N} \quad \text{H} \quad \text{O} \quad \text{H} \\
\end{align*}
\]
The first step, a, was the activation of the carbonyl compound and of the hydrazoic acid by the strongly polar sulphuric acid. The active molecules combine (b) to give the addition complex which loses nitrogen (c), and the residue undergoes transformation (d) to give the amide. The transformation was considered to be analogous to the pinacol-pinacolone and allied transformations. When R = OH is a carboxylic acid, a carboxylic acid is produced, which spontaneously loses carbon dioxide to give a primary amine. This afforded an explanation of the formation of amines from carboxylic acids and hydrazoic acid in the presence of sulphuric acid, first reported in 1928 by Schmidt (15).

With certain modifications this is the mechanism, for the reaction accepted today. Newman and Gildenorn (16) pointed out that the active form of hydrazoic acid postulated by Hurd is merely one of the contributing resonance forms, and does not depend on a strongly polar environment for its existence. Further, the hypothesis of activation of organic molecules under the influence of sulphuric acid has been replaced by one of carbonium ion formation. Thus ionisation of the carbonyl group occurs by addition of a proton to the oxygen atom at the negative end of the permanent C=O dipole.

\[ R_2\cdot C=O \xrightarrow{H^+} R_2\cdot C\cdot OH^\cdot \]
They wrote for the Schmidt reaction of ketones:

\[
\begin{align*}
R' \text{C}^+ \text{+} \text{R'-N}_2^+ & \rightarrow R' \text{C}^+ \text{N}^\neg\text{+} \rightarrow R \text{C}^+ \text{N}^\neg\text{+} \\
OH & \rightarrow OH
\end{align*}
\]

These authors also suggested a mechanism for the Schmidt reaction of carboxylic acids. In general, solutions of carboxylic acids in sulphuric acid exhibit van't Hoff "i" factors of 2, due to ionisation according to the following equation:

\[
\text{R.COO}_2^+ + \text{H}_2\text{SO}_4 \rightarrow \text{R.COO}_2^+ \text{H}_{2+}^+ + \text{H}_2\text{SO}_4^+
\]

Newman and Deno (17) had shown that certain carboxylic acids behaved in an anomalous manner. 2:4:6-Trimethylbenzoic acid could be esterified by pouring its sulphuric acid solution into methanol. Further, it was found that solutions of the acid in sulphuric acid exhibited a van't Hoff "i" factor of nearly 4. The following equation was put forward to explain this fact:

\[
(\text{CH}_3)_3\text{C}_6\text{H}_2^\neg\text{CO}_2^+ + 2\text{H}_2\text{SO}_4 = (\text{CH}_3)_3\text{C}_6\text{H}_2^\neg\text{CO}_2^+ + \text{H}_2^\neg + 2\text{H}_2\text{SO}_4
\]

Benzoic acid cannot be esterified by use of the method indicated above. It had been found that mesitoic acid underwent the Schmidt reaction at 0°, whereas benzoic acid did not react below 40°. Newman and Gildenhorn concluded that only ions of type (ii) take part in the reaction. Whence:
Evidence for this is afforded by their discovery that the Curtius reaction, the decomposition of acyl azides, is acid-catalysed, whence the protonated azide, R.CO.NH₂.N₂, may reasonably be postulated as an intermediate in this reaction and in the Schmidt reaction.

Simultaneously with the publication of the above, another mechanism for the Schmidt reaction of ketones was suggested by P.A. Smith (18).

In this reaction scheme, the protonated azide III loses water to give the intermediate IV. This which could exist as two geometrical isomers in which the -N=N group is syn or anti to group R, undergoes rearrangement with loss of nitrogen to give the intermediate V, which takes up water. Subsequent
deprotonation of the entity VI affords the amide. Smith believes that, by analogy with the Beckmann rearrangement of ketoximes, there is *trans* migration in the rearrangement of the intermediate IV.

Many unsymmetric ketones have been subjected to the Schmidt reaction. On inspection it is a steric factor which in the main controls which group, R or R', will migrate to the greater extent during the course of the reaction: the larger group, in many cases, migrating to the greater extent. (See Table Ia). In a study of the Schmidt reaction of para-substituted and para-di-substituted benzophenones, Smith et al. (19) found that the ratio of the two amides obtained was approximately 1:1 in all cases, including the extreme case of p-nitro-p'-methoxybenzophenone, where the migration of the methoxyphenyl group would be favoured if electronic effects involving electron-availability at the reaction centre were important. Smith concluded, therefore, that electronic effects did not play an important part in the ketonic Schmidt reaction; the steric factor was more important.

This mechanism has been widely used, and there is much experimental evidence that has been interpreted with its use. The substituted carbon atom migrates preferentially during the reaction of 2-alkyl-cyclopentanones and
Table Ia
The Migration of Groups in the Schmidt Reaction of
Unsymmetrical Ketones.

\[
R \text{CO} \text{.} R' \rightarrow R' \text{NH} \text{CO} \text{.} R' + R' \text{NH} \text{CO} \text{.} R
\]

<table>
<thead>
<tr>
<th>R</th>
<th>R'</th>
<th>% Migration R</th>
<th>% Migration R'</th>
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<tr>
<td>methyl</td>
<td>ethyl</td>
<td>-</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>isobutyl</td>
<td>-</td>
<td>71</td>
</tr>
<tr>
<td></td>
<td>p-tolyl</td>
<td>-</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>p-anisyl</td>
<td>-</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>naphthyl</td>
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<td>73</td>
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<td>p-diphenyl</td>
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<td>p-tolyl</td>
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<td>p-anisyl p-chlorophenyl</td>
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<td></td>
<td>p-nitrophenyl</td>
<td>49</td>
<td>51</td>
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</tbody>
</table>

+ Sanford et al. (9), the other isomer was not isolated.

@ Smith et al. (19).
Table IIa

The Migrations of Groups in the Schmidt Reaction of Unsymmetrical Ketones, (one group carrying an ortho substituent).

\[
R\text{-CO.R'} \rightarrow R\text{-NH.COO.R'} + R'\text{-NH.COO.R}
\]

<table>
<thead>
<tr>
<th>R</th>
<th>R'</th>
<th>% Migration R</th>
<th>% Migration R'</th>
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<tr>
<td>2-CH\text{3.H}_4</td>
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<td>1</td>
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<td>2-CO\text{2.H}</td>
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<td>2-CH\text{3}</td>
<td>C\text{6.H}_5</td>
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<td>83</td>
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<td>2-Br</td>
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<td>81,83</td>
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<td>2-CH\text{2.O}</td>
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<td>2-NO\text{2}</td>
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<td>2-C\text{6.H}_5</td>
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<td>95,70</td>
<td>5,30</td>
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<td>2:4:6-(CH\text{2})_3C\text{6.H}_2&quot;</td>
<td>&quot;</td>
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<td>5</td>
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<tr>
<td>c-C\text{10.H}_7</td>
<td>&quot;</td>
<td>—</td>
<td>64</td>
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<tr>
<td>l-C\text{14.H}_9</td>
<td>&quot;</td>
<td>—</td>
<td>predominates</td>
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</table>

+ Smith, (22)
\(\text{\textcopyright}\) Badger et al., (23)
\(\text{\textcopyright}\) Dice and Smith, (24)
-cyclohexanones, also of 2-cyanocyclohexanone (20). Fusco and Rossi (21) have found that the phenyl group migrates to the greater extent in the Schmidt reaction of a series of ketones C_6H_5.CO.CH_2.X, where X = CN, CO.NH_2, CO.NH.Ph, NO_2, SO_2.Ph.

It is not, however, always the case that the larger group migrates. The reaction of a number of ketones, Ar.CO.C_6H_5, in which Ar is an ortho-substituted aryl group or an analogous polycyclic aromatic group, has been examined. (See Table IIa). With the following the larger group migrates preferentially: 2-nitro-, 2-phenyl-, 2:4:6-trimethylbenzophenone. In the following the smaller group migrates preferentially: 2-methyl-, 2-chloro-, 2-bromo-benzophenone, 1-benzoylnaphthalene, and 1-benzoylphenanthrene. The results for 2-acylbenzoic acids cannot properly be included here since Arcus and Coombs (25) have shown that the mechanism for these compounds is not that for a simple ketone, and further relevant evidence is given in the present Thesis.

The results given above do not lead to simple rules enabling one to predict the probable ratio of isomers formed in the Schmidt reaction of a ketone.

Smith's mechanism has been recently criticised by Arcus, Coombs, and Evans (26), who propose an alternative mechanism similar to that of Newman and Gildenhorn (16). It was pointed out that Smith does not state at what point the cation V takes up a molecule of water.
Further to this, the acid reagent commonly used in the Schmidt reaction is concentrated sulphuric acid, which may effect the dehydration III to IV, but which is unlikely to liberate water to convert V to VI, whence it was considered that this last step would occur when the sulphuric acid is poured into water at the end of the reaction. The replacement of water by methanol would be expected, were Smith's mechanism correct, to lead to the formation of a methoxy compound VII.

Accordingly, fluorenone was allowed to undergo the Schmidt reaction in 100% sulphuric acid. At the end of the reaction the reaction mixture was added to cold, dry, methanol. Phenanthridone, the same product as that which is obtained when the reaction mixture is poured into water, was obtained, and this was not contaminated with 9-methoxyphenanthridine, the product which would have been expected from application of Smith's mechanism.
It was concluded, therefore, that Smith's mechanism, which involved dehydration and rehydration of reaction intermediates, was improbable.

Arcus et al. suggested the following structures VIII and IX for the protonated azide III. These structures possess a four-membered ring, considered to be planar, involving a hydrogen bond between the hydroxylic oxygen atom and the nitrogen atom adjacent to the "carbonyl" carbon atom. The ring nitrogen being in pyramidal form, it is possible to formulate the above geometric isomers, each possessing an optical isomer, and each being representative of a racemic mixture. The group trans to the $\text{N}_2^+$ fragment is considered to migrate when nitrogen separates. Thus VIII is expected to yield $R\cdot\text{CO.NH.R'}$, and IX $R'\cdot\text{CO.NH.R}$. It is thought that the configuration of the $\text{N=N}_2^+$ fragment relative to groups $R$ and $R'$ depends on the polar forces between the structures, and the bulk of the groups in the vicinity of the fragment.
The Reaction Between Certain Alcohols and Olefins and Hydrazoic Acid in the Presence of Strong Acids.

The reaction between compounds capable of giving carbonium ions in the presence of strong acids and hydrazoic acid has been further investigated in recent years.

It was shown by McWen, Gilliland, and Sparr (27) that the reaction between 1:1-diphenylethylene and hydrazoic acid in the presence of sulphuric acid led to the formation of aniline and acetophenone.

Arcus and Wesley (28) have investigated similar reactions of di- and tri-phenylmethanols, and fluoren-9-ol, from which were obtained respectively: aniline, benzaldehyde, and diphenylmethyl azide; triphenylmethyl azide; phenanthridine and 9-azidofluorene. To account for these results, the above authors proposed the following reaction mechanism, similar to those proposed for ketones by Newman and Cildenhorn (16), and for Olefins by McWen, Gilliland, and Sparr (27).

\[
\begin{align*}
\text{RC} = \text{NH} + \text{H}_2\text{SO}_4^- &\rightarrow \text{RC} + \text{H}_2\text{O}^+ + 2\text{HSO}_4^- \quad (i) \\
\text{RC} + \text{HNO}_3^- &\rightarrow \text{RCNO}_3^- \quad (ii) \\
\text{RCNO}_3^- &\rightarrow \text{R-CN} + \text{H}^+ \quad (iii) \\
\text{R-CN} &\rightarrow \text{RC=NH} \quad (iv) \\
\text{RC=NH} &\rightarrow \text{RCO + NH}_3 \quad (v)
\end{align*}
\]

The formation of carbonium ions via equation (i) is in accord with both physical and chemical evidence. In contrast to certain aliphatic alcohols which dissolve in sulphuric acid to give alkyl hydrogen sulphates (29), many di- and tri-
arylmethanols dissolve in this acid to give coloured solutions, attributed to the formation of carbonium ions (30). When triphenylmethanol is dissolved in sulphuric acid, the solution exhibits an "i" factor of nearly 4, attributed by Newman (31) to ionisation according to equation (i) above. The absorption spectrum of the solution is very similar to that of the electrically conducting solution of triphenylmethyl chloride in sulphur dioxide. If the sulphuric acid solution is poured into water, triphenylmethanol is recovered; if the solution is poured into methanol the methyl ether is formed.

\[ \text{Ph}_3\text{C}^+ + \text{MeOH} = \text{Ph}_3\text{C.O.Me} + \text{H}^+ \]

In the above reaction scheme, steps (i) and (ii) represent the formation of the carbonium ion which reacts with a molecule of hydrazoic acid to give a protonated azide. The latter compound can either (iii) lose a proton to give the neutral azide, or, (iv) by loss of nitrogen and simultaneous migration of a group from bonding with carbon to bonding with nitrogen, give rise to the proton adduct of a Schiff's base, acid hydrolysis of which would yield (v) a carbonyl compound and a primary aromatic amine. Steps (iv) and (v) are in accord with known data concerning the acid-catalysed decomposition of alkyl azides, e.g., Curtius and Darapsky (32) have obtained \( p \)-tolualdehyde and ammonia, \( p \)-toluidine and formaldehyde from \( p \)-tolylmethy azide. In the rearrangement of the protonated azide formed from fluoren-9-ol, loss of nitrogen and rearrangement led to the
formation of the stable, heterocyclic phenanthridinium ion, which was not subject to further reaction.

It had been shown that the Schmidt reaction of carboxylic acids involved an intramolecular rearrangement (33). From this result, together with the fact that phenanthridine was formed from fluoren-9-ol by a ring expansion, Arcus and Mesley (23) considered that rearrangement (iv) proceeded by the simultaneous loss of nitrogen and the intramolecular migration of the aryl group, the four electrons originally constituting the nitrogen lone pair and the C-aryl bond finally appearing as the N-aryl bond and the \( \pi \) electrons of the C-H bond. It was also considered that the isolation of substantial quantities of azide from favourable cases was an indication that the decomposition of the protonated azide is the rate determining step in the reaction, as had been shown for the reactions of carboxylic acids and olefins by McEwen and Mehta (34).

That there was a similarity between the reactions of certain alcohols and olefins and hydrazoic acid was demonstrated by Kuhn and DiDomenico (35). If the group R in the carbonium ion \( \text{RR}'\text{R}''\text{C}^+ \) has a methylene group to the central carbon atom, then this ion might also arise by protonation of the requisite olefin. Both 1:1-diphenylethylene and 1:1-diphenylethanol gave the same products, acetophenone and aniline, on reaction with hydrazoic and sulphuric acids.

\[
\text{Ph}_2\cdot\text{C}=\text{CH}_2 \rightarrow \text{Ph}_2\cdot\text{C}^+\cdot\text{CH}_3 \quad \text{---} \quad \text{Ph}_2\cdot\text{C}^-\cdot\text{CH}_3
\]
It is apparent, on inspection, that from an unsymmetrical diarylethylene \( \text{Ar} \cdot \text{Ar}' \cdot \text{C} = \text{CH}_2 \) (\( \text{Ar} = \text{phenyl} \), \( \text{Ar}' = \text{substituted phenyl} \)) there will result a mixture of products depending on the relative rates of migration of \( \text{Ar} \) and \( \text{Ar}' \) to \( \text{N} \).

\[
\begin{align*}
\text{Ar} \cdot \text{C} = \text{CH}_2 & \quad \text{Ar}' \cdot \text{CO} \cdot \text{CH}_3 \\
\text{Ar}' & \quad \text{Ar} \cdot \text{CO} \cdot \text{CH}_3
\end{align*}
\]

A similar situation holds for substituted fluoren-9-ols,

\[
\begin{align*}
\text{H} & \quad \text{N} \\
\text{CH} = \text{CH} & \quad \text{N}
\end{align*}
\]

and also for substituted diphenylethanols

\[
\begin{align*}
\text{CH} \cdot \text{CH} & \quad \text{CH} \cdot \text{CH}
\end{align*}
\]

In each of these separate cases it has been shown that migration proceeds quantitatively as predicted by Hamnett's \( \sigma \)-values for the electronic character of the substituents in the migrant groups.

Hamnett (36) has found that the effect of a substituent in the meta or para position in a benzene ring upon either the rate or equilibrium of a reaction in which the reacting group is in a side chain attached to the ring may be expressed by the following expression:-
\[ \log \frac{k}{k_0} = \sigma \rho \]

where \( k \) = the rate constant or the equilibrium constant of the reaction with the substituted compound,
\( k_0 \) = the same for the unsubstituted compound,
\( \sigma \) = a constant for the substituent,
\( \rho \) = a constant for the reaction.

It is found that the relationship does not hold for ortho substituted benzene derivatives or for aliphatic compounds. In these cases, Hammett believes that there are considerable changes in kinetic energy of rotation and vibration in addition to changes in potential energy due to the interaction of electrostatic charges. In meta and para substituted benzene derivatives the remoteness of the substituent from the reaction centre and the rigidity of the ring render changes in kinetic energy small, and one is only concerned with the relative changes in potential energy of reactants and products.

\( \sigma \) is a measure of the influence of the substituent on the relative change in potential energy for a series of reactants, and this is related to the electron-availability, influenced by the substituent, at the reaction centre.

Where there is no substituent, \( \sigma = 0 \). When \( \sigma \) is positive electrons are less available at the reaction centre and vice versa.

\( \rho \) is a measure of the susceptibility of the reaction in question to changes in electron density. For purposes of comparison an arbitrary standard was adopted.
Hammett decided to employ an accurately and extensively studied reaction, the ionisation equilibrium of substituted benzoic acids, as the standard. \( \rho \) was assigned the value 1, whence \( \log \frac{k}{k_0} = \sigma \). If for any reaction \( \log \frac{k}{k_0} \) is plotted against \( \sigma \) and a straight line results, it follows that the reaction is dependent on the electronic nature of the substituent, and the extent of this dependence is indicated by the slope of the line, a steep slope indicating marked dependence. A negative value of \( \rho \) indicates that an increase in electron-availability at the reaction centre enhances the reaction rate. If the points are scattered, the reaction in question is not solely dependent on electron-availability at the reaction centre, and, as is the case with ortho substituted benzene derivatives, a steric factor may be involved.

For the rearrangements mentioned above, namely the reactions of \( m- \) and \( p- \)-substituted-diarylethylenes, and \( m- \) and \( p- \)-substituted-diphenylmethanols, it is apparent that \( \log \frac{k}{k_0} \) is the same as the logarithm of the ratio in which the products are formed. In the first case, MeEwen and Mehta (34) plotted the logarithm of product ratio acetophenone: substituted acetophenone against the value for the appropriate substituent and found:-

\[
\log \text{(product ratio)} = -2.11\sigma + 0.293.
\]

These authors also applied the Hammett equation to experimental results obtained by Briggs and Lyttleton (14) for the Schmidt reaction of several substituted benzoic
acids, taking the time for \( \frac{1}{2} \) of the theoretical nitrogen to be evolved to be proportional to \( k \). It was found that there was a linear relationship between \( \log \frac{t_1}{t_0} \) and \( \sigma \), the slope of the line being -1.97.

From the above findings it was deduced that:

1. The rates of migration were almost entirely dependent on the electron density at the point of attachment of the migrating group, and
2. The rate controlling step was the migration of the aryl group with the simultaneous loss of a molecule of nitrogen.

The generality of these deductions is emphasised by the work of Tietz and McEwen (37), and Arcus et al. (26, 38).

Tietz and McEwen (37) have investigated the acid-catalysed decomposition of \( m \)- and \( p \)-substituted-diphenylmethyl azides, and plotted the logarithm of the ratio benzaldehyde: substituted benzaldehyde against the appropriate \( \sigma \) value, and found a linear relationship,

\[ \sigma = -2.03. \]

For the reactions of 2- and 3-substituted-fluoren-9-ols, Arcus, Coombs, and Evans (26) considered that in the rearrangement of the protonated azide \( X \) the rate of migration of ring \( A \) was dependent on the electron-availability
at the point of attachment to \( C(9) \), and that a measure of this availability was given by the \( pK \) of the corresponding 4- or 5-substituted-diphenyl-2-carboxylic acid (XI); similarly for ring B, a measure of the electron-availability at \( C(9) \) was given by the \( pK \) of the corresponding 3'- or 4'-substituted-diphenyl-2-carboxylic acid, (XII). The Hammett relationship was applied to the above system, and the following equation was deduced:

\[
\log \left( \frac{\% \text{ of product from migration of A}}{\% \text{ of product from migration of B}} \right) = r \left( d_K A - d_K B \right),
\]

where \( d_K A \) and \( d_K B \) are the dissociation constants for the diphenyl-2-carboxylic acids XI and XII.

No dissociation constants were available for the diphenyl-2-carboxylic acids, except for the unsubstituted acid (39). However, Berliner and Blommers (40) had shown that the dissociation constants of diphenyl-4-carboxylic acids substituted in positions 3' and 4' bore a linear relationship to the Hammett \( \sigma \) values for these substituents; for the relationship \( \sigma = 0.37 \), Arcus et al. assumed that the strengths of diphenyl-2-carboxylic acids would be influenced in the same way and to the same extent by substituents in the 3' and 4' positions; for the 4 and 5 positions, they assumed the substituents would influence the strengths of diphenyl-2-carboxylic acids in the same way and to the same extent as they do the corresponding benzoic acids. The Hammett equation was used to calculate the strengths of diphenyl-2-carboxylic acids as follows:
If \( k' \) = dissociation constant for the substituted diphenyl-2-carboxylic acid,

\( k'_o \) = the same for the unsubstituted acid,

\( k \) = the same for the substituted benzoic acid,

\( k_o \) = the same for benzoic acid,

then,

\[
\log k' - \log k'_o = \sigma \psi \frac{\log k - \log k_o}{\log k - \log k_o}
\]

Substituting \(- \log K = \psi K\), etc.,

\[
\psi k'_o - \psi k' = \sigma (\psi k'_o - \psi k)
\]

\[
\psi k' = \psi k'_o - \sigma (\psi k'_o - \psi k)
\]

where \( \sigma = 0.37 \) for 3' and 4' substituents,

and \( \sigma = 1 \) for 4 and 5 substituents.

It was found that there was a linear relationship between the logarithms of the product ratios and the differences between the \( \psi k \)'s of the substituted diphenyl-2-carboxylic acids, the slope of the line being -2.817. It was considered that the results shewed a simple correlation between the migratory aptitude of a group and its capacity for electron release at the migration origin in the reaction of fluoren-9-ols with hydrazoic acid in the presence of sulphuric acid.

Thus it is apparent that simple rules have been formulated enabling one to predict the probable ratio of isomers formed in the reaction between hydrazoic acid and certain alcohols and olefins in the presence of strong acids. However, this is not the case with regard to the Schmidt reaction of substituted benzophenones.
Bibliography to the Introduction.

(1) Schmidt, Per., 1924, 57, 704
(3) Schmidt, Per., 1925, 58, 2413.
(5) Oliveri-Mandala, Gazzetta, 1916, 4611, 137.
(6) Gleu, Per., 1928, 61, 702.
(12) Oliveri-Mandala, Gazzetta, 1925, 55, I, 271.
(15) Schmidt, D.R.P. 500435.
Smith and Ashby, *J. Amer. Chem. Soc.*, 1950, 72, 2503


(22) Smith, *J. Amer. Chem. Soc.*, 1954, 76, 431


(32) Curtius and Darapsky, *Ber.*, 1902, 35, 3229


The Objects of the Present Investigation.

The objects of the present investigation were to extend the synthetic uses of the reaction between certain cyclic compounds and hydrazoic acid in the presence of strong acids, in order to gain further knowledge of its mechanism. To this end the Schmidt reaction of 2-acylbenzoic acids was investigated in order to determine the effect of substituents on the course of the reaction, which was thought to proceed via a cyclic carbonium ion, and as a route to the benzoxazinones. An investigation of the reactions between 1:2-benzofluorenone and 1:2-benzofluoren-9-ol and hydrazoic acid in the presence of strong acids was also to be made in order to ascertain whether or not a steric effect on the course of these reactions would be apparent; further, this investigation would serve as an introduction to the possible synthesis of benzophenanthridones, and benzophenanthridines, of the six possible isomers of each class only two being known in each case. Thirdly, an attempt was to be made to subject other classes of cyclic compounds to the above reactions.

The statements briefly made above are enlarged in the three sections of the discussion of the experimental results.
PART II

THE DISCUSSION OF THE EXPERIMENTAL RESULTS.
It was found by Badger, Howard, and Simons (1) that the Schmidt reaction of 2-benzoyl- and 2-α-naphthoylbenzoic acids gave, in the presence of chloroform, 2-substituted-6-oxo-4:5-benz-1:3-oxazines. If the reaction was carried out in the presence of trichloroacetic acid, the main product was an N-substitutedanthranilic acid. These authors considered that the reaction was that of a "ketonic" Schmidt reaction, and used Smith's mechanism (2, see p. 9) to explain their results. They considered that the benzoxazines were formed from the initially-formed N-substituted-anthranilic acids by dehydration of the latter compounds.

In each of these instances the \( \text{α}-\text{carboxyphenyl} \) group migrated in the course of the reaction.
Migration aptitude is a term introduced by Bachmann in some studies on the pinacol–pinacolone rearrangement.

\[
\begin{align*}
R' & - C - OH & R' & - C - R & R' & - C - R \\
\downarrow & & \downarrow & & \downarrow \\
R' & - C - OH & R' & - C = 0 & R' & - C = 0 \\
\downarrow & & \downarrow & & \downarrow \\
R & & & & H_2O
\end{align*}
\]

The relation of the structure of \( R \) and \( R' \) to the ratio of ketones produced was of interest, and Bachmann, from the experimental ratios found, calculated the migration aptitude of a given group relative to that of the phenyl group, which he took as a standard. For example, when \( R = \text{p-tolyl} \), and \( R' = \text{phenyl} \), it was found that the migration ratio \( R : R' \) was 94:16, whence the migration aptitude of the \( \text{p-tolyl} \) group is 15.7 that of the phenyl group. It was found that phenyl groups carrying electron-releasing substituents had high migration aptitudes.

It was pointed out that earlier work by Smith had indicated that migration aptitudes did not play a large part in determining which group in an unsymmetrical ketone would migrate during a Schmidt reaction on the ketone. It appeared that in such a reaction, the group having the greater bulk in the vicinity of the carbonyl group would migrate preferentially. Badger et al. agreed with Smith that
The Schmidt Reaction of some Unsymmetrical Ketones.
(Badger, Howard, and Simons (1)).

\[
\text{R.CO.R' } \rightarrow \text{R.NH.CO.R' + R.CO.NH.R'}
\]

<table>
<thead>
<tr>
<th>R</th>
<th>R'</th>
<th>Method A</th>
<th>Method B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Yield due to migration of:</td>
<td>Yield due to migration of:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R</td>
<td>R'</td>
</tr>
<tr>
<td>2-carboxy-phenyl</td>
<td>phenyl</td>
<td>93%</td>
<td>-</td>
</tr>
<tr>
<td>&quot;</td>
<td>-naphthyl</td>
<td>30%</td>
<td>-</td>
</tr>
<tr>
<td>phenyl</td>
<td>&quot;</td>
<td>did not react</td>
<td>64%</td>
</tr>
<tr>
<td>&quot;</td>
<td>9-anthryl</td>
<td>&quot;</td>
<td>did not react</td>
</tr>
<tr>
<td>&quot;</td>
<td>2-thiophenyl</td>
<td>&quot;</td>
<td>did not react</td>
</tr>
<tr>
<td>&quot;</td>
<td>3-(2:5-dimethyl) -thiophenyl</td>
<td>&quot;</td>
<td>did not react</td>
</tr>
<tr>
<td>&quot;</td>
<td>mesityl</td>
<td>did not react</td>
<td>did not react</td>
</tr>
</tbody>
</table>

+ 2-phenyl-6-oxo-4:5-benz-1:3-oxazine, 67%.
N-benzoylanthranilic acid, 31%. 
Table IIIb.

The Comparative Extents of Migration of R-\(\text{[Diagram]}\) for
the Schmidt Reaction, and the Beckmann Rearrangement.

(Smith and Korovitz, (4)).

The fractions migrating are R-\(\text{[Diagram]}\) and \(\text{[Diagram]}\).

<table>
<thead>
<tr>
<th>R</th>
<th>Schmidt Reaction</th>
<th>Beckmann Rearrangement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl</td>
<td>0.59 : 0.41</td>
<td>0.56 : 0.44 (6)</td>
</tr>
<tr>
<td>NO₂</td>
<td>0.51 : 0.49</td>
<td>0.50 : 0.50 (7)</td>
</tr>
<tr>
<td>CH₃</td>
<td>0.54 : 0.46</td>
<td>0.49 : 0.51 (6)</td>
</tr>
<tr>
<td>CH₃O</td>
<td>0.61 : 0.39</td>
<td>0.49 : 0.51 (6)</td>
</tr>
<tr>
<td>C₆H₅</td>
<td>0.52 : 0.48</td>
<td>0.51 : 0.49 (6)</td>
</tr>
</tbody>
</table>
steric effects were important, but, as is shewn in Table Ib, there were certain exceptions, e.g., with α-benzoylnaphthalene, there was a 64% yield of α-naphthenilide, resulting from the migration of the smaller phenyl group. It was concluded that the configuration of the intermediate

\[ \text{R} - \text{C} \]
\[ \text{N} - \text{R}^\prime \]

was not determined solely by the steric environment of the carbonyl group.

Smith and Horowitz (4) considered that the ketonic Schmidt reaction, and the Beckmann rearrangement of ketoximes followed parallel courses, and that the factors which governed the ratio of isomeric amides formed in the Schmidt reaction of a ketone, and the ratio of isomeric oximes formed in the oximation of the same ketone were similar. (See Table IIIb) However, Smith (5) shewed that there were certain exceptions. For example, the Schmidt reaction of 2-benzoylbenzoic acid gives N-benzoylanthranilic acid in good yield (see Table Ib). Oximation of the acid gives an oxime anhydride, a keto-benzoxazine, which is stable in the presence of phosphorus pentachloride and acetyl chloride. With concentrated sulphuric acid it gives phthalic acid, and aniline, the former in 90% yield, the latter in somewhat lower yield (8).
Arcus and Coombs (9), prior to the publication of Smith's paper (5), had shown that the Schmidt reaction of 2-benzoylbenzoic acid was not of the ketonic type, and that the initial product of the reaction was the benzoxazine, from which, by hydrolysis, was obtained the substituted anthranilic acid. These authors (9) reported the following facts concerning the reaction:

The oxazine, when its trichloroacetic-sulphuric acid solution is diluted with water, becomes hydrolysed to N-benzoylanthranilic acid. If the acid solution is diluted with chloroform, and the mixture shaken with cold water, the oxazine can be recovered nearly quantitatively, and when the acidic solution from the Schmidt reaction in trichloroacetic acid is similarly treated, the oxazine is obtained in 91% yield.

Newman, Kuivila, and Garrett (10) have found that 2-benzoylbenzoic acid in solution in sulphuric acid has a van't Hoff i factor of 3.8, in agreement with the equation below, which requires \( i = 4 \).

\[
\begin{align*}
\text{CO} & \quad \text{CO} \\
\text{H} & \quad \text{H} \\
\text{CO} & \quad \text{CO} \\
\text{H} & \quad \text{H}
\end{align*}
\]

\[+ 2\text{H}_2\text{SO}_4 \]

\[
\begin{align*}
\text{O} & \quad \text{O} \\
\text{H} & \quad \text{H} \\
\text{O} & \quad \text{O} \\
\text{H} & \quad \text{H}
\end{align*}
\]

\[+ \text{H}_3\text{O}^+ + 2\text{HSO}_4^-\]
Further evidence for the cyclic ion was afforded by the observation of Newman (11), who found that a considerable amount of methyl pseudo-2-benzoylbenzoate is formed when a solution of 2-benzoylbenzoic acid in sulphuric acid is poured into methanol.

```
+MeOH  →  +H^+
```

It was considered that the oxazine was formed in the following way:

Interaction of hydrazoic acid and the cyclic cation yields a protonated azide (III) which suffers loss of nitrogen, and the remainder of the molecule simultaneously undergoes rearrangement, as shown, to give the proton adduct of the oxazine (IV), the four electrons initially present as the A-CH bond and the nitrogen lone pair appearing finally as the A-NH^+ bond and π-electrons of the NH-CH bond.

This mechanism closely resembles that given for the formation of phenanthridine, by the reaction of hydrazoic/sulphuric acid with fluoren-9-ol (Arcus and Mesley (12)).

It was found (9) that 2-π-toluoylbenzoic acid, by a similar reaction, gave 6-oxo-2-π-toly 1:4:5-benz-1:3-oxazine, (83%).

x See Plate I
It was considered that further investigation into the reaction of 2-acylbenzoic acids and hydrazoic acid would be of interest. To this end, seven 2-acylbenzoic acids (I, R representing groups of different electronic character and size) were subjected to the Schmidt reaction under standardised conditions in order to ascertain whether there is a relationship between the nature of R and (a) the rate of formation of oxazine, and (b) the extent of rearrangement which leads, not to the oxazine, but ultimately to the amine RNH₂.

Further to this, it was thought the Schmidt reaction of alkylidenephthalides would be of interest, since these should give the same ion, on protonation, as the corresponding 2-acylbenzoic acid in sulphuric acid.
The Preparation of 2-Acylbenzoic Acids and Alkylidene-Phthalides.

The preparations of the 2-acylbenzoic acids used in this work fall into three classes:

(i) from 2-benzoylbenzoic acid,

(ii) by interaction between phthalic anhydride, and a suitable reagent in the presence of aluminium chloride,

(iii) from an alkylidene-phthalide.

Literature references are given in the appropriate places in the Experimental Section.

2-β-Nitrobenzoylbenzoic acid was prepared by nitrating 2-benzoylbenzoic acid in the presence of fuming sulphuric acid.

\[ \text{CO} - \text{C}_6\text{H}_5 - \text{CO}_2\text{H} \xrightarrow{\text{NO}_2^+} \text{CO} - \text{NO}_2 - \text{C}_6\text{H}_5 - \text{CO}_2\text{H} + \text{H}^+ \]

2-β-Chlorobenzoyl-, 2-β-methoxybenzoyl-, 2-α-naphthoyl-, and 2-mesitoyl-benzoic acids were prepared by a Friedel and Crafts method: phthalic anhydride was allowed to react, in the presence of aluminium chloride, with chlorobenzene, anisole, naphthalene, and mesitylene.
The alkyldenedephthalides were prepared by a Perkin reaction, (Michael and Gabriel (13) have shown that phthalic anhydride may be used as the carbonyl component in such a reaction), and these were converted by concentrated aqueous alkalies into 2-acylbenzoic acids.
The Schmidt Reaction of 2-Acylbenzoic Acids and Alkylidene-
Phthalides.

The 2-acylbenzoic acids and alkylidene-phthalides were subjected to the Schmidt reaction under the following standardised conditions:

To a suspension of sodium azide (0.0400 mole) in chloroform, cooled in ice water, was added, dropwise during 15 minutes, sulphuric acid (98%). After a further 15 minutes stirring, the ice-water was replaced by a water-bath at 30°C. and, during 1 hour, the keto acid or alkylidene-phthalide (0.0200 mole), in solution or in suspension in chloroform, was added. The mixture was stirred for a further 2 hours, and then poured on to ice. After being mechanically shaken for half an hour, the mixture, together with washings of water, and chloroform, was filtered (Product I). The acid aqueous layer was washed with chloroform, and the combined chloroform solutions were washed with a saturated aqueous solution of sodium hydrogen carbonate, and with water, dried over sodium sulphate, and evaporated to dryness (Product II). The sodium bicarbonate washings were acidified, and the precipitate collected (Product III). The aqueous sulphuric acid solution was concentrated somewhat, and made alkaline with sodium hydroxide, and extracted with ether; the ethereal solution was dried over sodium
### Table IIIb.
The Reaction of 2-Acylbenzoic Acids, and Alkylideneanthralides with Hydrazoic and Sulphuric Acids.

<table>
<thead>
<tr>
<th>2-Acyl-benzoic acid (g.)</th>
<th>Products</th>
<th>Weight (g.)</th>
<th>Percentage Yield (Average)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-&lt;p&gt;-methoxybenzoyl- (5.12)</td>
<td>2-&lt;p&gt;-methoxyphenyl-6-oxo-4:5-benz-1:3-oxazine</td>
<td>3.68</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>1-&lt;p&gt;-carboxyphenyl-5-&lt;p&gt;-methoxyphenyl-1:2:3:4-tetrazole</td>
<td>0.19</td>
<td>4</td>
</tr>
<tr>
<td>2-&lt;p&gt;-chlorobenzoyl- (5.21)</td>
<td>2-&lt;p&gt;-chlorophenyl-6-oxo-4:5-benz-1:3-oxazine</td>
<td>4.31</td>
<td>84</td>
</tr>
<tr>
<td></td>
<td>&lt;p&gt;-chloroaniline</td>
<td>0.07</td>
<td>3</td>
</tr>
<tr>
<td>2-&lt;p&gt;-nitrobenzoyl- (5.42)</td>
<td>2-&lt;p&gt;-nitrophenyl-6-oxo-4:5-benz-1:3-oxazine</td>
<td>4.61</td>
<td>87</td>
</tr>
<tr>
<td></td>
<td>&lt;p&gt;-nitroaniline</td>
<td>0.11</td>
<td>4</td>
</tr>
<tr>
<td>2-mesityl- (5.36)</td>
<td>2-mesityl-6-oxo-4:5-benz-1:3-oxazine</td>
<td>1.66</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>N-mesitylphthalimide</td>
<td>1.01</td>
<td>13</td>
</tr>
<tr>
<td>2-&lt;p&gt;-naphthoyl- (5.52)</td>
<td>2-&lt;p&gt;-naphthyl-6-oxo-4:5-benz-1:3-oxazine</td>
<td>2.51</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>&lt;p&gt;-naphthylamine</td>
<td>0.20</td>
<td>7</td>
</tr>
<tr>
<td>2-phenylacetyl- (5.16)</td>
<td>N-phenylacetylanthranilic acid</td>
<td>4.07</td>
<td>85</td>
</tr>
<tr>
<td>2-butyryl- (3.84)</td>
<td>N-n-butyrylanthranilic acid</td>
<td>3.24</td>
<td>77</td>
</tr>
<tr>
<td></td>
<td>n-propylamine</td>
<td>0.04</td>
<td>5</td>
</tr>
<tr>
<td>Alkylideneanthralide (g.)</td>
<td>Products</td>
<td></td>
<td></td>
</tr>
<tr>
<td>benzylideneanthralide (4.44)</td>
<td>N-phenylacetylanthranilic acid</td>
<td>2.64</td>
<td>62</td>
</tr>
<tr>
<td>propylideneanthralide (3.84)</td>
<td>N-n-butyrylanthranilic acid</td>
<td>2.89</td>
<td>69</td>
</tr>
<tr>
<td></td>
<td>n-propylamine</td>
<td>0.05</td>
<td>5</td>
</tr>
</tbody>
</table>
sulphate, and evaporated to dryness (Product: amine).

Each reaction was carried through in duplicate and the products, and the yield in each experiment together with the average percentage yield are listed in Table IIIb.

2-Phenyl- and 2-<£-tolyl-6-oxo-4:5 benz-1:3-oxazine have been obtained (9) in 80 and 88% yield, respectively, by a procedure almost identical with that of the present work. It is apparent from these results together with those of the Table that (apart from the reaction of 2-mesitoxybenzoic acid) the presence of groups of markedly different electronic character in the benzoyl group have little effect on the course of the reaction, the oxazine being isolated in 75-88% yield. The effects which these substituents exert are as follows: methyl as a &- or 0-substituent is a +I group, in addition to which it can exert hyperconjugative electron release; methoxyl and chlorine are -I, and +T groups; nitro is a -T, -M group. (+T electronic movements here represent both "permanent" mesomeric (+M) effects, and the capacity for electromeric (+M) release on demand during migration.

The yield of oxazine from 2-a-naphthoylbenzoic acid was somewhat lower than those above; that from 2-mesitoxybenzoic acid was comparatively small, and, unlike any other, this reaction yielded an appreciable quantity of the phthalimidic acid. 2-Phenylacetyl- and 2-butyryl-benzoic acid gave the N-acylanthranilic
acids in yields which lie in the range of those of the phenyl-oxazines, above. Benzylidene- and propylidene-phthalides also gave the N-acylanthranilic acids. The yields of major products in these two cases were somewhat lower than in the experiments with the corresponding keto-acids.

In four cases a primary amine was isolated from the reaction mixture, and characterised. p-Chloro- and m-nitro-aniline, α-naphthylamine, and n-propylamine were so obtained; the largest yield was that of α-naphthylamine: 7%. In the reaction of 2-α-methoxybenzoylbenzoic acid, a primary aromatic amine was isolated, but not characterised.

The mechanism of the formation of 2-substituted-6-oxo-4:5-benz-1:3-oxazines, and N-acylanthranilic acids.

(See Plate 1).

The mechanism for the formation of 2-phenyl- and 2-α-tolyl-6-oxo-4:5-benz-1:3-oxazines from 2-benzoyl- and 2-α-toluoyl-benzoic acids has already been discussed (9). It is considered that the present work affords additional evidence for the correctness of this mechanism.

It has already been shown (see p. 30) that 2-benzoyl-benzoic acid, in solution in sulphuric acid, exhibits a van't Hoff "i" factor of 3.8, which is in agreement with
the equation which leads to the formation of the cyclic ion (II, \( R=\text{phenyl} \)). One other 2-acylbenzoic acid relevant to the present work has been investigated in a similar way. Newman and Deno (14) have shown that 2-mesitylbenzoic acid, in solution in sulphuric acid, exhibits a van't Hoff "\( i \)" factor of 3.68, which these authors consider to be evidence for the formation of the cyclic ion (II, \( R=2:4:6\)-trimethylphenyl).

The same products were obtained from the Schmidt reactions of (a) 2-phenylacetylbenzoic acid and benzylidene-phthalide, and (b) 2-butyrylbenzoic acid and propylidene-phthalide. That reaction succeeds with the alkylidene-phthalides is considered to support the mechanism of the reaction via the cyclic ion (VII), since the ion (IX), derived from the protonation of the 2-acylbenzoic acid regarded simply as a ketone, can only arise by the hydration, as well as the protonation of the alkylidene-phthalide, a process unlikely to occur in concentrated sulphuric acid.

It is evident, therefore, that the Schmidt reaction of 2-acylbenzoic acids cannot be regarded as a "ketonic" Schmidt reaction as has been stated by Badger et al. (1), and Smith (5).

The isolation of the \( N \)-acylanthranilic acid from the reaction when \( R \) is alkyl or aralkyl (Plate I) is attributed to the hydrolysis of the initially-formed oxazine at the point where the chloroform-sulphuric acid reaction mixture is poured on to crushed ice. 2-Benzyl- and 2-\( n \)-propyl-6-oxo-4:5-benz-1:3 oxazines were prepared by the ring closure of the
corresponding N-acyl-anthranilic acids by boiling with acetic anhydride according to Zentmeyer and Wagner (15). Each was then subjected to the conditions of the Schmidt reaction, but without sodium azide; hydrolysis occurred, and 97, and 88% respectively of the N-acylanthranilic acid was isolated. The marked difference in the case of hydrolysis of 2-alkyl- and 2-aryl-oxobenzoxazines has been noted by the above authors, and is demonstrated by the following observations. 2-Benzyl-, 2-n-propyl-, and 2-p-chlorophenyl-6-oxo-4:5-benz-1:3-oxazines were heated for 30 minutes with 80% acetic acid, and 80% ethanol: from the 2-benzylloxazine 94 and 88% of N-phenylacetylanthranilic acid were isolated, and from the 2-n-propyloxazine 90 and 95% of N-butyralanthranilic acid; of the 2-n-chlorophenyloxazine 73 and 96% were recovered, 13% of N-p-chlorobenzoylanthranilic acid being isolated from the treatment with aqueous acetic acid.
Table IVb.

The ratio of isomers formed in the Schmidt reaction of a ketone, and the corresponding secondary alcohol.

<table>
<thead>
<tr>
<th>R''</th>
<th>% migration a</th>
<th>% migration b</th>
<th>% migration a</th>
<th>% migration b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl</td>
<td>59</td>
<td>41</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>MeO</td>
<td>61</td>
<td>39</td>
<td>87</td>
<td>13</td>
</tr>
<tr>
<td>NO₂</td>
<td>51</td>
<td>49</td>
<td>4</td>
<td>96</td>
</tr>
</tbody>
</table>
The character of the substituent in the benzoyl group in the reactions of Table IIIb does, however, exert a limited effect on the course of the reaction, as may be demonstrated as follows:

The yield of product resulting from the migration of the "2-carboxyphenyl" group in the reactions with 2-\(\text{p}-\text{methoxy-}\), 2-\(\text{p}-\text{chloro-}\), and 2-\(\text{m}-\text{nitro-}\)benzoylbenzoic acid was 79, 84, 87% respectively, while the yield, in the second and third cases, of product resulting from a counter rearrangement was 3 and 4% respectively. In the first case there was a 2% yield of a primary aromatic amine which was presumably \(\text{p}-\text{anisidine}\); however, attempts to characterise this body did not succeed.

It is interesting to compare these results with those for the Schmidt reaction of \(\text{p}-\text{methoxy, p-chloro, and p-nitrobenzophenones}\), and the corresponding secondary alcohols (see Table IVb). In the former cases, as has already been mentioned (see p.10), the electronic character of the substituent "\(\text{R}\)" has little effect on the ratio of isomers formed in the reaction. In the latter cases however, Tietz and McEwen (16) have shown that the nature of the substituent has a great bearing on the ratio of isomers formed. Let us consider the two extreme cases. When \(\text{R}'' = \text{MeO}\), the phenyl group bearing the substituent had the greater tendency to migrate (\(\text{MeO, -I, +T}\)). When \(\text{R}'' = \text{NO}_2\), the unsubstituted group had the greater tendency to migrate (\(\text{NO}_2, -\text{I, -T}\)). Tietz and McEwen have shown that the ratio of isomers obtained in this reaction with a benzhydrol carrying a given \(\text{m}\) or \(\text{p}\) substituent is dependent
on the electronic nature of that substituent. A plot of the logarithm of the ratio benzaldehyde : substituted benzaldehyde against the Hammett \( \sigma \) function of the substituent is linear.

It is seen, Fig. I, that where

\[ \text{a} = \text{yield of product due to the migration of the "2-carboxyphenyl" group,} \]

and \( \text{b} = \text{yield of amine,} \)

the plot of \( \log \frac{\text{a}}{\text{b}} \) against the \( \sigma \) function is linear. It should however, be pointed out that, since \( \text{a} \) is large and \( \text{b} \) small, the former is a relatively more accurate quantity than the latter, whence the quotient \( \frac{\text{a}}{\text{b}} \) is mainly dependent on numerical accuracy of \( \text{b} \). A similar graph constructed from the results of Smith and Horowitz (4) for the corresponding substituted benzophenones is not linear.

The yield of oxazine is markedly affected by the presence of ortho groups in \( R \). The yield of oxazine from the reaction with 2-\( \alpha \)-naphthoylbenzoic acid was 51%, and the yield of amine was 7%. With 2-mesitylbenzoic acid, the yield of oxazine was only 25%, and this reaction was unique in that there was an appreciable yield (13%) of N-mesitylphthalamidic acid, which was characterised in the following way: on fusion with resorcinol in the presence of sulphuric acid, it gave fluorescein, and, by heating with acetic acid, it was cyclised to N-mesitylphthalamide. The extent of rearrangement with migration of \( R \) is seen to be greatest in the two examples (mesityl and \( \alpha \)-naphthyl) in which \( R \) has the greatest bulk in the neighbourhood of the keto carbon atom.
Fig. I

<table>
<thead>
<tr>
<th>Substituent</th>
<th>%a</th>
<th>%b</th>
<th>log_{10} a/b</th>
<th>σ</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-MeO</td>
<td>79</td>
<td>2</td>
<td>1.597</td>
<td>-0.268</td>
</tr>
<tr>
<td>1-Cl</td>
<td>84</td>
<td>3</td>
<td>1.147</td>
<td>+0.277</td>
</tr>
<tr>
<td>m-NO₂</td>
<td>87</td>
<td>4</td>
<td>1.336</td>
<td>+0.710</td>
</tr>
</tbody>
</table>
The mechanism of the formation of N-substituted-phthalamidic acids, and primary aromatic amines.

The exact mechanism of the counter rearrangement is not fully understood. It had been supposed that there might be a partition of the various products, or their precursors, in the above reactions, between the chloroform and sulphuric acid layers. Accordingly the following procedure was applied to the reactions with 2-phenylchlorobenzoyl-, 2-mesityl-, and 2-butyrylbenzoic acids, compounds which yield as main end products respectively oxazine, oxazine and phthalamidic acid, and N-acylanthranilic acid; the chloroform layer was separated at the end of the reaction, but before the addition to ice, and evaporated; in each instance it contained no solute. All the products at this stage of the above reactions are, therefore, present in the sulphuric acid layer, presumably as their hydrogen sulphates.

In completion of the above reactions, the separated sulphuric acid layers were poured on to ice; essentially the same products as those of Table IIIb were obtained, except that the absence of chloroform as a diluent led to certain secondary reactions. The reaction with 2-phenyl-
chlorobenzoylbenzoic acid gave N-p-chlorobenzoylbenzoylanthranilic acid, together with a much reduced yield of oxazine, a result ascribed to the hydrolysis of the oxazine, the occurrence of which, on dilution of a sulphuric acid solution of this compound, was directly confirmed. The analogous products have been obtained from the Schmidt reaction with 2-benzoylbenzoic acid (9) on dilution in the presence and absence of chloroform. The yield of 2-mesityl-6-oxo-4:5-benz-1:3-oxazine (26%) is close to that (Table IIIb) obtained in the presence of chloroform, and no hydrolysis was encountered; the greater resistance of this oxazine is attributed to protection of the site of hydrolysis by the o-methyl groups of the mesityl substituent. In one instance N-mesitylphthalamidic acid (22%) was obtained, but in two cases it had become cyclised to N-mesitylphthalimide (20%), the occurrence or absence of conversion of the phthalamidic acid to the phthalimide depending, apparently, on small variations in experimental conditions. From 2-butyrylbenzoic acid there was obtained N-p-butyrylanthranilic acid in nearly the same yield as in Table IIIb.

It appeared possible that the amine NH₂ is formed by the hydrolysis of the corresponding phthalamidic acid. Accordingly, N-m-nitrophenylphthalamidic acid was subjected to the conditions of the Schmidt reaction: m-nitroaniline (29%) was isolated, the remaining phthalamidic acid being partly
recovered (39%), and in part isolated as the phthalimide. Hydrolysis of the phthalamic acid is, therefore, too slow to account satisfactorily for the presence of amine.

It is apparent on inspection that the intermediate (III) (Plate I) could rearrange in two ways (Plate II) other than that which leads to the oxazine. Firstly, migration of R might lead to the intermediate (X), and thence to an iso-anil (XII); secondly, migration of oxygen may lead to a 3-substituted-6-oxo-4:5-benz-1:2-oxazine, these rearrangements being in other respects closely analogous to that in which the "2-carboxyphenyl" group migrates.

A survey of the literature showed that certain iso-anils had been prepared. Van der Meulen (17) obtained phthaloiisoanil (R = phenyl) by warming N-phenylphthalamic acid with acetyl chloride in the presence of carbon disulphide, with subsequent decomposition of the hydrochloride by aqueous potassium hydroxide in the presence of ether. This author found that the isoanil was decomposed by hydrogen chloride to phthalic acid bis [anilide], phthalic anhydride, and N-phenylphthalimide.

It is also recorded that the corresponding benzyl, and the m-nitrophenyl compounds have been prepared. However, the preparation of the latter compound is in doubt. Kuhara, Nomatsu, and Nishiyori (18), and Dobreff (19) reported that phthaloiiso-m-nitroanil had been prepared; these preparations were repeated by Sherrill, Schaeffer, and Shoyer (20), who
reported that no trace of the isoanil was obtained. Kuhara et al. claim to have prepared this body by treating an ethereal solution of \( m \)-nitroaniline with an ethereal solution of phthaly chloride at \(-10^\circ\). Sherrill et al. showed that the products were \( N-m \)-nitrophenylphthalimide, \( N-m \)-nitrophenylphthalamic acid, and phthalic acid bis[\( m \)-nitroanilide]. By heating together \( m \)-nitroaniline and phthaly chloride, according to Dobreff's method, they obtained \( N-m \)-nitrophenylphthalimide, and phthalic acid bis[\( m \)-nitroanilide]. Further to these experiments, Sherrill et al. attempted to prepare phthaloiso\( m \)-nitroanil by Van der Meulen's method (17), but were unsuccessful.

Attempts have been made to prepare the mesityl analogue by the latter method, but these proved unsuccessful. \( N \)-Mesitylphthalamic acid was partially converted to \( N \)-mesitylphthalimide. An attempt to prepare phthaloisoanil also failed.

In view of the failure to prepare the mesityl analogue, and of the report that the \( m \)-nitrophenyl analogue had not, in fact, been prepared, it was not possible to obtain experimental evidence with regard to an isoanil being an intermediate in the reaction.

The Beckmann rearrangement of 3-phenyl-6-oxo-4:5-benz-1:2-oxazine has received attention. Thorpe (21) reported that if 2-benzoylbenzoic acid, hydroxylamine hydrochloride, and ethanol were heated together in a sealed tube at \( 130^\circ \) for
eight hours, the major product, on crystallisation from acetic acid had m.p. 191-193°; if this substance was sublimed, and crystallised from acetic acid, the product had m.p. 203°, and this, on heating in a sealed tube with hydrochloric acid, was hydrolysed to phthalic acid and aniline hydrochloride. Thorpe considered that an oxime of 2-benzoylbenzoic acid was formed initially, and that this, by the action of temperature and hydrochloric acid, underwent a Beckmann rearrangement to give N-phenylphthalimidic acid, which was subsequently cyclised to N-phenylphthalimide, which in turn hydrolysed to phthalic acid and aniline. (Meyer and Sundmacher (22) record m.p. 170° (decomp.) for the phthalimidic acid, which then solidifies and remelts at 203°, the melting point of N-phenylphthalimide.) Thorpe also prepared what he thought was the oxime (he later shewed that it was an oxime anhydride (23)), and found that, when it was heated in a sealed tube with hydrochloric acid, it gave phthalic acid and aniline hydrochloride.

Further investigations were made by Meisenheimer and Meis (8), who found that the oxime-anhydride, by the action of concentrated sulphuric acid, gave phthalic acid (90%), and a somewhat lower yield of aniline. They considered that N-phenylphthalimide was first formed, but did not isolate it; their description of their experimental procedure would lead one to expect that if this compound had been formed, they would have hydrolysed it.
Since, on inspection, reactions of the type described above might lead to the presence of a primary aromatic amine in the Schmidt reaction of a keto-acid of the type considered, the following reactions were carried out.

(a) Greer and Pearson (24) prepared the oxime of 2:4:6-trimethylacetophenone by allowing a mixture of the ketone, hydroxylamine hydrochloride, and pyridine to stand at room temperature for four weeks. They obtained the oxime in fair yield, stirred it with concentrated sulphuric acid, and obtained 2:4:6-trimethylacetanilide in 94% yield. In view of this preparation, and bearing in mind Thorpe's experiment (21), 2-mesitoylbenzoic acid, hydroxylamine hydrochloride, and pyridine were heated together in a sealed tube at 120° for eight hours. From the resulting mixture was obtained 25% of unreacted acid. An attempt to prepare the oxime-anhydride of this acid by a method similar to that used by Weisenheimer and Meis (3) to prepare the oxime-anhydride of 2-benzoylbenzoic acid, by heating the acid, hydroxylamine hydrochloride, barium carbonate, and ethanol under reflux, gave a compound which on heating melted at 110-120° (decomp.), then solidified, and remelted at 209°. It did not contain nitrogen, and was considered to be an ethyl alcoholate of 2-mesitoylbenzoic acid. There was no trace of a nitrogenous compound.

(b) 3-π-Chlorophenyl-6-oxo-4:5-benz-1:2-oxazine was prepared by heating together, under reflux, 2-π-chlorobenzoylbenzoic acid, hydroxylamine hydrochloride, and ethanol.
The compound was subjected to the conditions of the Schmidt reaction (sodium azide omitted). There was obtained N-\textit{p}-chlorophenylphthalamic acid (20\%), and a solid, m.p. 152-153\degree which was not identified. There was no trace of \textit{p}-chloroaniline.

The present findings with regard to the two rearrangements (Plate II) of the intermediate III which lead, not to the 2-substituted-6-oxo-4:5-benz-1:3-oxazine, but to a phthaloisoanil (XII) and to a 3-substituted-6-oxo-4:5-benz-1:2-oxazine (XIII) are as follows:-

(1) The formation of phthalamidic acid and amine \textit{via} the isoanil remains a theoretical possibility; however, efforts to prepare an isoanil did not succeed.

(2) It has been found experimentally that the phthalamidic acid can be formed from the 3-substituted-6-oxo-4:5-benz-1:2-oxazine (route XI, XIII), but no amine resulted.

It has also been shown

(3) That hydrolysis of the phthalamidic acid is too slow to account for the yields of amine obtained.

The exact mechanism of the rearrangement which leads to the amine is, therefore, not understood.

The conversion of substituted fluorenones into phenanthridones by means of the Schmidt reaction, and the synthesis of phenanthridines from substituted fluoren-9-ols by the interaction of the latter compounds with hydrazoic acid in the presence of sulphuric acid has been described (Introduction, p. 16).

The above reactions with fluorenones and fluoren-9-ols bearing a group which might sterically interfere with the course of the reaction at the keto, or alcoholic part of the molecule have not as yet been investigated. In this respect, it was considered that a study of the 1:2-benzofluorene system would be of interest.

A survey of the literature has shown that of the 6 benzophenanthridones, and of the 6 benzophenanthridines only two isomers of each class of compound are known, namely the 1:2- and 7:8-isomers. A study of the reaction with 1:2-benzofluorene derivatives would, since the compounds that could be formed are known, serve as an introduction to syntheses in the benzophenanthridone and benzophenanthidine field.

Graebe and Hönigsberger (25) found that the Beckmann rearrangement of chrysenequinone mono-oxime (II) lead to two amido-acids (III, IV). At a later date, Graebe (26) assigned
structures to these compounds on the basis of the following experimental evidence:—

(a) If either acid was fused with caustic soda at 210-220°, chrysodiphenic acid was produced.

(b) The lower melting isomer, m.p. 220°, did not form a methyl ester, when treated with methanol and hydrogen chloride, and was hydrolysed to chrysodiphenic acid by heating it with concentrated hydrochloric acid at 150°.

(c) The other isomer, m.p. 275°, gave a methyl ester readily, but was not hydrolysed by hydrochloric acid at 150°. It was considered that in case (b), the carboxylic acid group is in a hindered site, and that in (c) the amide group occupies this site. The isomer m.p. 275° was assigned structure (III), 2-o-carboxyphenyl-l-naphthoamide. The isomer m.p. 220° was assigned structure (IV), 2-o-benzamido-l-naphthoic acid.

Graebe found that these compounds, (III, IV), on treatment with sodium hypochlorite gave 1:2-, and 7:8-benzophenanthridone (V and VI) respectively, which, on distillation with zinc dust, gave 1:2- and 7:8-benzopphenanthridine (VII and VIII).
The correctness of Graebe's structures is proved by the independent syntheses of 1:2-benzophenanthridine by Kenner, Ritchie, and Statham (27), and by Ritchie (28).

The Schmidt reaction of chrysenequinone (I) has been studied by Caronna (29), and by Badger and Seidler (30). Caronna found that if chrysenequinone was allowed to react with an excess of hydrazoic acid in the presence of sulphuric acid 1:2-benzophenanthridone (V) was formed exclusively. Badger and Seidler, following further investigations by Caronna (31) into the Schmidt reactions of phenanthraquinone and retenequinone, found that the reaction between chrysenequinone and one mole of hydrazoic acid in the presence of sulphuric acid gave 2-α-benzamido-1-naphthoic acid (IV), which on further reaction with a second mole of hydrazoic acid gave 1:2-benzophenanthridone. Badger and Seidler also found that the Schmidt reaction of 2-α-carboxyphenyl-1-naphthoamide gave 7:8-benzophenanthridone (VI).

The reaction schemes given above are outlined in Plate III.

The Preparation of 1:2-Benzofluorenone and 1:2-Benzofluoren-9-ol.

1:2-Benzofluorenone was prepared by the method of Bamberger and Burgdorf (32): distillation of a mixture of chrysenequinone and lead monoxide in a combustion tube at 50 mm. pressure. The crude ketone was obtained in 84% yield, and was sufficiently pure to be used for the preparation of the
PLATE III.

I

II

NO

Schmidt Reaction

Beckmann Rearrangement

CO₂H CONH₂

III

NaOCl

O

Schmidt Reaction

NH

IV

NaOCl

V

Zinc Dust Dist

VII

VIII
corresponding alcohol.

1:2-Benzofluoren-9-ol was prepared by reducing the ketone, using aluminium isopropoxide. The crude alcohol was crystallised from a mixture of benzene and n-heptane, when the alcohol, m.p. 175.5°, was obtained in 71\% yield. The alcohol was characterised by the preparation of its acetyl derivative. Bamberger and Kranzfeld (33), who prepared the alcohol by reducing the ketone with zinc and hydrochloride acid record m.p. 166-167° for the alcohol.

The Behaviour of 1:2-Benzofluorenone and Hydrazoic Acid in the Presence of Strong Acids. (1) In the presence of sulphuric acid.

(a) To a solution of the ketone in concentrated sulphuric acid, cooled in ice-water, was added, during one hour, sodium azide, and the resulting mixture was stirred for a further one and a half hours. (There were no signs of gas evolution during, or after the addition of sodium azide.) The resulting mixture was poured on to ice, whence the ketone was recovered.

(b) The above procedure was followed, the temperature of the reaction mixture being maintained at 40°. There were signs of gas evolution during, and after, the addition of sodium azide. The reaction mixture having been poured on to ice, a dark brown solid separated. This solid, of high melting point, contained both nitrogen and sulphur, and liberated carbon
dioxide from aqueous sodium hydrogen carbonate. The solid was shaken with 2N-sodium hydroxide, and the mixture was filtered; the residue contained nitrogen and sulphur, as did the solid which was precipitated when the alkaline filtrate was acidified. This residue was subjected to fractional vacuum sublimation; the first fractions, collected up to 200°, had m.p. 131.5-135°, and were specimens of unchanged 1:2-benzofluorenone (38%). From 200-350°, there were obtained three small fractions, m.p. 190-260° (5%) the third of which was found to contain nitrogen, but no sulphur. The residue (53%) in vacuum sublimation apparatus was a black mass.

(ii) In the presence of trichlorosacetic acid.
To a mixture of 1:2-benzofluorenone and trichlorosacetic acid at 65° was added sodium azide, in small portions. After further stirring, the mixture was poured into ice-water. From the oil, which separated, 1:2-benzofluorenone was recovered.

(iii) In the presence of polyphosphoric acid.
To a mixture of 1:2-benzofluorenone and polyphosphoric acid at 65° was added, in small portions, sodium azide. After further stirring, the mixture was poured on to ice. The solid which separated was dried, and subjected to fractional vacuum sublimation. The first fractions, collected up to 200°, had m.p. 131-136°, and consisted of unchanged 1:2-benzofluorenone (47%). From 200-350°, there were obtained three small fractions m.p. 150-280° (6%), the third of which was found to contain nitrogen. The residue in the apparatus was a black mass.
The Interaction between 1,2-Benzofluoren-9-ol and Hydrazoic Acid in the Presence of Strong Acids.

(i) In the presence of sulphuric acid.
This alcohol was subjected to reaction with hydrazoic acid in the presence of sulphuric acid by the method of Arcus and Coombe (34): sulphuric acid was added, dropwise, to a suspension of sodium azide in chloroform, cooled in ice; the temperature of the mixture was raised to 25°, and a suspension of the alcohol in chloroform was added during one hour. After a further two hours' stirring, the reaction mixture was poured on to ice, the mixture was mechanically shaken, and then filtered. The residue, which contained both nitrogen and sulphur, was shaken with aqueous sodium hydroxide and benzene. The greater part of the solid was recovered from this treatment. A small quantity of a brown resin was obtained from the benzene solution, but this was not identified. The aqueous alkaline solution gave a positive test for the sulphate ion. The chloroform solution was washed with dilute hydrochloric acid, and was then dried. On evaporation, it yielded a brown oil, which was not identified. The acid solutions were made alkaline with aqueous ammonia, a flocculent grey precipitate was formed. It had m.p. 245-250°, and contained nitrogen and sulphur. It was not characterised.

(ii) In the presence of trichloroacetic acid.
The alcohol, in suspension in chloroform, was added to a stirred mixture of sodium azide, chloroform, and tri-chloroacetic acid at 30°. After a further two hours'
stirring the reaction mixture was poured on to ice. The chloroform layer was washed with aqueous sodium hydrogen carbonate, dried, and evaporated to dryness. A buff solid remained; this was crystallised from light petroleum, and yielded buff needles of 9-azido-1:2-benzofluorene. This compound was found to decompose on heating, and in the presence of strong acids.


The azide was warmed in an oil bath at 130°; initially there was a slow evolution of gas from the melt; suddenly, however, there was a violent evolution of gas. The residue was cooled and crystallised from methanol. On cooling of the solution two types of crystalline solid separated. One, of a light orange colour, was recrystallised from methanol to give golden needles, m.p. 106.5°. The other, of a dark orange colour was recrystallised from methanol, and golden needles together with dark orange prisms were obtained. These last had m.p. 108-108.5°. Both the needles and the prisms gave good analyses for C_{17}H_{11}N; they are considered to be the two geometrically isomeric forms of 1:2-benzofluorenone imine, since, on hydrolysis, a mixture of the two forms gave an almost quantitative yield of 1:2-benzofluorenone.
The Acid-catalysed Decomposition of 9-Azido-1:2-benzofluorene.

(i) In the presence of sulphuric acid.

To a solution of the azide in chloroform was added, with vigorous stirring at 0°, a small quantity of sulphuric acid. Having been stirred for a further 20 minutes, the black reaction mixture was poured on to ice. The brown insoluble substance which separated was shaken with benzene and 2N-sodium hydroxide. The mixture was filtered, and the two layers of the filtrate were separated; from the benzene layer there was obtained an oily residue, to which was added a solution of picric acid in ethanol; there was no precipitate. (Both 1:2- and 7:8-benzophenanthridine picrate are almost insoluble in ethanol.) From the chloroform solution was isolated unchanged 9-azido-1:2-benzofluorene.

(ii) In the presence of trifluoroacetic acid.

A mixture of the azide and trifluoroacetic acid was heated under reflux for 45 minutes, the resulting mixture was cooled, and poured on to ice. A buff amorphous solid separated, and this was shaken with 2N-sodium hydroxide. The residue was dried, and warmed with acetone; the acetone solution was filtered, and a solution of picric acid in acetone was added to the filtrate. A yellow precipitate separated; it was warmed with dioxan, the mixture was cooled, and the insoluble material was collected. The acetone mother liquors were evaporated to dryness; to the oily residue was added ethanol when a buff precipitate was formed. This was warmed with dioxan, and the mixture was cooled, and the yellow
insoluble material was collected. The two crops of insoluble material were considered to be a mixture of the picrates of 1:2- and 7:8-benzophenanthridine. This mixture was shaken with 10% aqueous sodium hydroxide; the whole was then extracted with ether, which yielded a mixture of the bases having m.p. 136-137°.

Attempts to separate this mixture by fractional crystallisation from ethanol, and by fractional sublimation under high vacuum, failed.
Table (V)b.

Acid-catalysed Decomposition of 9-Azido-1:2-benzo[fluorene.

<table>
<thead>
<tr>
<th></th>
<th>(i)</th>
<th>(ii)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield of picrate-</td>
<td>1.86 g. (34.8%)</td>
<td>1.95 g. (36.5%)</td>
</tr>
<tr>
<td>mixture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield of base-</td>
<td>0.86 g. (32.2%)</td>
<td>0.89 g. (33.3%)</td>
</tr>
<tr>
<td>mixture</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Separation of the 1:2- and 7:8-benzorhendriline mixture (0.40 g.)

<table>
<thead>
<tr>
<th></th>
<th>(i)</th>
<th>(ii)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:2-isomer, A.</td>
<td>0.22 g.</td>
<td>0.26 g.</td>
</tr>
<tr>
<td>7:8-isomer, B.</td>
<td>0.06 g.</td>
<td>0.09 g. *</td>
</tr>
<tr>
<td>Ratio of isomers,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1:2-) to (7:8-)+</td>
<td>3.66 : 1</td>
<td>2.98 : 1</td>
</tr>
</tbody>
</table>

* Based on the yield of picrate.

+ From a previous separation of material which may have become relatively enriched in the second isomer, the ratio was found to be c. 2 : 1.
Separation was effected by use of a chromatographic method. A solution of the mixture of the bases in benzene was added, dropwise, to an alumina chromatographic column. The course of separation was followed by irradiating the column with ultra-violet light from time to time. Initially a broad blue band was observed at the head of the column. During the course of eluting the column with benzene, the broad band split into two, and eventually one band was washed from the column. The eluate was evaporated to dryness; the residue was 1:2-benzophenanthridine. In order to remove the second band from the column, two methods were employed. Firstly (experiment (i)), that part of the column which held the band was removed from the containing vessel, and the alumina was extracted with boiling benzene. The benzene solution was evaporated to dryness, and the residue was found to be 7:8-benzophenanthridine. In the second experiment (ii) the second band was washed from the column by acetone, the eluate was evaporated to dryness and a semi-solid oil was obtained. To this was added ethanol and picric acid; a yellow precipitate was formed; it proved to be the picrate of 7:8-benzophenanthridine.

Table (V)b gives the weights and percentages of the mixtures of picrates and bases obtained from two parallel experiments, together with the estimated ratios in which the isomers are formed.
1:2- and 7:8-Benzophenanthridines were crystallised to constant melting points, which were in good agreement with those in the literature (26, 30). Further to this, good analyses for carbon, hydrogen, and nitrogen were obtained for these compounds. 1:2- and 7:8-Benzophenanthridine picrates were prepared. The latter was recrystallised from dioxan to constant decomposition point, and a good nitrogen analysis was obtained. The former had a decomposition point close to that given in the literature (26, 27), but the analyses for nitrogen were persistently low. The best analysis was given by material obtained by adding a solution of the base in dioxan to a solution of picric acid in dioxan. It appears that this picrate is decomposed on recrystallisation from dioxan. The chloroplatinate of 1:2-benzophenanthridine was prepared, and a good analysis for platinum was obtained.

The Discussion of the Experimental Results.

1:2-Benzofluorenone.

Attempts have been made to perform the Schmidt reaction on 1:2-benzofluorenone. This ketone was recovered in high yield from the reaction mixture from experiments in sulphuric acid at 0°, and in trichloroacetic acid at 65°. In the experiments in sulphuric acid at 40°, and in polyphosphoric acid (82.5% \(\text{P}_2\text{O}_5\)) at 65°, small quantities of high melting substances, containing nitrogen, were obtained from the
reaction product by fractional sublimation at reduced pressure. In both of these experiments the ketone was recovered in 38, and 47% yield respectively. The high-melting product, which contained nitrogen, may have contained 1:2- and/or 7:8-benzophenanthridones, but the quantities of the fractions obtained were too small to allow characterisation.

The resistance of this ketone is attributed to steric hindrance at the reaction centre. It is known that hindered ketones do not readily undergo the Schmidt reaction. Badger, Howard, and Simons (1) found that benzoylmesitylene did not undergo the Schmidt reaction; however, it was later shown (5) that, under drastic conditions, very small quantities of products derived from the migration of the bulky mesityl group could be isolated. It is also recorded (35) that 2:3(1’:2’-naphtho)-fluorenone is resistant to the Schmidt reaction, although in this case the ketone is apparently less hindered than in the examples considered above.

**1:2-Benzofluoren-9-ol.**

This fluorenol was subjected to reaction with hydrazoic acid in the presence of sulphuric acid by a procedure similar to that used by Arcus et al. (34, 36, 37) for other fluorenols. A large quantity of a substance containing nitrogen and sulphur was obtained from the reaction mixture, and this was not base-sulphate. A similar substance was obtained from the products of sulphuric acid-decomposition of 9-azido-1:2-benzofluorene.
It is possible, therefore, that this substance is formed by reaction between sulphuric acid and the protonated azide, which Arcus et al. (34, 36, 37, 38) consider to be an intermediate in the formation of phenanthridines from substituted fluoren-9-ols by reaction with hydrazoic acid in the presence of sulphuric acid. Neither 1:2- nor 7:8-benzophenanthridine was isolated from the products obtained from the above reactions.

In the presence of trichloroacetic acid, 1:2-benzo-fluoren-9-ol reacts with hydrazoic acid to give the corresponding azide in good yield. This does represent a good method for the preparation of 9-azidofluorenes, and has been used to prepare 9-azido-9-phenylfluorene, and 9-azido-2:3-benzofluorene. A similar method has been used by Tietz and McEwen (39), but these authors did not isolate the free azides. (See p. 20).

9-Azido-1:2-benzofluorene.

In common with 9-azidofluorene (36), 9-azido-1:2-benzo-fluorene yields different products on acid-catalysed decomposition, and on pyrolysis.

The decomposition of this azide in the presence of sulphuric acid did not, as has already been mentioned, lead to the formation of phenanthridines. Decomposition in the presence of boiling trifluoroacetic acid gave a 53% yield of a mixture of 1:2- and 7:8-benzophenanthridine.

Use of this acid to catalyse decomposition of alkyl azides has been made by Ege and Sherk (40). These authors found that 1-azido-1:1-diphenylethylene is unaffected by cold
trichloroacetic acid, but decomposes when the mixture is heated. In the presence of trifluoroacetic acid, also of stannic chloride, there was a slow evolution of gas at room temperature. With concentrated sulphuric acid there was a violent evolution of gas. Edge and Sherk gave the following series, the order from left to right being the order of increasing efficacy as an acid catalyst in the reaction:

\[
\text{CCl}_3\cdot\text{CO}_2\text{H} < \text{CF}_3\cdot\text{CO}_2\text{H}; \quad \text{SnCl}_4 < \text{H}_2\text{SO}_4
\]

The best value for the ratio 1:2-benzophenanthridine to 7:8-benzophenanthridine was found to be (Table (V)b) 2.9 : 1, the substituted ring migrating preferentially to the unsubstituted ring.

As has been described in the Introduction (r.r.222), Arcus et al. (34, 38) have shown that there is a direct relationship between the capacity for electron release at C(9), by each of the rings attached to it, and the ratio of isomeric phenanthridines formed.

In the present case, as in those studied by these authors, a measure of the electron-availability at C(9) is given, for each ring, by the pK of the corresponding substituted diphenyl-2-carboxylic acid (IX, X).
The pK of (X), 2-phenyl-α-naphthoic acid, can be calculated from known data: Wegscheider (41) found that the dissociation constant of the acid in water at 25° is $9.3 \times 10^{-4}$, whence $pK = 3.03$. However, the pK of IX is not known, whence a comparison is not possible.

Qualitatively, the ratio of isomers is in accord with other evidence. Hey and Lawton (42) found that on nitration 2-phenyl-naphthalene yielded, principally, 1-nitro-2-phenyl-naphthalene.

Thus it would appear that the point of maximum electron-availability is at the 1 position in 2-phenyl-naphthalene. Of the two isomeric phenanthridines formed in the acid-catalysed decomposition of 9-azido-1:2-benzofluorene, the 1:2 isomer is formed in the greater quantity. Thus, of the two bonds from C(9) attached to the fluorene system, the bond attached to the 1:2-benz- substituted ring has migrated preferentially, indicating this to be the position of greater electron-release, which is in accord with the conclusion derived from the nitration evidence.

The pyrolysis of 9-azido-1:2-benzofluorene leads, not to a mixture of isomeric phenanthridines, but to a
mixture of two crystalline forms of 1:2-benzofluorenone imine, i.e. there is no ring expansion to give a six-membered heterocyclic ring, but the five-membered carbo-cyclic ring remains.

This fact is in accord with the behaviour of 9-azido-fluorene. Arcus and Mesley (36) found that this compound decomposes on heating above its melting point, and on storage, to fluorenone imine.

A mixture of the two forms of 1:2-benzofluorenone imine was subjected to hydrolysis, and an excellent yield of 1:2-benzofluorenone was obtained.

Two crystalline forms of certain fluorenone derivatives have been noted by other authors. Coombs (43) found that 2-nitrofluorenone imine existed in two crystalline forms of the same melting point. Recently Taylor and Fletcher (44) have described the preparation of 32 azomethine derivatives of fluorene. Of these derivatives, two existed in crystalline forms of different melting point: when 2:5-dinitrofluorenone was condensed with either aniline or 2-fluoroaniline two compounds were formed in each case, and separation was effected by repeated crystallisations. In both cases the two products gave the correct elemental analysis for nitrogen. Although the possibility of dimorphism cannot be excluded, it appears most probable that in every case the two forms are the geometrically isomeric imines.
The findings with regard to the interaction between 1:2-benzofluorenone, and 1:2-benzofluoren-9-ol, and hydrazoic acid in the presence of strong acids may be summarised as follows:

(i) 1:2-benzofluorenone, like other hindered ketones, is resistant to the Schmidt reaction.

(ii) a. 1:2-benzofluoren-9-ol does not react with hydrazoic acid in the presence of sulphuric acid to give a mixture of isomeric benzophenanthridines. Evidence is given that the protonated azide, which is an intermediate in the reaction, reacts with sulphuric acid to give a sulphur-containing product.

(ii) b. In the presence of trichloroacetic acid, 1:2-benzofluoren-9-ol reacts with hydrazoic acid to give 9-azido-1:2-benzofluorene.

(iii) a. 9-Azido-1:2-benzofluorene, in the presence of hot trifluoroacetic acid, decomposes, and rearranges to give a mixture of 1:2- and 7:8-benzophenanthridine in the ratio 2:9 : 1.

(iii) b. Pyrolysis of 9-azido-1:2-benzofluorene leads to the formation of 1:2-benzofluorenone imine, which exists in two isomeric forms.

(A summary of the above reactions is given in Plate IV).
The preparation of 9-azido-9-phenylfluorene has been recorded by Pinck and Hilbert (45). These authors prepared 9-hydrazino-9-phenylfluorene from the 9-chloro compound by use of hydrazine hydrate, and treated the hydrazino compound with sodium nitrite in an acidified alcoholic solution. This is a three stage synthesis from the fluoren-9-ol; the overall yield cannot be estimated from the experimental details given. These authors found that the azide decomposed on heating to give 9-phenylphenanthridine.

It was considered that it would be of interest to attempt to prepare 9-azido-9-phenylfluorene by the method used to prepare 9-azido-1:2-benzofluorene, since this would represent a more convenient method to prepare a 9-aryl-9-azidofluorene than the method described above. Further to this, the acid-catalysed decomposition and the heat decomposition of the azide could be investigated, both reactions would be expected to yield 9-phenylphenanthridine. (Arcus and Coombs (34) record that interaction between 9-phenylfluoren-9-ol and hydrazoic acid in the presence of sulphuric acid leads to a 94% yield of 9-phenylphenanthridine.)
The Preparation, Acid-catalysed Decomposition, and Heat Decomposition of 9-Azido-9-phenylfluorene.

This compound was prepared in 89% yield by the method used to prepare 9-azido-1,2-benzofluorene. A solution of the fluorenol in chloroform was added to a stirred mixture of sodium azide, chloroform, and trichloroacetic acid. After further stirring of the mixture, it was poured on to ice; the product from the chloroform solution on crystallisation from light petroleum gave prisms of 9-azido-9-phenylfluorene.

The acid-catalysed decomposition of 9-azido-9-phenylfluorene.

To a stirred mixture of sulphuric acid and chloroform at 25° was added, during 20 minutes, a solution of the azide in chloroform. After further stirring of the mixture, it was poured on to ice. The chloroform solution was washed with 10N-sulphuric acid; the combined acid solutions yielded a base which was crystallised from light petroleum, and gave 9-phenylphenanthridine (yield 87%).

The action of heat on 9-azido-9-phenylfluorene.

The azide was heated in an oil bath at 170-180° until no more gas was evolved. To the oily residue was added a solution of picric acid in ethanol, and there was obtained 9-phenylphenanthridine picrate in 85% yield.
The discussion of the results of the experiments on 9-phenylfluoren-9-ol.

It was found that interaction between the fluorenol and hydrazoic acid (added as sodium azide) in the presence of chloroform and trichloroacetic acid gave a good yield of the azide. This, therefore, represents a better method for the preparation of 9-aryl-9-azido-fluorenes than the method of Pinck and Hilbert (45). It is also a more convenient method than that of Ege and Sherk (40), which requires the passage of anhydrous hydrazoic acid into a solution of the reactant in benzene and trichloroacetic acid.

As had already been noted (p.66) interaction between 9-phenylfluoren-9-ol and hydrazoic acid in the presence of sulphuric acid leads to the formation of 9-phenylphenanthridine (94%); Arcus and Coombs (34) suggested that the azide was an intermediate in the reaction. It has now been established that the acid-catalysed decomposition of the azide does lead to 9-phenylphenanthridine, and this fact supports the suggested course of reaction for the fluorenol.

On pyrolysis, the azide gave 9-phenylphenanthridine in good yield, a result in accord with the finding of Pinck and Hilbert (45) for 9-azido-9-α-naphthylfluorene.

It is apparent that there is a marked difference in the behaviour of secondary and tertiary 9-azido-fluorenes on pyrolysis, whereas in the presence of strong acids their behaviour is similar. Under the former conditions secondary 9-azidofluorenes decompose, with loss of nitrogen, to give a
fluorenone imine, e.g., fluorenone imine from 9-azidofluorene (36), 1:2-benzofluorenone imine from 9-azido-1:2-benzofluorene (p.55). On the other hand, the tertiary 9-azidofluorenes decompose on heating to give 9-substituted-phenanthridines. The acid-catalysed decomposition of both classes of azide leads, via a ring expansion, to phenanthridines.
RING EXPANSION VIA THE SCHMIDT REACTION. EXPERIMENTS
WITH BENZYLIDENEINDENE AND 1:3-DI-KETOHYDRINDENE.

One facet of interest in the Schmidt reaction of certain cyclic compounds is that in many instances a heterocycle is formed, by ring expansion, as a major product of the reaction. There are examples in the literature of ring expansions from 5, 6, and 7-membered rings to 6, 7, and 8-membered rings respectively.

Briggs and Death (46) have shown that dihydrocarbostyril can be obtained from indan-l-one, the Schmidt reaction of substituted fluorenones leads to the formation of substituted phenanthridones (47). Schlechter and Kirk (48) have investigated the Schmidt reaction of 2-substituted-cyclopentenones and cyclohexanones. It was found that ring expansion accounted for the products of reaction, and that it was the substituted carbon atom which migrated during the course of the reaction whether the substituent was electron releasing or electron withdrawing. A diagrammatic representation of their findings is given below:

\[
\begin{align*}
\text{CH}_2-\text{CO}-\text{CH}-R & \quad \xrightarrow{\text{(CH}_2)_n} \quad \text{CH}_2-\text{CO}-\text{NH} \\
\text{(CH}_2)_n & \quad \text{(CH}_2)_n
\end{align*}
\]

When \( n=2 \), \( R=\text{Me}, \text{Et}, \text{n-Pr}, \text{iso-Pr}, \text{CN} \).

When \( n=3 \), \( R=\text{Me}, \text{Et}, \text{n-Pr}, \text{CN}, \text{NCO}_2\text{Et} \).

The interaction between compounds capable of giving cyclic cations in the presence of strong acids, and hydrazoic
Acid, has received attention. From fluoren-9-ols phenanthridines can be obtained. An extension of this reaction, the acid-catalysed decomposition of 9-azidofluorenes, has already been discussed (see p. 41 and p. 48).

Not all compounds which would be expected to give cyclic cations in the presence of strong acids react smoothly with hydrazoic acid to give simple heterocyclic products.

Kuhn and DiDomenico (49) report that indene polymerises rapidly in sulphuric acid and does not react with hydrazoic acid. However, Arcus and Coombs (50) have found that although indene does polymerise in sulphuric acid there is an appreciable yield (20%) of a basic oil. This oil was not fully identified but was considered to be polymeric material derived from a dihydroquinoline or dihydroisoquinoline, or a mixture of the two. From the oil, by catalytic dehydrogenation, was obtained a small quantity of a base which was considered to be a mixture of quinoline and isoquinoline. The mixture was not separated.

In the course of the present investigations (see p. 51) it was found that the product of reaction between 1:2-benzo-fluoren-9-ol and hydrazoic acid in the presence of sulphuric acid, and that formed in the sulphuric acid-catalysed decomposition of the corresponding azide were similar; both contained nitrogen and sulphur, suggesting that they were formed by interaction between a decomposition product of the azide and the acidic medium.
Arcus and Coombs (34) have subjected 9-methylfluoren-9-ol to reaction with hydrazoic acid in the presence of sulphuric acid. Besides 9-methylphenanthridine there was obtained a compound \( \text{C}_{28}\text{H}_{21}\text{N} \), which was considered to be a methylfluorenyl-methylphenanthridine, possibly formed by reaction between an intermediate compound and 9-methylphenanthridine.

Boyer and Canter (51) have investigated the reaction between cyclopentanol, cyclohexanol, and cycloheptanol and hydrazoic acid in the presence of sulphuric acid, and Boyer, Canter, Hamer, and Putney (52) have investigated the sulphuric acid catalysed decomposition of the corresponding azides. The products of reaction in corresponding cases were similar. It was found that in each reaction at least two products were isolated, one due to a ring expansion (path A), and one in which the ring-size was retained (path B), ring expansion accounting for the greater part of the products isolated. The mechanisms for these reactions were thought to be similar to those proposed by Arcus et al. for the behaviour of certain alcohols and hydrazoic acid in the presence of sulphuric acid.

\[
\begin{align*}
\text{CH}_2\text{CH}=-\text{OH} & \xrightarrow{\text{H}_2\text{SO}_4} \text{CH}_2\text{CH}+ 2\text{H}_2\text{SO}_4 + \text{H}_2\text{O} \\
\text{HN}_3 & \xrightarrow{\text{H}^+} \text{CH}_2\text{CH}-\text{N}^-\text{N}^+\text{N}^- & \xrightarrow{\text{H}^+} \text{CH}_2\text{CH}^- + \text{CH}_2\text{C}^+ + \text{NH}_2 + \text{N}_2 \\
\text{CH}_2\text{CH}-\text{N}^-\text{N}^+\text{N}^- & \xrightarrow{a} \text{CH}_2\text{CH}^- \xrightarrow{b} \text{CH}_2\text{C}^+ \\
\end{align*}
\]
In each case a product was obtained via path b; the proportion of reaction proceeding by this path was based on the yield of 2,4-dinitrophenylhydrazone of the ketone derived from the ketone imine. In each case the nitrogen-containing material was obtained which was considered to be formed via path a; however, in only one pair of reactions with cyclopentyl alcohol and azide, was the product identified: piperidine was obtained, and this, on standing, polymerised to isotripiperidine. In the other pairs of cases the product was considered to be polymeric material derived either from the cyclic imine, or from the \( \alpha \)-aminoaldehyde derived from it.

From the above evidence, the factors to be desired in the reaction of a cyclic compound with hydrazoic acid in the presence of a strong acid are as follows:-

The cyclic compound, the intermediate compounds, and the reaction products should not polymerise in, react with one another in, or react with the acidic medium.

It was considered to be of interest to subject benzylideneindene and 1:3-diketohydrindene to the conditions of the Schmidt reaction, since these compounds would be expected to yield carbonium cations which might yield protonated azides, which, in turn, might undergo ring expansion. From benzylideneindene one might expect to obtain 2-benzylquinoline and/or 1-benzylisoquinoline, and from 1:3-diketohydrindene one might expect to obtain 2:4-dihydroxyquinoline and/or 1:4-dihydroxyisoquinoline (see Plate V).
Benzylideneindene was prepared as follows: to a mixture of benzaldehyde, indene, and methanol was added methanolic potash. The resulting mixture was allowed to stand overnight, when yellow crystals of benzylideneindene separated, and were recrystallised from methanol.

The compound was subjected to reaction with hydrazoic acid in the presence of sulphuric acid, sulphuric acid monohydrate, and trichloroacetic acid by a method similar to that employed for the Schmidt reactions of 2-acylbenzoic acids (see p. 35).

In the first case there was extensive sulphonation. A small quantity of a basic substance was isolated from the reaction mixture, but it was not identified.

In the second and third cases the benzylideneindene polymerised. From the chloroform solutions was obtained a brown resin, which was purified by precipitation from its benzene solution by ethanol.

The reaction in trichloroacetic acid was repeated, but without the addition of sodium azide, and it was found that under these conditions benzylideneindene polymerised.

Whitby and Katz (53) record that benzylideneindene polymerises on standing in chloroform solution, with antimony pentachloride, to give a hexamer, and that prolonged heating alone yields a tetramer.

Thus benzylideneindene resembles styrene, and to a lesser extent indene, in that the compound polymerises under the conditions of the Schmidt reaction.
The Schmidt reaction of 1:3-diketohydrindene has been investigated by Fusco and Rossi (54), who found that 2:4-dihydroxyquinoline could be obtained in excellent yield (actual weights indicate 105%).

It was considered that it would be of interest to verify this ring expansion and to compare the yield with ring-expansions in the present work. Accordingly, 1:3-diketohydrindene was subjected to the Schmidt reaction by a method similar to that used for the Schmidt reactions of 2-acylbenzoic acids. During the addition of the chloroform solution of the diketone to the mixture of hydrazoic acid, sulphuric acid, and chloroform there was an evolution of gas. On pouring of the reaction mixture on to ice a buff solid separated, and this was found to be 2:4-dihydroxyquinoline, formed in 64% yield. The compound was characterised by the formation from it of 2:4-dichloroquinoline, by treatment with phosphorus oxychloride. From the chloroform solution of the Schmidt reaction was obtained a small quantity of nitrogen-containing crystalline material (6%), which was not identified.

Fusco and Rossi (54) investigated the Schmidt reaction of a series of carbonyl compounds containing a methylene group. It was found that for compounds of the type 
\[ C_6H_5\cdot CO\cdot CH_2X, \text{ where } X = \text{CHO}, \text{Ac, Bz, CO}_2\text{H, CO}_2\text{NH}_2, \]
\[ \text{CO}_2\text{NH}_2\cdot C_6H_5, \text{CN, SO}_2\cdot C_6H_5, \text{NO}_2, \] the NH group entered the compound between the carbonyl group and the aromatic nucleus. 1:3-Diketohydrindene, as has been stated, behaved similarly. With 2-cyanocyclohexanone the NH group entered between the
carbonyl group and the CHCN group, in agreement with the 
work of Schlechter and Kirk (48).

Fusco and Rossi considered that their results 
verified Smith's hypothesis (see p. 9) that in the Schmidt 
reaction of carbonyl compounds a diazoimide cation is formed, 
which has two geometric forms analogous to the two geometric 
forms of certain ketoximes; the more highly substituted, 
bulkier, group takes up a position anti to the diazo group, 
and eventually migrates.

One point of interest that Fusco and Rossi did not 
stress was the fact that from 1:3-diketohydridene, containing 
a 5-membered carbocyclic ring having two reactive centres, 
there is formed via the Schmidt reaction, 2:4-dihydroxy-
quinoline, a compound containing a stable six-membered 
heterocyclic ring. Reaction stops at this point, and there 
is no second stage of expansion involving the remaining 
(enolised) keto group.
(8) Meisenheimer and Meis, Ber., 1924, 57, 289.
(13) Gabriel and Michael, Ber., 1877, 10, 1554.
(17) Van der Heulien, Rec. trav. chim., 1896, 15, 323.
(19) Dobrell, Ber., 1895, 28, 940.
(21) Thorpe, Ber., 1893, 26, 1261
(22) Meyer and Sundmacher, Ber., 1899, 32, 2123
(23) Thorpe, Ber., 1893, 26, 1795
(25) Graebe and Honigsberger, Annalen, 1900, 311, 257.
(26) Graebe, Annalen, 1904, 335, 122.
(29) Caronna, Gazzetta, 1941, 71, 481.
(31) Caronna, Gazzetta, 1950, 82, 211.
(32) Bamberger and Burgdorf, Ber., 1890, 23, 2437
(33) Bamberger and Franzfeld, Ber., 1835, 18, 1934.
(41) Wegscheider, Monatsh., 1916, 37, 247.
Petrow, J. Chem. Soc., 1946, 200, 898. See also (38)
(48) Schlechter and Kirk, J. Amer. Chem. Soc., 1951, 73, 3087
(49) Kuhn and DiDomenico, J. Amer. Chem. Soc., 1950, 72, 5777.
(50) Arcus and Coombs, unpublished work.
(52) Boyer, Canter, Hamer, and Putney, J. Amer. Chem. Soc.,
1956, 78, 325
(54) Fusco and Rossi, Gazzetta, 1951, 81, 511.
PART III.

THE EXPERIMENTAL SECTION.

(Melting points are corrected.)
THE PREPARATION OF 2-ACYLBENZOIC ACIDS
AND ALKYLIDENE PHTHALIDES

2-\(\alpha\)-Naphthoylbenzoic Acid

(Method of Heller and Schulke,(1).)

Phthalic anhydride (100 g.) and naphthalene (130 g.) were fused together, and, after cooling, the mixture was ground and placed in a 2L. flask fitted with a reflux condenser and a mercury-sealed stirrer. To the ice-cooled flask was added benzene (262 ml.) and then aluminium chloride (208 g.). The reaction mixture was stirred, being cooled in ice for one hour and standing at room temperature for eight hours. The viscous mass was then cautiously treated with water (500 ml.). After standing overnight, the mixture was steam distilled to remove benzene and excess of naphthalene. Sodium carbonate solution (175 g. in 525 ml. water) was then added, the mixture being heated by passing steam through it. The resulting mixture was then filtered and the filtrate acidified with concentrated hydrochloric acid (50 ml.). The mixture was filtered, and the residue, the crude acid, was dried; yield 165 g. The acid was ground with glacial acetic acid (330 ml.), and the mixture filtered. The residue, on one recrystallisation from toluene, and two recrystallisations from ethanol gave the pure acid (50 g.), m.p. 175.5-176°.

(Macmullen, (2), records m.p. 176°; Heller and Schulke, (1), record m.p. 173°).
2-\textit{p}-Methoxybenzoylbenzoic acid.

\textit{(Method of Lee Che Kin, (3).)}

Into a 3 necked, 500 ml. flask, fitted with a thermometer, calcium chloride tube, and a mechanical stirrer, was introduced phthalic anhydride (29.6 g.), nitrobenzene (50 ml.) and anisole (22 ml.). The mixture was cooled in an ice-salt freezing mixture. Aluminium Chloride (60 g.) was added to the stirred mixture during 45 minutes so that the temperature did not rise above 5°. After 2½ hour's stirring, the freezing mixture was removed and the reaction mixture was allowed to stand in a cool place for one week. The viscous reaction mixture was then treated with crushed ice and hydrochloric acid. Nitrobenzene (150 ml.) was added to facilitate removal of the mixture from the reaction vessel. The nitrobenzene layer was washed with N-sulphuric acid (2 x 300 ml.), and with water (2 x 300 ml.) by decantation, and then steam distilled. In the distillation flask, together with water, there remained an oily liquid, which solidified on cooling. It, (36.8 g.), was recrystallised, and decolourised with charcoal from ethanol, and then toluene to give 2-\textit{p}-methoxybenzoylbenzoic acid, m.p. 147°.

\textit{(Lee Che Kin, (3), records m.p. 145°.)}
2-<i><b>n</b></i>-Chlorobenzoylbenzoic acid.

(Groggins and Newton, (4).)

Into a 1L. 3-necked flask, carrying a thermometer, mechanical stirrer, and a reflux condenser, the upper end of which carried a hydrogen chloride "excluder", was introduced phthalic anhydride (30 g.), chlorobenzene (122 ml.) and aluminium chloride (64 g.). The mixture was heated in an oil bath at 50° for 5 hours. After cooling in ice, the reaction mixture was decomposed by the addition of dilute sulphuric acid (22.5 ml. in 500 ml. water). The mixture was then steam distilled to remove excess of chlorobenzene, cooled, and filtered. The residue was added to dilute sodium hydroxide solution (40 g. in 1500 ml. water), and the resulting solution was steam distilled to remove the last traces of chlorobenzene. After stirring with charcoal (5 g.) for 15 minutes, the solution was filtered, and the filtrate acidified with dilute sulphuric acid (50 ml. in 550 ml. water). The solution was filtered, and the residue was washed several times with water and then dried. It, (45 g.) on recrystallisation from benzene, gave 2-<i><b>n</b></i>-chlorobenzoylbenzoic acid (38.4 g.) m.p. 150.5 - 151°.

* An absorption tube through which a current of water was passed.
2′-Nitrobenzoylbenzoic acid.

(Method of Basler, (5).)

To a solution of 2′-benzoylbenzoic acid (11.3 g.) in strong sulphuric acid (11.5 ml. conc. sulphuric acid, 3.9 ml. water) was added, with stirring and cooling, a mixture of 20% oleum (43.75 g.) and nitric acid (d 1.42, 4.00 ml.) so that the temperature of the reaction mixture did not rise above 20°. The mixture was then heated at 50° for 30 minutes, and the product poured on to crushed ice. The solution was filtered, and the residue was washed with water. The crude acid was crystallised twice from glacial acetic acid. It, 3.47 g., had melting point 181.5-182°. The nitration was repeated three times and the product was in each case crystallised from glacial acetic acid. The crops were combined; 15.2 g. of the crude acid were dissolved in sodium hydroxide solution (5 g. NaOH in 200 ml. water), and decolourising charcoal (1.5 g.) was added. The mixture was warmed on a steam bath for 20 minutes and was filtered. The filtrate was acidified with dilute sulphuric acid, the mixture was filtered, and the residue washed with water. Two crystallisations from ethanol gave the required acid (8.43 g.) m.p. 189-189.5°.

(Basler, (5), records m.p. 186-187°).
2-Mesitoylbenzoic acid.

A mixture of mesitylene (15 ml.) phthalic anhydride (15 g.) and s-tetrachloroethane (75 ml.) was heated in a 500 ml. flask until the phthalic anhydride had dissolved. The solution was cooled to 5° in an ice bath, and aluminium chloride (30 g.) was added. After 10 minutes' shaking in the ice bath, the reaction mixture was allowed to stand at room temperature for 30 minutes, and was warmed at 50° for 30 minutes. The reaction mixture was then added to ice (100 g.) and concentrated hydrochloric acid (20 ml.). The resulting mixture was steam distilled until no oily drops appeared in the distillate. The solution was cooled and then filtered. The residue was treated with sodium carbonate solution (7.5 g. in 200 ml. water), and steam was passed into the mixture to facilitate solution. After cooling somewhat, the solution was stirred with animal charcoal (1 g.) until it was at room temperature. It was then filtered, and the filtrate was acidified with dilute sulphuric acid and filtered; the residue was washed several times with cold water. The crude acid was crystallised from aqueous ethanol. There resulted 2-mesitoylbenzoic acid, (20.0 g.) m.p. 214-214.5°. (Newman and McCleary, (6), record m.p. 214-6°).
Benzylideneanthalide.

(Method of Weiss, (7).)

Into a 250 cc. round-bottomed flask were placed phthalic anhydride (50 g.), phenylacetic acid (55 g.), freshly fused sodium acetate (1.3 g.), and a little porous pot. The flask was embedded to the neck in sand, and was fitted with a cork bearing a thermometer, and a wide bent glass tube leading to a condenser. The bath was heated rapidly until the temperature of the reaction mixture was 230°. The temperature was raised to 240° in two hours, and, after a further hour and a half at this temperature, no more water was evolved and the reaction mixture was allowed to cool to 90°. To the hot mixture was added ethanol (150 ml.), and then the mixture was warmed to effect solution, the solution was filtered, the flask and the filter paper being rinsed with hot ethanol (75 ml.). On cooling, there separated benzylideneanthalide (54.0 g.), orange-yellow crystals, m.p. 98-99°. On recrystallisation from ethanol there was obtained pale yellow crystals, (51 g.), m.p. 100-100.5°.

(Weiss, (7) records m.p. 100-101°).

(The procedure given here is essentially that of Gabriel (8)).
2-Phenylacetylbensonic acid monohydrate.

(Method of Gabriel and Michael, (9).)

Benzylideneephthalide (31.3 g.) was heated with potassium hydroxide solution (30 g. in 100 ml. water) for 30 minutes. After cooling, the solution was filtered, and the filtrate was acidified with dilute sulphuric acid. A red oil separated, and this solidified to a pink solid. This (35 g., m.p. 70-71°) was dissolved in aqueous sodium hydrogen carbonate, and the solution was acidified until a faint, permanent precipitate was obtained. The resulting solution was extracted with chloroform (4 x 30 ml.), and then acidified with 2N-sulphuric acid. After filtering, the residue was washed several times with water. Two recrystallisations from aqueous ethanol gave 2-phenylacetylbensonic acid, prisms, 22.0 g., m.p. 74.5-75°. (Found, by titration with sodium hydroxide: equiv., 259. C_{15}H_{14}O_{4} requires equiv., 258).

(Gabriel & Michael (9) record m.p. 74-75° for this compound.)
Propyldenephthalide.

(Method of Ulyot, Taylor and Dawson (10)).

Into a 500 ml. round-bottomed flask were placed sodium acetate (32.5 g., fused), phthalic anhydride (58.5 g.), and butyric anhydride (b.p. 95-96°/30 mm., 125 g.). The flask was fitted with an air condenser, and a thermometer was placed in the mixture. The reaction mixture was heated to 180°, and its temperature was maintained between 180° and 190° for 7 hours. After cooling, the residue was distilled at reduced pressure. A yellow liquid (b.p. 60-80°/20 mm.) was obtained. The residue in the flask was rendered alkaline with ammonia (d 0.88), and then extracted with chloroform (6 X 100, and 1 X 50 ml.). The combined chloroform solutions were washed with water (2 X 250 ml.), dried over anhydrous sodium sulphate, and the solvent removed. The residue was distilled at reduced pressure to give propyldene- phthalide (40.9 g., b.p. 146-149°/4 mm.). This was contaminated with phthalic anhydride, and this was removed as follows. To the phthalide was added ethanol (40 ml.), and 0.12 N-sodium hydroxide was added until the solution was alkaline (phenol phthalein paper was used as an external indicator). The solution was then extracted with chloroform (2 X 50 ml.), and the chloroform was washed with water (2 X 50 ml.), dried (Na₂SO₄), and the solvent removed by distillation. The residue was distilled at reduced pressure, and gave propyldenephthalide, (27.8 g., b.p.
149-150°/4 mm., n_D^20/1.582). 
(The lower-boiling fraction, and residue (7.1 g. in all) 
were kept and hydrolysed as below).
(Ullyot et al (10) record b.p. 143-145°/5 mm. and n_D^20/1.586 
for this compound.

2-Butyrylbenzoic acid.
(Method of Bromberg, (11)).
Propylideneanthallide (22.9 g.), sodium hydroxide 
(6.0 g.) isopropyl alcohol (20 ml.), and water (20 ml.) were 
heated at 70-75° for 30 minutes. The resulting solution 
was acidified with dilute sulphuric acid and a yellow oil 
separated, which solidified. The solid, 23.2 g., 
m.p. 84-85° was dissolved in aqueous sodium bicarbonate 
(11.0 g in water (200 ml.)). The solution was so acidified 
as to precipitate a small quantity of the acid. The orange 
solution was extracted with chloroform (4 X 50 ml.). The 
aqueous solution was then completely acidified, and the 
precipitate dried. On recrystallisation from ether and 
light petroleum (b.p. 40-60°) there resulted 2-butyrylbenzoic 
acid, m.p. 89.5-90°, 13.5 g.
(Bromberg (11 records m.p. 89° for the acid)
THE SCHMIDT REACTION OF 2-ACYLBENZOIC ACIDS, AND
ALKYLIDENEPHTHALIDES.

The above 2-acylbenzoic acids and alkylidenepthalides were subjected to the Schmidt reaction by the following standardised procedure.

Sulphuric acid (98%, 15 ml.) was added dropwise to a stirred ice-cooled mixture of sodium azide (2.6 g., 0.040 mole) and chloroform (15 ml.). After a further 15 minutes, the ice was replaced by a water-bath maintained at 30°, and the 2-acylbenzoic acid or alkylidenepthalide, (0.020 mole) in solution or suspension in chloroform (20 ml.), was added during 1 hour; stirring was continued for 2 hours. The mixture was then poured on to ice (200 g.). The whole, together with washes of water and chloroform (25 ml.), was shaken mechanically for ½ an hour, and filtered (product I). The aqueous solution was extracted with chloroform (2 x 25 ml.), and the combined chloroform solutions were extracted with aqueous sodium hydrogen carbonate (2 x 25 ml.), washed with water (2 x 25 ml.), and dried (Na₂SO₄), and evaporated to dryness (product II). The sodium hydrogen carbonate extract was acidified with dilute hydrochloric acid, and the product III filtered off. The acidic aqueous solution was concentrated by distillation, filtered, brought to pH 10 with sodium hydroxide solution, and extracted with ether (2 x 50, 2 x 25 ml.). The extract was dried (Na₂SO₄) and evaporated to dryness (amine).
Reaction of each acylbenzoic acid, and alkylidene-
phthalide was carried out in duplicate or triplicate, and
the weights and m.p.s. observed in the individual
experiments are denoted by (i), (ii), (iii).

2-α-Naphthoylbenzoic acid.

Reaction with 2-α-naphthoylbenzoic acid ((i), (ii),
(iii) 5.52 g.) gave:

I, a brown amorphous solid ((i) 0.73, (ii) 0.80,
(iii) 0.77 g.); it gave fluorescein on heating with resorcinol
and sulphuric acid, but was not characterised.

II, a buff solid ((i) 3.80, (ii) 4.05, (iii) 3.60 g.),
m.p. (i) 121-126°, (ii) 126-129° (iii) 132.5-134°, which
on crystallisation from ethanol gave 2-α-naphthyl-6-oxo-
4:5-benz-1:3-oxazine, orange needles ((i) 2.51, (ii) 3.08,
(iii) 2.78 g.), m.p. 137.5-138°.

Found: N, 5.10. Calc. for C_{18}H_{11}O_{3}N: N, 5.15%.
Ladger, Howard and Simons, (12) record m.p. 135° for this
compound.

Amine ((i) 0.20, (ii) 0.15, (iii) 0.23 g.). It was
benzoylated by the Schotten-Baumann method, and the derivative
was crystallised from aqueous ethanol. It had m.p.
(1) 159.5°, (ii) 146.5-150.5°, (iii) 158-159° alone, and
then mixed with benz-α-naphthalide of m.p. 162.5-163° it
had m.p. (1) 161.5-162°, (ii) 146.5-150.5°, (iii) 160-161°.
2-<i>p</i>-Methoxybenzoylbenzoic acid.

Reaction with 2-<i>p</i>-methoxybenzoylbenzoic acid ((i), (ii) 5.12 g.) gave:

I, a white solid ((i) 0.10, (ii) 0.11 g.); it had no sharp m.p. and was not identified.

II, a white solid ((i) 4.28, (ii) 4.40 g.), m.p.
(i) 155-157°, (ii) 151-152°, which on crystallisation from ethanol gave needles, ((i) 3.68, (ii) 3.87 g.), m.p. (i), (ii) 157.5-158°. After four recrystallisations from ethanol there was obtained 2-<i>p</i>-methoxyphenyl -6-oxo-4:5-
benz-1:3-oxazine, needles, m.p. 158.5°. Found: C, 71.0;
N, 4.45, N, 5.7. C<sub>15</sub>H<sub>7</sub>O<sub>3</sub>N requires C, 71.4; N, 4.4; N, 5.55°.

III, a white solid ((i) 0.19, (ii) 0.29 g.), m.p.
(i) 196°, (ii) 194° (decomp.). The solid did not give fluorescein on fusion with sulphuric acid and resorcinol. It was twice recrystallised from ethanol to give 1-<i>p</i>-
carboxyphenyl-5-<i>p</i>-methoxyphenyl -1:2:3:4- tetrazole,
prisms, m.p. 198-199° (decomp.). Found; C, 60.8; H, 4.05;
N, 18.9, by titration with sodium hydroxide, M, 297.
C<sub>15</sub>H<sub>12</sub>O<sub>3</sub>N<sub>4</sub> requires C, 61.0; H, 4.05; N, 18.3%; M, 296.

2-<i>p</i>-Chlorobenzoylbenzoic acid.

Reaction with 2-<i>p</i>-chlorobenzoylbenzoic acid ((i), (ii) 5.21 g.) gave:

II, a white solid ((i) 4.79, (ii) 4.73 g.), m.p.
(i), (ii) 189°, which on crystallisation from <i>n</i>-butanol gave
white needles of 2-\(\gamma\)-chlorophenyl-6-oxo-4:5-benz-1:3-oxazine \((i) 4.31, (ii) 4.35 \text{ g.})\), m.p. \((i) 190.5-191^\circ\).

Found: N, 5.6; Cl, 14.1. Calc. for \(\text{C}_{14}\text{H}_{7}\text{O}_{3}\text{NCl}:\text{N}, 5.45;\) Cl, 13.75%. (Zentmeyer and Wagner \((13)\) record m.p. 190\(^\circ\) for this compound.)

\textbf{Amine.} \((i) 0.07, (ii) 0.06 \text{ g.})\), m.p. \((i) 63.5^\circ,\) \((ii) 66.5-7^\circ.\) (i), when mixed with an authentic specimen of \(\gamma\)-chloroaniline of m.p. 70-71\(^\circ\), had m.p. 63-66\(^\circ\).

(i) was benzoylated by the Schotten-Baumann method and the derivative was twice crystallised from aqueous ethanol; it had m.p. 191.5\(^\circ\) alone and m.p. 192-193\(^\circ\) when mixed with a specimen of benz-\(\gamma\)-chloroanilide of m.p. 194-194.5\(^\circ\).

\underline{2-\(\gamma\)-Nitrobenzoylbenzoic acid.}

Reaction with 2-\(\gamma\)-nitrobenzoylbenzoic acid \((i), (ii) 5.42 \text{ g.})\) gave:

\(\text{II} - \) a buff solid \((i) 4.90, (ii) 4.93 \text{ g.})\), m.p. \((i) 165-165.5^\circ, (ii) 164.5-165^\circ.\) On crystallisation from \(n\)-butanol there was obtained 2-\(\gamma\)-nitrophenyl-6-oxo-4:5-benz-1:3-oxazine \((i) 4.61, (ii) 4.73 \text{ g.})\), yellow needles, m.p. \((i) 169-169.5^\circ, (ii) 169.5^\circ.\) Found: N, 10.45. Calc. for \(\text{C}_{14}\text{H}_{7}\text{O}_{4}\text{N}_{2}: \text{N}, 10.5\%.\) Bogert, Gortner and Amend, \((14)\), record m.p. 167-8\(^\circ\) for this compound.

\textbf{Amine.} There was obtained a yellow solid \((i) 0.11, (ii) 0.09 \text{ g.})\), having m.p. \((i) (ii) 111-111.5^\circ\) which was not depressed when the amine was mixed with an authentic specimen
of m-nitroaniline. The amine (i) was benzoylated by the Schotten-Baumann method; the derivative had m.p. 158° alone, and when mixed with an authentic specimen of benz-m-nitroanilide.

2-Mesitylbenzoic Acid.

The reaction with this compound ((i), (ii) 5.36 g.) yielded:

I: A white solid ((i) 1.68 g. (ii) 1.62 g.) of m.p. (i) 165.5-166.5 (decomp), (ii) 175-177° (decomp). On crystallisation there was obtained a colourless solid ((i) 0.64 g. (from ethanol) (ii) 1.01 g. (from dioxan), m.p. (i) 190.5° (decomp) (ii) 193.5° (decomp). The compound liberated CO₂ from sodium bicarbonate solution and, when fused with resorcinol and a little concentrated sulphuric acid gave fluorescein. The compound was considered to be N-mesitylphthalamic acid: Found: C, 72.5; H, 6.25; N, 5.30. C₁₇H₁₇O₃N requires: C, 72.1; H, 6.05; N, 4.95%. Equivalent (by titration) = 284. Calculated equivalent = 233. This identification was confirmed by the following cyclisation.

The compound (0.1 g.), and glacial acetic acid (1.3 ml.) were heated under reflux for 30 minutes; after cooling, water was added, and a white precipitate was formed. Two recrystallisations from aqueous acetic acid gave N-mesitylphthalimide m.p. 180-180.5° alone and when mixed with an
authentic specimen of the same melting point.

II: a yellow solid ((i) 2.97 g., (ii) 3.02 g.), m.p. (i) 107-110°, (ii) 90-92°; on crystallisation from ethanol it gave golden needles ((i) 1.66 g., (ii) 1.40 g.) having m.p. (i) 137-8° (ii) 138-9°. After further recrystallisations from ethanol there was obtained 2-mesityl-6-oxo-4:5-benz-1:3-oxazine, golden needles, m.p. 182.5°. Found; C, 76.6; H, 5.70; N, 5.55. C_{17}H_{15}O_{2}N requires; C, 76.9; H, 5.70; N, 5.30%.

Benzylidenephthalaldehyde and 2-phenylacetylbenzoic acid.

The reaction with benzylidenephthalaldehyde ((i), (ii) 4.44 g.), and with 2-phenylacetylbenzoic acid ((iii), (iv) 5.16 g.) gave:

I. A white solid ((i) 3.18, (ii) 3.06, (iii) 4.30, (iv) 3.90 g.), m.p. (i) 179.5 - 180.5, (ii) 181.5-182.5, (iii) 179-180.5, (iv) 183.5-184.5°, which on crystallisation from aqueous ethanol gave silky needles ((i) 1.91, (ii) 1.64, (iii) 3.82, (iv) 3.58 g.), m.p. (i) 187, (ii) 188-188.5, (iii) 186.5-187, (iv) 186-189°. The product I., on 5 recrystallisations from aqueous ethanol, gave N-phenylacetyl-anthranilic acid, colourless needles, m.p. 190°. Found; C, 70.4; H, 5.05; N, 5.60%, equivalent (by titration), 252. Calc. for C_{15}H_{15}O_{2}N: C, 70.5; H, 5.15; N, 5.50%, equivalent, 255. Diesbach, Gross and Teckemann (15) record m.p. 188° for this compound.
II. A brown solid ((i) 0.25, (ii) 0.58, (iii) 0.36, (iv) 0.63 g.) m.p. (i) 164-166, (ii) 82-86, (iii) 164-166, (iv) 170-171°. Solids (i), (iii), and (iv) were treated as follows: The solid, trichloroacetic acid (2.0 g.) and sulphuric acid (98%, 1 ml) ((iv) with double quantities of reagents) were rapidly heated to 50°, and the mixture was maintained at 50° for one minute, and then poured into water; the solid which separated was crystallised from aqueous ethanol. There was obtained white needles ((i) 0.19, (iii) 0.11, (iv) 0.40 g.), m.p. (i) 171-174, (iii) 175-179, (iv) 186-187°, and mixed melting point with N-phenylacetylanthranilic acid of m.p. 189° was: (i) 186-187, (iii) 186-187, (iv) 189°.

III. A white solid ((i) 0.81, (ii) 0.47, (iii) 0.34, (iv) 0.37 g.), m.p. (i) 181.5-182.5, (ii) 184-185, (iii) 186-186.5 (iv) 185-186°, which, on crystallisation from aqueous ethanol, gave silky needles of N-phenylacetylanthranilic acid ((i) 0.73, (ii) 0.41, (iii) 0.25, (iv) 0.28 g.), m.p. (i) 189-189.5, (ii), (iii), (iv) 186.5-187°.

Hydrolysis of N-phenylacetylanthranilic acid.

This compound (1.00 g.) was heated with aqueous sodium hydroxide (3.7 ml, 30%) for two hours. The solution was cooled, diluted, acidified with sulphuric acid and extracted with ether. The latter yielded phenylacetic acid (0.43 g.) m.p. 75.5-76° alone and m.p. 77.5° when mixed with an authentic specimen of m.p. 77.5°. The acidic solution was
made alkaline and brought to pH 5 with acetic acid, extraction with ether then yielded anthranilic acid (0.30 g.), which, after recrystallisation from aqueous acetic acid, had m.p. 147-147.5° alone and when mixed with an authentic specimen.

**Propylidenephthalide and 2-butyrylbenzoic acid.**

The reaction with propylidenephthalide ((i), (ii) 3.48 g.) and with 2-butyrylbenzoic acid ((iii), (iv) 3.48 g.) gave:

**II.** - a dark oil ((i) 0.31 (ii) 0.37 (iii) 0.26 (iv) 0.32 g.), which was not characterised.

**III.** - a white solid ((i) 2.39 (ii) 2.76 (iii) 3.24 (iv) 3.11 g.) of m.p. (i) 118-118.5, (ii) 118 (iii), (iv) 117.5-118°. It (0.5 g.), on recrystallisation once from aqueous ethanol, and once from benzene and ligroin, yielded N-n-butyrylanthranilic acid (0.3 g.), colourless needles, m.p. 118°. Equivalent (by titration) 209. C_{11}H_{13}O_3N requires 207. Pictet and Duparc, (16), record m.p. 118-118.5° for this compound.

**Amine.** The acid aqueous solution was concentrated to c.100 ml., and made alkaline with Gn-NaOH. The alkaline solution was subjected to steam distillation until a neutral distillate was obtained. To this was added Gn-NaOH, and benzoyl chloride (0.7 ml), and the mixture was shaken. After cooling, it was extracted with ether (2 x 15 ml), and the ether solution was dried (Na_2SO_4), and evaporated to dryness. The residue ((i) 0.15, (ii) 0.19, (iii) 0.11, (iv) 0.25 g.) had
w.p. (i) 69-71, (ii) 68-69, (iii) 77-78, (iv) 77-78°. On recrystallisation from benzene and light petroleum (b.p. 60-80°) it had m.p. (i) 76-76.5, (ii) 79.5-80, (iii) 82, (iv) 80.5° alone and (i) 76.5-77, (ii) 80, (iii) 82 (iv) 80.5° when mixed with N-n-propylbenzamide of m.p. 81.5°.
A. 6-oxo-2-n-propyl-4:5-benz-1:3 oxazine.

(1) Preparation

(Method of Zentmeyer and Wagner, (13))

N-n-Butyrylanthranilic acid (8.2 g.), and acetic anhydride (32.0 ml.) were heated under reflux for 2 hours, after distillation of acetic acid and anhydride, finally at reduced pressure, the product was recrystallised twice from anhydrous methanol; it yielded 6-oxo-2-n-propyl-4:5 benz-1:3 oxazine (3.60g), needles, m.p. 59.5°. The above authors record m.p. 59-60° for this compound.

(ii) This oxazine (0.95 g., 0.005 mole) was subjected to the Schmidt procedure on 1/4 scale. There was obtained:

I: White solid, 0.26 g., m.p. 110°
II: " " , 0.22 g., m.p. 115°
III: " " , 0.43 g., m.p. 116°

The mixed melting point of each specimen with N-n-butyrylanthranilic acid, m.p. 118°, was determined:


(iii) Treatment with aqueous solvents.

(a) The oxazine (0.95 g.) was heated on a steam bath with acetic acid - water (80:20, 9.5 ml.) for 30 minutes. No solid separated from the cold solution, but addition of
water gave a precipitate of N-n-butyrylanthranilic acid (0.96 g.) which had m.p. 116° alone and when mixed with an authentic specimen.

(b) The oxazine (0.80 g.) was treated with ethanol - water (80:20, 8 ml.) as shown above for 30 minutes. The cold solution was extracted with chloroform (3 × 10 ml.). The chloroform solution was dried (Na₂SO₄), and evaporated to dryness, yielding N-n-butyrylanthranilic acid (0.82 g.) m.p. 112° and mixed m.p. 114.5-115° with an authentic specimen.

B. 2-Benzyl-6-oxo-4:5-benz-1:3-oxazine.

(i) Preparation.

N-phenylacetylanthranilic acid (2.55 g.) and acetic anhydride (7.5 ml.) were heated under reflux for 45 minutes. The acetic acid formed in the reaction was removed by distillation at atmospheric pressure. Excess of acetic anhydride was removed by distillation at reduced pressure. The residual yellow oil solidified on standing. It, on two crystallisations from acetic anhydride, gave colourless needles of 2-benzyl-6-oxo-4:5-benz-1:3-oxazine, m.p. 90°.

Found: C; 75.3; H, 4.80; N, 5.80. C₁₅H₁₁O₂N requires: C, 75.9; H, 4.65; N, 5.90%.

(ii) The oxazine (1.18 g., 0.0050 mole) was subjected to the conditions of the Schmidt reaction on ½ scale. There was obtained:

I: White Solid, 1.23 g., m.p. 180°.
On recrystallisation from aqueous ethanol I gave N-phenylacetylanthranilic acid (0.96 g.) m.p. 187.5-133° alone, and when mixed with an authentic specimen.

(iii) Treatment with aqueous solvents

(a) The oxazine (0.80 g.) was treated as above with acetic acid-water (80:20, 8.0 ml.). On cooling, there separated N-phenylacetylanthranilic acid (0.81 g.) m.p. 183° alone, and when mixed with an authentic specimen.

(b) A similar experiment with ethanol-water (80:20) gave the same acid (0.76 g.) having m.p. 188.5-189° alone, and when mixed with an authentic specimen.

C. 2-r-Chlorophenyl-6-oxo-4:5-benz-1:3-oxazine.

(i) Preparation

(See page )

(ii) This oxazine was not subjected to the Schmitz procedure as it is prepared by such a procedure.

(iii) Treatment with aqueous solvents.

(a) The oxazine (1.80 g.) was treated as above with acetic acid-water (80:20, 10 ml.). After cooling, the mixture was filtered, yielding a product (0.92 g.), m.p. 177-182°, which was dissolved in chloroform (30 ml.), the solution was extracted with aqueous sodium hydrogen carbonate (2 x 20 ml.), washed with water (20 ml.) and dried (Na$_2$CO$_3$). It yielded the oxazine (0.73 g.), m.p. 188.5° alone, and when mixed with an authentic specimen. From the sodium hydrogen carbonate solution a solid (m.p. 300°) separated which on
treatment with dilute hydrochloric acid gave a product (0.14 g.) having m.p. 207°. (Zentmeyer and Wagner (13) record m.p. 204-205° for N-p-chlorobenzoylanthranilic acid.)

(b) The oxazine (1.00 g.) was treated with ethanol-water (80:20, 10 ml.) as previously described: it (0.96 g.) was recovered having m.p. 189.5° alone, and when mixed with an authentic specimen.

**Modified Schmidt reaction procedure.**

Three Schmidt reactions were carried out by the method previously described (p. ) except that, at the end of the reaction, the chloroform and sulphuric acid layers were separated. The latter was washed with chloroform (2 X 25 ml.), and the combined chloroform solutions were filtered, and evaporated to dryness, in each instance they gave no residua. The sulphuric acid layer was poured on to ice.

**A. 2-p-Chlorobenzoylbenzoic acid.**

(1) 2-p-Chlorobenzoylbenzoic acid (5.21 g.) yielded material (5.30 g.), m.p. 182-4°, which was stirred with chloroform (150 ml.); the latter was filtered, washed with aqueous sodium hydrogen carbonate, dried (Na₂SO₄), and evaporated; it gave a product (0.36 g.), which on recrystallisation from ethanol gave the oxazine (0.23 g.), m.p. 189.5°. The chloroform-insoluble material (4.18 g.) and that obtained on acidification of the sodium hydrogen carbonate solution (0.56 g.) after two
recrystallisations from aqueous ethanol gave
N-\(\ce{p}\)-chlorobenzoylanthranilic acid (3.46 g.), m.p. 207.5°.

(ii) 2-\(\ce{p}\)-chlorophenyl-6-oxo-4:5-benz-1:3-oxazine was
dissolved in sulphuric acid (98%, 6 ml.), the solution was
kept at 30° for 30 minutes, and then poured on to ice; the
solid which separated was recrystallised from aqueous ethanol,
yielding N-\(\ce{p}\)-chlorobenzoylanthranilic acid (1.68 g.), m.p.
207.5°.

B. 2-Mesitylbenzoic acid.

The sulphuric acid layer obtained from reaction
with 2-mesitylbenzoic acid ((i)-(iii), 2.68 g., 0.0100 mole)
having been poured on to ice, the mixture was shaken with
chloroform (50 ml.) and the whole was filtered. The
chloroform layer was separated, washed with aqueous sodium
hydrogen carbonate (2 x 25 ml.) and water (2 x 25 ml.), dried
(Na\(_2\)SO\(_4\)), and evaporated to dryness. It yielded 2-mesityl-6-
oxo-4:5-benz-1:3-oxazine((i) 0.77, (ii) 0.60, (iii) 0.70 g.,
from ethanol), m.p. 134-136° and, on further crystallisation,
m.p. 139° alone, and m.p. 139.5-140° when mixed with an
authentic specimen. The material which was insoluble in
dilute sulphuric acid and in chloroform was recrystallised
from aqueous dioxan; in two experiments it yielded
N-mesitylphthalimide ((i) 0.61, (iii) 0.45 g.) having m.p.
178-179°, and, on further recrystallisation, m.p. 180° alone,
and when mixed with an authentic specimen of the same m.p.;
in (ii) it gave N-mesitylphthalamidic acid (0.62 g.)
m.p. 191.5-192.5° (decomp.) raised by further recrystallisation
to m.p. 193.5-194° (decomp.).

C. 2-Butyrylbenzoic acid.

The sulphuric acid layer obtained from reaction with
2-butyrylbenzoic acid (3.84 g., 0.0200 mole) having been
poured on to ice, a white solid separated. It (3.19 g.) had
m.p. 115° alone, and m.p. 116° when mixed with an authentic
specimen of N-n-butyrylanthranilic acid.
Experiments concerning the formation of base and substituted phthalamic acid.

Experiments with N-m-nitrophenylphthalamic acid.

(i) Preparation.

m-Nitroaniline (2.0 g.), phthalic anhydride (2.0 g.) and toluene (75 ml.) were heated under reflux for 15 minutes. There soon separated a pale yellow solid. The cooled mixture was filtered; the residue was dried and re-crystallised from aqueous ethanol to give N-m-nitrophenylphthalamic acid (2.14 g.), pale yellow needles, m.p. 206.5° (decomp.). On further heating it solidified, and melted again at 247-248°. (Meyer and Lüders (17) record m.p. 201° (decomp.), resolidification, and re-melting at 240° for this compound.

N-m-Nitrophenylphthalamic acid (0.9 g.), and glacial acetic acid (10 ml.) were heated together under reflux for 15 minutes. To the cooled solution was added water when a pale yellow precipitate was obtained. The mixture was heated, and the solid dissolved. On cooling there separated N-m-nitrophenylphthalimide (0.72 g.), needles m.p. 250-251°. (Gabriel (18) records m.p. 242-243° for this compound.)

(ii) N-m-Nitrophenylphthalamic acid ((i), (ii) 0.36 g.), sulphuric acid (98%, 15 ml.), and chloroform (35 ml.) were stirred at 30° for 2 hours, and the mixture was then treated as in the Schmidt reaction procedure. The following were obtained.
I: (i) 0.14 g., m.p. 206° (decomp). (Unchanged N-m-nitrophenylphthalamic acid.)

II: (i) 0.11, (ii) 0.10 g., which, on crystallisation from ethanol, yielded N-m-nitrophenylphthalimide, m.p. 243° alone, and m.p. 243.5° when mixed with an authentic specimen, m.p. 250.5-251°.

Amine: From the acidic aqueous solution was obtained m-nitroaniline, ((i), (ii) 0.04 g.), m.p. 107-111°, and on recrystallisation from water, m.p., and mixed m.p. 111.5-112°.

The preparation of N-mesitylphthalamic acid.

(1) Nitromesitylene.

(Method of Garfield and Johnson (19).)

Into a 250 ml. flask was placed mesitylene (23 ml.) and acetic anhydride (23 ml.). To this solution was added (20 minutes), with shaking and cooling so that the temperature did not rise above 20°, a mixture of nitric acid (a 1.5, 10.5 ml.), acetic anhydride (9.5 ml.), and acetic acid (9.0 ml.). (The nitration mixture was prepared by adding the nitric acid to the acetic anhydride/acetic acid mixture, with cooling, so that the temperature of the mixture did not rise above 10°.) After standing for 1½ hours at room temperature the reaction mixture was heated at 50° for 10 minutes, and, after cooling, it was poured on to ice (400 g.). The solid which separated was filtered off; to the filtrate was added sodium chloride (10 g.), and it was
extracted with ether (150 ml.). To the ethereal solution was added the above solid, and the whole was then washed with 2N-sodium hydroxide (4 x 50 ml.), and then with water (100 ml.). After evaporation of the solution, the residue was subjected to steam distillation. In the distillate was a yellow oil which soon crystallised to give nitromesitylene (27.5 g.), m.p. 42-43°.

(ii) Mesidine.

To a mixture of nitromesitylene (17 g.) and granulated tin (25 g.) was added, in small volumes, concentrated hydrochloric acid (50 ml.). After warming on a steam bath for 20 minutes, the mixture was cooled, and sodium hydroxide solution (38 g. in 50 ml. water) was added. The resulting mixture was steam distilled until the distillate no longer contained oily drops. The distillate was extracted with ether (3 x 50 ml.), and the ethereal solution was dried (Na₂SO₄), and evaporated to dryness. The residue was distilled at reduced pressure to give mesidine (11.7 g., 84%), b.p. 140-141°/41 mm.

Benmesidine was prepared by the Schotten-Baumann method. Recrystallisations, once from aqueous ethanol and once from ethanol, gave benmesidine, m.p. 200°.

(Nieder and Schack (20) record m.p. 204°.)

N-Mesitylphthalimide was prepared as follows:-
A mixture of phthalic anhydride (0.1 g.), mesidine (0.1 g.), and acetic acid (1 ml.) was heated under reflux for 30 minutes. The solution was cooled and water was added drop-
wise until a white precipitate was obtained. After heating of the mixture, a clear solution was obtained, and, on cooling, needles separated. Two recrystallisations from aqueous acetic acid gave N-mesitylphthalimide, m.p. 180.5°. (Eisenberg (21) records m.p. 171° for this compound).

(iii) N-Mesitylphthalimide acid.

Mesidine (2.55 g.), phthalic anhydride (2.80 g.), and toluene (75 ml.) were heated under reflux for 15 minutes. The cooled mixture was filtered, and the residue was washed with toluene. It (2.70 g.) needles, had m.p. 199.5° (decomp.). (The melting point varied with the rate of heating.)


A mixture of N-mesitylphthalimide acid (1.00g.), m.p. 199.5° (decomp.), and acetyl chloride (6 ml.) was heated at 60° for 7 minutes. The mixture was cooled, and carbon disulphide (10 ml.) was added. The mixture was filtered, and the residue was shaken with ether (20 ml.) and aqueous potassium hydroxide (1 ml., 33%). The ethereal solution was dried (Na₂SO₄), and evaporated to dryness. There was no residue. The alkaline solution was acidified. A white solid separated; it (0.18g.) had m.p. 199.5° (decomp.). The carbon disulphide/acetyl chloride solution was evaporated to dryness. The residue (0.73g.) had m.p. 181° alone, and when mixed with an authentic specimen of N-mesitylphthalimide.
The attempted preparation of 3-mesityl-6-oxo-1,5-benz-1,2-oxazine.

(i) A mixture of 2-mesitoylbenzoic acid (2.73g.), hydroxylamine hydrochloride (1.50g.), barium carbonate (2.00g.), and ethanol (20ml.) was heated under reflux for 3 hours. The resulting mixture was filtered, and the residue was washed with ethanol (20 ml.). (The residue dissolved in an excess of 2N-hydrochloric acid.) The filtrate was evaporated to dryness, and the residue was recrystallised from ethanol (15 ml.) There was obtained a colourless, crystalline, solid (0.90g.), which melted 110-120°C (decomp.), resolidified, and remelted at 210-211°C. This melting-range was not altered by recrystallising the solid from ethanol. To the mother liquor was added water, and the precipitate which was formed was recrystallised from aqueous ethanol to give 2-mesitoylbenzoic acid (0.72g.), m.p. 214°C. A small quantity of the material which melted with decomposition was dissolved in aqueous ethanol; on cooling the solution, there separated a colourless, crystalline, solid m.p. 213°C alone, and when mixed with an authentic specimen of 2-mesitoylbenzoic acid, m.p. 214°C.

Another sample of the solid (0.20g.) was warmed over a Bunsen flame until there was no more effervescence. After cooling the melt, the solid was recrystallised from aqueous ethanol to give a colourless solid (0.15g.), m.p. 212-213°C alone, and when mixed with a sample of 2-mesitoylbenzoic acid.
(ii) 2-Mesitoylbenzoic acid (1.00 g.), hydroxylamine hydrochloride (0.70 g.), and pyridine (2.4 ml.) were heated together in a sealed tube at 120° for 8 hours. The tube was then cooled to room temperature, and the contents were washed into a beaker. The mixture was acidified with 2M-hydrochloric acid. There was obtained 2-mesitoylbenzoic acid (0.95 g.), m.p. 213.5°.

(iii) Double quantities of the above reagents were allowed to stand, with occasional shaking, for four weeks. To the resulting mixture was added a little water, and the mixture was filtered. The filtrate was acidified with 2M-hydrochloric acid, and the white precipitate was collected. Both the residue (1.30 g.), and the white precipitate (0.62 g.) had m.p. 213-214° alone, and when mixed with an authentic specimen of 2-mesitoylbenzoic acid.

The preparation of 3-p-chlorophenyl-6-oxo-4:5-benz-1:2-oxazine.

A mixture of 2-p-chlorobenzoylbenzoic acid (5.20 g.), hydroxylamine hydrochloride (2.80 g.), sodium acetate trihydrate (5.50 g.), and ethanol (100 ml.) was heated under reflux for 4 hours. To the resulting mixture was added water (100 ml.), and the mixture was filtered. The residue was crystallised from ethanol to give 3-p-chlorophenyl-6-oxo-4:5-benz-1:2-oxazine (3.27 g.), colourless needles, m.p. 191°. Buu-Hoi, Hoàn, and Xuong (22) record m.p. 191° for this compound.
The behaviour of 3-\(\alpha\)-chlorophenyl-6-oxo-4:5-benz-1:2-
oxazine under the conditions of the Schmidt reaction.

A mixture of 3-\(\alpha\)-chlorophenyl-6-oxo-4:5-benz-1:2-
oxazine (0.25g.), chloroform (35 ml.), and sulphuric acid (98%, 15 ml.) was stirred at 30\(^\circ\)C for 2 hours. The resulting mixture was poured on to ice (200g.), and the mixture was worked up in the manner previously described (p. ). There was obtained:

I, a white solid (0.06g.), m.p.182-184\(^\circ\) (decomp.) which resolidified, and remelted at 195-195.5\(^\circ\). The solid was heated under reflux with acetic acid (1 ml.) for 30 minutes. To the hot solution water was added until a faint, permanent precipitate was obtained. On cooling, there was obtained a crystalline solid (0.04g.), m.p. 195\(^\circ\) alone, and 196\(^\circ\) when mixed with an authentic specimen of \(N-\beta\)-chlorophenyl-
phthalimide of m.p.196\(^\circ\). Sherrill, Schaeffer, and Shoyer (23) record that \(N-\beta\)-chlorophenylphthalimidic acid melts at 187.5\(^\circ\), solidifies, and remelts at 192\(^\circ\).

II, a buff solid (0.12g.), m.p. 152-153\(^\circ\), which was not identified.

Amine: no trace of a primary aromatic amine was found.

The Preparation of 1:2-Benzofluorenone, and 1:2-Benzofluoren-9-ol.

Chrysenequinone.

(Method of Bamberger, and Burgdorf, (24).)

A mixture of chrysene (50g.), glacial acetic acid (500g.), and sodium dichromate (220g.) was heated under reflux for 9 hours. The reaction mixture was then poured into water (1L.), and the resulting mixture was filtered. The red residue was washed several times with water, and dried. It (46g.) was sufficiently pure for the preparation of 1:2-benzofluorenone; a sample, after two recrystallisations from glacial acetic acid, had m.p. 211.5°. Graebe, and Höngisberger (25) record m.p. 239.5° for this compound.

1:2-Benzofluorenone.

(Method of Bamberger, and Burgdorf, (26).)

A mixture of chrysenequinone (2g.) and litharge (15g.) was placed in a copper boat, which was introduced into a Pyrex tube in a combustion furnace. The mixture was heated
at reduced pressure (50 mm.) until no more sublimate was formed. This procedure was repeated several times. The sublimate (22.7 g.), on recrystallisation from glacial acetic acid, gave 1:2-benzofluorenone, (20.2 g.), orange needles, m.p. 130°. Bamberger, and Burgdorf (26) record m.p. 132.5° for this compound.

1:2-Benzofluoren-9-ol.

A mixture of sheet aluminium (12.4 g.), and anhydrous isopropanol was heated under reflux. After the addition of a small quantity of mercuric chloride (0.1 g.), a vigorous reaction ensued. After all the aluminium had dissolved (4 hours), a solution of 1:2-benzofluorenone (30 g.) in benzene (300 ml.) was added, and the mixture was heated under reflux for a further 3.5 hours. The solvents were removed by distillation at reduced pressure, and the residue was decomposed by the addition of ice-cold hydrochloric acid. The mixture was filtered, the residue was washed several times with water, and dissolved in benzene (500 ml.). Wet benzene was removed by distillation, and, to the hot mixture, benzene (15 ml.) was added to effect complete solution, and then n-heptane (50 ml.). On cooling there separated 1:2-benzofluoren-9-ol (21.5 g.), m.p. 175.5°. The melting point was raised to 176°, after two recrystallisations from benzene and n-heptane. (Found: C, 87.3; H, 5.15. Calc. for C_{17}H_{12}O: C, 87.9; H, 5.2%). Bamberger, and Kranzfeld,
(27), who prepared this compound by reducing 1:2-benzofluorenone with zinc and hydrochloride acid, record m.p. 166-167°.

9-Acetoxy-1:2-benzofluorene.

A mixture of 1:2-benzofluoren-9-ol (0.5g.), acetic anhydride (1ml.), and pyridine (5ml.) was heated on a steam bath for 3 hours. On pouring of the reaction mixture on to ice, a yellow oil, which soon solidified, separated. Three recrystallisations from ethanol gave 9-acetoxy-1:2-benzofluorene, prisms, m.p. 113°. (Found: C, 83.1; H, 5.15. C_{19}H_{14}O_2 requires: C, 83.3; H, 5.15%.)

The Behaviour of 1:2-Benzofluorenone and Hydrazoic Acid in the Presence of Strong Acids.

(i) In the presence of sulphuric acid.

I. To a vigorously stirred solution of 1:2-benzofluorenone (4.60g., 0.0200 mole) in sulphuric acid (98%, 20 ml.) at 0° was added, in small portions during 1 hour, sodium azide (2.60g., 0.0400 mole). After a further 1.5 hours' stirring, the reaction mixture was poured on to ice (200g.). The red residue (4.73g.), m.p. 128-130°, on recrystallisation from aqueous acetic acid, gave unchanged 1:2-benzofluorenone (3.69g.), m.p. 134.5°.

II. In this experiment, a procedure similar to the above was employed, but the temperature of the reaction mixture was
maintained between 40 and 50°. The residue (6.23 g.),

obtained by pouring the reaction mixture on to ice (200 g.),

and filtering, liberated carbon dioxide from sodium hydrogen
carbonate. It was shaken with 2N-sodium hydroxide (40 ml.),

and the mixture was filtered. The filtrate, on acidification,

yielded a dark brown solid, which was found to contain
both sulphur and nitrogen. A portion (1.00 g.) of the
residue, which also contained sulphur and nitrogen,

was subjected to fractional sublimation at reduced pressure.

(a) 150°; 0.19 g., m.p. 131.5-132°.

(b) 200°; 0.09 g., m.p. 133-135°.

(c) 250°; 0.03 g., m.p. 190-220°.

(d) 300°; 0.01 g., m.p. 214-260°.

(e) 350°; 0.01 g., m.p. 220-260°.

Residue: 0.53 g., (black).

Fraction (e) was found to contain nitrogen, i.e. the higher
melting fractions may contain 1:2-, and 7:8-benzophen-
anthrindones, (m.p 332.5°, and m.p. 338° respectively,
Graebe, (29)).

(ii) In the presence of trichloroacetic acid.

To the vigorously stirred dark red solution of the
ketone (2.30 g., 0.0100 mole) in trichloroacetic acid (23 g.)
was added, in small portions during 20 minutes, sodium azide
(1.30 g., 0.0200 mole). The temperature of the reaction
mixture was maintained between 65 and 85°. After 2 hours'
further stirring, the reaction mixture was poured on to ice
A dark oil separated, which would not solidify. To the acid mixture was added sodium carbonate until it was alkaline. The solid, which was then obtained (2.49 g.), m.p. 120-125°, was crystallised from aqueous acetic acid, and gave unchanged 1:2-benzofluorenone (1.64 g.), m.p. 130°.

(iii) In the presence of polyphosphoric acid.

A mixture of phosphoric oxide (10 g.) and phosphoric acid (10 g., 65% P₂O₅), was heated, with stirring, until a clear solution was obtained. At 65°, the ketone (1.15 g., 0.005 mole) was added, and, during 10 minutes, sodium azide (0.65 g., 0.01 mole) was added. Stirring at 65° was continued for a further 1.5 hours; ice (100 g.) was then added to the reaction mixture. The solid product, collected by filtration, was subjected to fractional sublimation at 0.5 mm.

- (a) 130°; 0.23 g., m.p. 131-131.5°.
- (b) 150°; 0.12 g., m.p. 135°.
- (c) 200°; 0.19 g., m.p. 134-136°.
- (d) 250°; 0.06 g., m.p. 150-220°.
- (e) 300°; 0.01 g., m.p. 260-280°.
- (f) 350°; trace, m.p. 265-280°.

Residue; 0.53 g., black.

Fraction (f) was found to contain nitrogen.
The Interaction between 1:2-Benzofluoren-9-ol and Hydrazolic Acid in the Presence of Sulfuric Acid.

(i) In the presence of sulfuric acid.

To a suspension of sodium azide (2.60g., 0.0400 mole) in chloroform (30 ml.) at 0° was added, during 15 minutes, sulfuric acid (98%, 8 ml.). After a further 15 minutes stirring, the temperature of the mixture was raised to 25°, and a suspension of the carbinol (4.64g., 0.0200 mole) in chloroform (20 ml.) was added during 1 hour. After a further 2 hours' stirring, the reaction mixture was poured on to ice (320 g.), and the mixture was mechanically shaken for 30 minutes, and then filtered.

(i) The residue (3.77 g.), a brown amorphous solid, containing nitrogen and sulfur, was mechanically shaken with 2N-sodium hydroxide (100 ml.) and benzene (50 ml.) for 4 hours. The mixture was filtered. There was obtained as a residue a brown amorphous solid (3.42 g.). The benzene solution was dried (Na₂SO₄), and evaporated; it yielded a small quantity (0.20 g.) of a brown resin. Acidification of the aqueous solution with 2N-hydrochloric acid gave no precipitate; addition of aqueous barium chloride gave a white precipitate, insoluble in an excess of hydrochloric acid, indicating the presence of the sulfate ion.

(ii) The chloroform solution was washed with 2N-hydrochloric acid (2X50 ml.) (the washings were added to the acidic aqueous solution), dried (Na₂SO₄), and evaporated; it gave a dark oil (0.48 g.).
(iii) The acidic aqueous solution was made alkaline with ammonia (d 0.88) and a grey flocculent precipitate was obtained. It (0.52 g.), m.p. 245-250°, contained nitrogen and sulphur. Ethereal extraction of the aqueous solution yielded 0.01 g. of a dark oil.

(ii) In the presence of trichloroacetic acid.
A mixture of sodium azide (2.60 g., 0.0400 mole), chloroform (20 ml.), and trichloroacetic acid (40 g.) was stirred at room temperature for 15 minutes. At 30°, during 30 minutes, a suspension of 1:2-benzofluoren-9-ol (4.64 g., 0.0200 mole) in chloroform (20 ml.) was added to the reaction mixture. After being stirred for a further 2 hours, the reaction mixture was poured on to ice (200 g.). The chloroform solution was washed with saturated aqueous sodium hydrogen carbonate (2×25 ml.), and with water (2×25 ml.), dried (Na₂SO₄), and evaporated to dryness. The residue was crystallised from light petroleum (b.p. 60-80°), and there was obtained 9-azido-1:2-benzofluoren, (3.53 g.), buff needles, m.p. 90-90.5°. (Found: C, 79.3; H, 4.25; N, 16.5.
C₁₇H₁₁N₃ requires C, 79.4; H, 4.3; N, 16.35%).

The Acid Catalysed Decomposition of 9-Azido-1:2-benzofluoren.

(i) In the presence of sulphuric acid (98%).
To a solution of the azide (1.00 g.) in chloroform (10 ml.) was added, at 0°, during 10 minutes, sulphuric acid (0.5 ml.). After being stirred for a further 20 minutes, the black reaction mixture was poured on to ice.
(a) The insoluble residue (0.62 g.) was shaken with a mixture of 2N-sodium hydroxide (25 ml.), and benzene (25 ml.). The mixture was filtered, and the aqueous solution was extracted with benzene. To the oily residue from the evaporation of these benzene solutions was added a solution of picric acid in ethanol; there was no precipitate.

(b) The chloroform solution was washed with 2N-hydrochloric acid (25 ml.), with water (25 ml.), dried (Na$_2$SO$_4$), and evaporated to dryness. The residue (0.39 g.), m.p. 75°, on recrystallisation from light petroleum (b.p. 60-80°), yielded buff needles of 9-azido-1;2-benzofluorene, m.p. 87.5-88° alone and m.p. 89.5° when mixed with an authentic specimen of m.p. 89.5°.

(ii) In the presence of trifluoroacetic acid.

A mixture of the azide (3.00 g.), and trifluoroacetic acid (30 ml.) was heated under reflux for 45 minutes. After cooling, the reaction mixture was poured on to ice (100 g.). The mixture was filtered, and the residue was shaken with 2N-sodium hydroxide (75 ml.) for 1 hour. The mixture was filtered, and the residue was dried; it (2.56 g.) had m.p. 107-115°. It was treated with acetone (125 ml.), and the mixture was filtered. (The residue was a buff amorphous solid 0.1 g.). To the filtrate was added a solution of picric acid (moist, 5.0 g.) in acetone (25 ml.). A yellow solid separated. It (1.89 g.) was warmed with dioxan (25 ml.), and the mixture was allowed to cool to room temperature. There was obtained a yellow solid (1.49 g.), m.p. 236-237° (decomp.).
The acetone mother liquors were concentrated to 25 ml, and ethanol (25 ml.) was added. The precipitate (1.04 g.) was warmed with dioxan (12.5 ml.). The mixture was cooled and filtered. The residue (0.37 g.) had m.p. 236-237° (decomp.).

Thus there was obtained 1.86 g. of a mixture of picrates. It was shaken with 10% sodium hydroxide (62.5 ml.) for 30 minutes. The resulting mixture was extracted with ether (4X50 ml.); the ethereal solution was washed with water (4X50 ml.), dried (Na₂SO₄), and evaporated to dryness, and yielded a buff solid (0.86 g.), m.p. 131-132°.

In a parallel experiment there was obtained 1.95 g. of the mixture of picrates, and 0.89 g. of the mixture of bases.

The basic mixture was separated as follows, by a chromatographic method.

A 3 cm. bore glass tube, 100 cm. long, the lower end of which carried a cork, carrying a corked tube of smaller diameter, was mounted vertically, and three-quarters filled with benzene. A small cotton wool pad was pushed to the lower end of the column, and chromatographic alumina was added in a thin stream until a column 90 cm. long had been prepared. A small cotton wool pad was placed at the head of the column, and the upper end of the glass tube was fitted with a cork carrying a dropping funnel.

The mixture of bases (0.40 g.) in benzene (25 ml.) was added, dropwise, to the head of the column, the cork of the delivery tube at the lower end of the column being removed.
The solution having been added, the column was eluted with benzene. After some time, when the column was viewed by an ultra-violet light, two blue fluorescent bands could be seen. After some 2 L. of eluate had been collected, the first blue band (A) began to be washed from the column. It was collected in 2.60 L. of solution. On evaporation to dryness, there was obtained a white solid (0.22 g.), m.p.132.5-133°. The second band (B) adhered firmly to the top of the column. The top 30 cm. of the column, which held it, were removed, and washed with boiling benzene (4x100mL). The benzene solution was evaporated to dryness. There remained a white solid (0.06 g.), m.p.171.5-172°.

A sample (0.40 g.) of the basic mixture from the second decomposition was separated in a similar fashion to the above, except that:

(i) a smaller column (75 cm. long, 2.5 cm. bore) was used.
(ii) the second band (B) was washed from the column by use of acetone. The acetone solution was evaporated to dryness. There remained a buff solid contaminated with a yellow oil. To this mixture was added ethanol (25 mL.), and the mixture was warmed, and filtered. To the filtrate was added picric acid (0.3 g., moist) in ethanol (5 mL.). The yellow precipitate, which was formed, was filtered off, and dried. It (0.18 g.) had m.p.272.5° (decomp.).

The fractions A, on recrystallisation from ethanol
gave 1:2-benzophenanthridine, m.p. 135°. (Found: C, 89.0; H, 4.75; N, 5.95. Calcd. for C\textsubscript{17}H\textsubscript{11}N: C, 89.0; H, 4.85; N, 6.10\%). An ethanolic solution of this compound, when treated with an ethanolic solution of picric acid, gave a yellow solid, m.p. 256° (decomp.), which was considered to be 1:2-benzophenanthridine picrate. No good analysis for nitrogen could be obtained for this compound. (Found: N, 11.15, 10.95, 10.7, 11.3. Calcd. for C\textsubscript{25}H\textsubscript{14}O\textsubscript{7}N\textsubscript{4}: N, 12.2\%). The last analysis was obtained on the crude picrate, above. The first three analyses were obtained on once recrystallised material, m.p. 255.5° (decomp.). To an aqueous solution of platinic chloride (2%, 10 ml.) was added a solution of 1:2-benzophenanthridine (0.1 g.) in concentrated hydrochloric acid (10 ml.). There separated a buff solid, m.p. 279-280° (decomp.), 1:2-benzophenanthridine chloroplatinate. (Found: Pt, 21.8. (C\textsubscript{17}H\textsubscript{11}N)\textsubscript{2}H\textsubscript{2}PtCl\textsubscript{6} requires Pt, 22.5\%).

The fractions B, on recrystallisation from ethanol, gave 7:8-benzophenanthridine, m.p. 182°. (Found: C, 88.5; H, 4.75; N, 5.95. Calcd. for C\textsubscript{17}H\textsubscript{11}N: C, 89.0; H, 4.85; N, 6.10\%). An ethanolic solution of this compound, when treated with an ethanolic solution of picric acid, gave a yellow solid, which, on recrystallisation from dioxan gave 7:8-benzophenanthridine picrate, needles, m.p. 277-278° (decomp.). (Found: N, 11.95. C\textsubscript{23}H\textsubscript{14}O\textsubscript{7}N\textsubscript{4} requires: N, 12.2\%).

Badger and Seidler (28) record m.p. 136° for 1:2-benzophenanthridine, and m.p. 183° for 7:8-benzophenanthridine. Graebe (29) records m.p. 256° (decomp.) for 1:2-
benzophenanthridine picrate.


The azide (1.50 g.) was warmed in an oil bath at 130°. Initially there was a slow evolution of gas from the melt. After a short time, however, there was a violent evolution of gas. The residue was cooled, and dissolved in methanol. The resulting solution was treated with decolourising charcoal (0.1 g.), filtered, and the filtrate was concentrated to 15 ml.. There separated a light orange solid (0.74 g.), and a dark orange solid (0.11 g.). The former was recrystallised from methanol to give 1:2-benzofluorenone imine, golden needles, m.p. 106.5° (Found: C, 88.9; H, 5.0; N, 6.0. \( \text{C}_{17}\text{H}_{11}\text{N} \) requires C, 89.0; H, 4.85; N, 6.1%) The dark orange solid was recrystallised from methanol. There were obtained golden needles and dark orange prisms, which were separated manually. The dark orange prisms had m.p. 108-108.5°. (Found: C, 88.8; H, 5.15; N, 5.90%.)

A mixture (0.20 g.) of the two forms of 1:2-benzofluorenone imine and aqueous sulphuric acid (30%, 10 ml.) was heated under reflux for 30 minutes, and the product was filtered off, washed with water, and dried. There was obtained 1:2-benzofluorenone (0.18 g.), m.p. 134° alone, and when mixed with an authentic specimen.
9-azo-9-phenylfluorene.

Preparation.

To a stirred solution of trichloracetic acid (20 g.) in chloroform (10 ml.) at 20° was added, in small portions, sodium azide (1.3 g.) during 10 minutes. After a further 10 minutes stirring, the temperature of the reaction mixture was raised to 30°, and, during 20 minutes, a solution of 9-phenylfluoren-9-ol (2.56 g., m.p. 109°) in chloroform (10 ml.) was added. After being stirred for a further 1.5 hours, the reaction mixture was poured on to ice (100 g.). The aqueous layer was extracted with chloroform (2×10 ml.), and the combined chloroform solutions were washed with saturated aqueous sodium hydrogen carbonate (2×25 ml.), and water (2×25 ml.), dried (Na$_2$SO$_4$), and evaporated to dryness. The product (2.52 g., m.p. 75-76°) yielded, after three recrystallisations from light petroleum (b.p. 60-80°), 9-azo-9-phenylfluorene, rectangular prisms, m.p. 78-78.5°.

(Found: C, 80.1; H, 4.75; N, 14.65. C$_{15}$H$_{15}$N$_3$ requires C, 80.5; H, 4.6; N, 14.85%.)

The decomposition of 9-azo-9-phenylfluorene.

I. Action of heat.

The azide (0.83 g.) was heated in an oil bath at 160-170° until no more gas was evolved. To the residual dark oil was added ethanol (15 ml.) and picric acid (damp,
A yellow solid (1.20 g., m.p. 248-250° (decomp.)) was precipitated. It, after two recrystallisations from glacial acetic acid, gave 9-phenylphenanthridine picrate, m.p. 251° (decomp.). The picrate (0.83 g.) was treated with 2N-sodium hydroxide, and the alkaline solution was extracted with ether (4X50 ml.). The ethereal solution was washed with water (4X50 ml.) dried (Na₂SO₄), and evaporated to dryness. The residue, after two recrystallisations from light petroleum (b.p. 40-60°), gave 9-phenylphenanthridine, 0.18 g. m.p. 104°. Arcus and Coombs (30) record m.p. 106° for the base, and m.p. 251° (decomp.) for the picrate.

II. Decomposition in the presence of sulphuric acid.

A mixture of sulphuric acid (98%, 2 ml.) and chloroform (4 ml.) was vigorously stirred at 25° during the dropwise addition (20 minutes) of a solution of 9-azido-9-phenylfluorene (0.80 g.) in chloroform (4 ml.). After being stirred for a further 1 hour at 25°, the reaction mixture was poured on to ice (80 g.). The chloroform solution was washed with 10N-sulphuric acid (2X10 ml.) and the combined acid solutions were made alkaline with sodium hydroxide. The alkaline solution was extracted with ether (2X50, 2X25 ml.), and the ethereal solution was dried (Na₂SO₄), and evaporated to dryness. The residue, after recrystallisation from light petroleum (b.p. 60-80°), gave 9-phenylphenanthridine, (0.63 g.), m.p. 104°.
EXPERIMENTS WITH BENZYLIDENEINDENE AND HYDRAZOIC ACID

IN THE PRESENCE OF ACID CATALYSTS.

Benzylideneindene.

(Method of Thiele, (31)).

To a mixture of benzaldehyde (10.6 g.), indene (12.0 g., b.p. 82°/28 mm.), and methanol (200 ml.) was added methanolic potash (potassium hydroxide, 28 g., in methanol, 100 ml.). There was a rapid colour change from colourless, through blue and green, to brown. The mixture was allowed to stand overnight. The solution was filtered and the residue was washed with methanol. Two recrystallisations from methanol gave benzylideneindene (3.8 g.), yellow plates, m.p. 88.5°. Thiele (31) records m.p. 88° for this compound.

Experiments with benzylideneindene and hydrazoic acid in the presence of acid catalysts.

I. 98% Sulphuric acid.

Sulphuric acid (98%, 7.5 ml.) was added dropwise to a stirred, ice-cooled mixture of sodium azide (1.3 g., 0.0200 mole) and chloroform (7.5 ml.). After a further 10 minutes, the ice was replaced by a water-bath at 30°, and benzylideneindene (2.04 g., 0.0100 mole) in solution in chloroform (10 ml.) was added, dropwise, with stirring, during 30 minutes. After stirring for a further 90 minutes, the mixture was poured on to ice (100 g.) and chloroform (50 ml.) was added. After standing, the aqueous layer was decanted from the chloroform layer and the insoluble residue; the chloroform
layer was separated from the insoluble residue by means of a centrifuge.

(i) The solid residue was shaken with 6N-ammonia. The mixture was extracted with ether (2X50 ml.), and the ethereal solution was dried (Na$_2$SO$_4$), and evaporated to dryness. The residue (0.15 g.) contained nitrogen, but no sulphur; it partially dissolved in dilute hydrochloric acid and addition of dilute sodium hydroxide to the acid solution gave a faint opalescence. The solid residue partially dissolved in 3N-sodium hydroxide; on acidification there was obtained a gelatinous precipitate of a sulphur-containing compound.

(ii) The chloroform layer was washed with 3N-hydrochloric acid (2X50 ml.), dried (Na$_2$SO$_4$), and evaporated to dryness. The residue (0.35 g.) was a dark oil. The acid washings were made alkaline with 6N-ammonia, and extracted with ether, which, however, gave no residue on evaporation.

(iii) The aqueous layer was made alkaline with 6N-ammonia, and extracted with ether, which yielded a brown oil (0.01 g.).

II Sulphuric acid monohydrate.

The experiment described above was repeated with sulphuric acid monohydrate (d$_4^{20}$1.777, 7.5 ml.).

(i) The chloroform layer was washed with 3N-hydrochloric acid (2X25 ml.), aqueous sodium hydrogen carbonate (2X25 ml.), and water (25 ml.), dried (Na$_2$SO$_4$), and evaporated to dryness. The residue (2.12 g.) was a yellow resin, m.p. 226° (decomp.).
It was purified by precipitation from its benzene solution by ethanol. The amorphous buff solid obtained had m.p. 234-236°.

(ii) No basic material was obtained from the aqueous solution.

III Trichloroacetic acid.

To a mixture of trichloroacetic acid (20 g.) and chloroform (10 ml.) at 0° was added, in small portions during 5 minutes, sodium azide (1.30 g., 0.0200 mole). The ice was replaced by a water-bath maintained at 30°, and during 30 minutes, with stirring, a solution of benzylideneindene (2.00 g.) in chloroform (10 ml.) was added. After being stirred for a further 1 hour, the reaction mixture was poured on to ice.

The chloroform solution was washed with 3N-sodium hydroxide (2X25 ml.), 3N-hydrochloric acid (2X25 ml.), and water (2X25 ml.), dried (Na₂SO₄), and evaporated to dryness. The residue (2.07 g.), m.p. 227° (decomp.), was a buff solid, containing neither nitrogen nor chlorine.

The polymerisation of benzylideneindene in the presence of trichloroacetic acid.

Experiment III was repeated, omitting the addition of sodium azide. From the chloroform layer was obtained a buff solid (2.00 g.), m.p. 185-190°.
Whitby and Katz (32) record that benzylideneindene polymerises on standing in chloroform solution with antimony pentachloride to give a hexamer of m.p. 252–255°C, and that prolonged heating alone yields a tetramer of m.p. 238–242°C.
THE SCURF REACTION OF 1:3-DIKETODYRINDENE.

Sulphuric acid (98%, 15 ml.) was added dropwise to a stirred, ice-cooled, mixture of sodium azide (2.60 g., 0.0400 mole) and chloroform (15 ml.). After a further 15 minutes, the ice was replaced by a water-bath at 30° and 1:3-diketodyrindene ((i), (ii) 2.92 g., 0.0200 mole) in solution in chloroform (20 ml.) was added during 1 hour; stirring was continued for 2 hours, the mixture was then poured on to ice (200 g.). The whole was then shaken mechanically for 30 minutes, and then filtered.

The aqueous layer was extracted with chloroform (2x25 ml.), and the combined chloroform solutions were washed with aqueous sodium hydrogen carbonate (2x25 ml.), and water (2x25 ml.), dried (Na₂SO₄), and evaporated to dryness. The residue ((i) 0.18, (ii) 0.19 g.) had m.p. (i) 218-219°, (ii) 194-196°.

The insoluble residue ((i) 1.99, (ii) 2.10 g.) had m.p. (i) 311° (decomp.), (ii) 322° (decomp.). It was soluble in acetic acid, n-butanol, 2-ethoxyethanol, 3N-hydrochloric acid, and insoluble in ethanol and light petroleum (b.p. 60-80°).

It (0.50 g.) dissolved in n-butanol (70 ml.). On cooling pale purple needles (0.16 g.), m.p. 331° (decomp.) separated. It (0.72 g.) dissolved in 3N-hydrochloric acid (40 ml.), decolourising charcoal (0.1 g.) was added,
and the solution was filtered. From the solution soon separated white needles (which on standing in the solution became red in colour) of 2:4-dihydroxyquinoline (0.24 g.), m.p. 326° (decomp.).

It (0.5 g.) and phosphorus oxychloride (5 ml.) were heated together on a steam bath for 2 hours; the reaction mixture was poured on to ice (200 g.), and the whole was made alkaline with sodium carbonate and extracted with ether (3×50 ml.). The ethereal solution was dried (Na₂SO₄), and evaporated to dryness. The residue (0.35 g.), had m.p. 63-64°, and, after decolourisation and recrystallisation from aqueous ethanol, yielded 2:4-dichloroquinoline, needles, m.p. 66°.

Fusco and Rossi (33) record that 1:3-diketohydrindene undergoes the Schmidt reaction to give 2:4-dihydroxyquinoline, (m.p. 355°, Niamentowski (34)). Koller (35) prepared 2:4-dichloroquinoline (m.p. 67-68°) from 2:4-dihydroxyquinoline by treatment with phosphorus oxychloride.
BIBLIOGRAPHY TO THE EXPERIMENTAL SECTION.

(1) Heller and Schulke, Ber., 1908, 41, 3633
(2) MacMullen, J. Amer. Chem. Soc., 1922, 44, 2508
(3) Lee Che Kin, Ann. Chim. (France), 1940 11, 317
(4) Crossing and Newton, Ind. Eng. Chem., 1929, 21, 369
(5) Basler, D.R.P., 148110.
(6) Newman and McCleary, J. Amer. Chem. Soc., 1941, 63, 1540
(8) Gabriel, Ber., 1885, 18, 3470
(9) Gabriel and Michael, Ber., 1878, 11, 1018.
(10) Ullyot, Taylor, and Dawson, J. Amer. Chem. Soc., 1943, 70, 542
(11) Bromberg, Ber., 1896, 29, 1436
(14) Bogert, Gortner, and Amend, J. Amer. Chem. Soc., 1911
     33, 952
     34, 1020
(16) Pictet and Du Parc, Ber., 1887, 20, 3421.
(18) Gabriel, Ber., 1878, 11, 2261
     p.449
(20) Hübner and Schack, Ber., 1877, 10, 1711.
(21) Eisenberg, Ber., 1880, 15, 1017.
(22) Buu-Hoi, Hoän, and Xuong, Rec. trav. chim., 1950, 69, 1105.
(24) Banburger and Burgdorf, Ber., 1890, 23, 2437.
(26) Bamberger and Burgdorf, Ber., 1885, 18, 1933.
(27) Bamberger and Kranzfeld, Ber., 1885, 18, 1934.
(29) Graebe, Annalen., 1904, 335, 129.
(31) Thiele, Ber., 1900, 33, 3398.
(33) Fusco and Rossi, Gazzetta., 1951, 81, 511.
(34) Niementowski, Ber., 1907, 40, 4288.
(35) Koller, Ber., 1927, 60, 1110.