A STUDY IN CARBAZOLE, DIPHENYLAMINE, AND FLUORENE.

By

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THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

Part I.

Carbazole and Diphenylamine.

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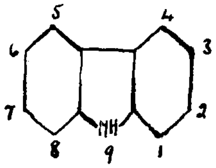
The oxidation of carbazole and its derivatives gives rise to dicarbazyls, and compounds of higher molecular weight whose structure is unknown.

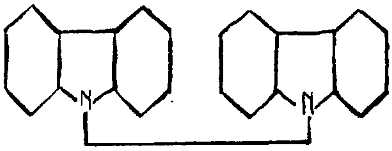
Carbazole itself, when oxidised in acid solution, gives different compounds from those isolated from oxidation in alkaline solution.

In all the acid oxidations of carbazole and its derivatives, brightly coloured quinonoid substances are obtained. The constitution of these substances will be discussed later.

It is evident that there are a great number of dicarbazyls theoretically possible; but if we bear in mind that the reactive positions in carbazole are the 1, 3, and 9- positions,



there are really only six dicarbazyls we need consider.



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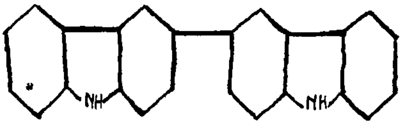

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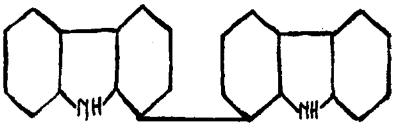

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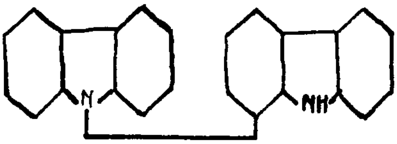

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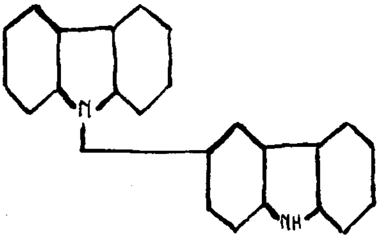

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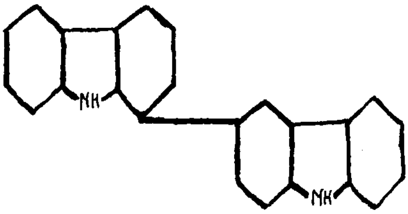


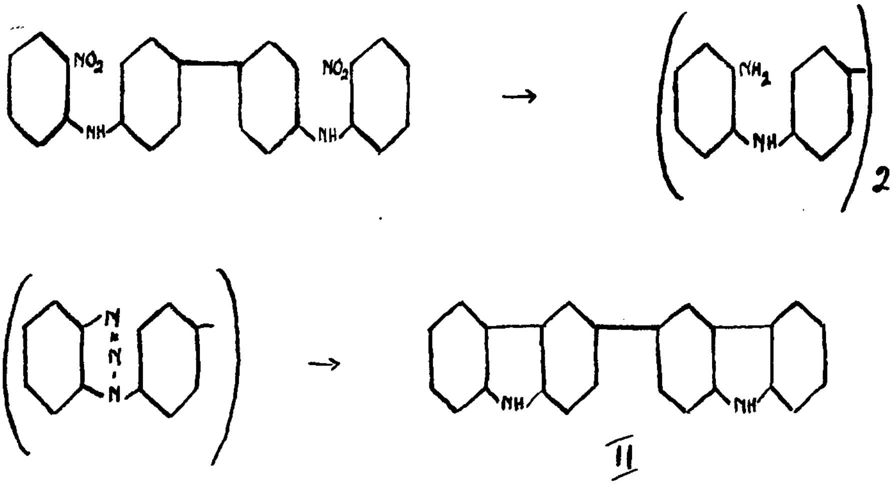
VI

In 1921 Perkin and Tucker (J.C.S., 1921, 119, 216) described three products, two crystalline, A and B, and a third, C, amorphous, all obtained by the oxidation of carbazole in acetone solution with potassium permanganate. They did not assign definite constitutions to any of these compounds; but it was apparent, from the analyses and molecular weight determinations, that A and B were dicarbazyls.

The product, C, obtained in greatest yield, was not examined further, as it could not be obtained in a crystalline state.

Three separate lines of experiment were then started in this laboratory, the object of all three being to obtain some information which might help to determine the constitution of these dicarbazyls.

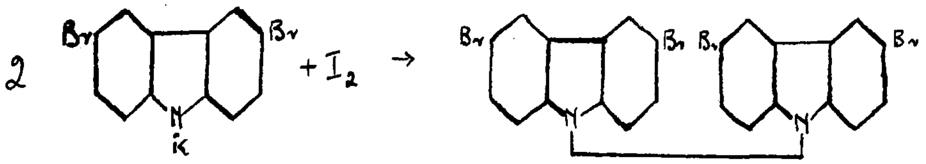
I. Tucker (J.C.S., 1926, 3033) synthesised 3:3'-dicarbazyl (II) according to the scheme:-



II

This dicarbazyl, however, was different from A, B, and C, and the original problem was still unsolved.

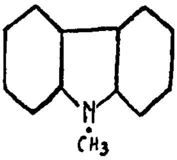
II. McLintock and Tucker (private communication) have shown indirectly that the substance A is 9:9'-dicarbazyl (I). They treated the potassium derivative of 3:6-dibromo-carbazole with iodine, and obtained a substance (VII), which was identical with the compound obtained by bromination of A.



VII

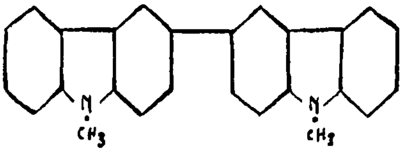
They also obtained (VII) by direct oxidation of 3:6 dibromocarbazole, (a) in alkaline solution, (b) in acid solution.

III. Side by side with these two lines the present research was developed. By oxidising 9-methyl carbazole,



we made sure that, in any dicarbazyl produced, the two carbazole nuclei would be united by a bond between two carbon atoms; i.e., we expected to get derivatives of (II) or (III) or (VI), the last mentioned being the most unlikely.

9-methyl carbazole does not oxidise at all in acetone solution with permanganate (Perkin and Tucker's method for carbazole), but when a mixture of acetic and sulphuric acids and sodium dichromate is used (Wieland's method, Ber., 1913, 46, 3296), a crystalline substance is obtained. It was hoped that either B or C would on methylation yield a compound identical with this new dimethyl dicarbazyl, but as it is actually identical with the methylation product of II, it is evidently 9:9'-dimethyl 3:3'-dicarbazyl (VIII),



VIII

and the constitutions of B and C remain unsolved.

These results were confirmed by analogous experiments on 9- ethyl carbazole, 9:9'-diethyl-3:3'-dicarbazyl being obtained. In both of these oxidations there was no evidence of the formation of any isomeric dicarbazyls, e.g., derivatives of 1:1' dicarbazyl (III) or 1:3' (VI).

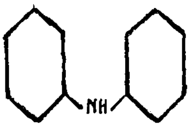
It is peculiar that no 3:3'-dicarbazyl is formed in Perkin and Tucker's oxidation of carbazole. This fact led us to attempt the oxidation by other methods.

Tucker (private communication) found that oxidation in boiling acetic acid with sodium dichromate gave a product containing chromium. We thought that the chromium might be attached in some way between the nitrogen atoms, and that, if the nitrogen were protected, chromium products might not be formed. Two methods of protection were tried, (a) by sulphuric acid, (b) by acetylation.

(a) Although no sulphate of carbazole has been isolated, we have obtained evidence for its existence in solution; for oxidation by Wieland's method gives 3:3'- dicarbazyl, uncontaminated with any 9:9' (I).

(b) Attempts to protect the nitrogen with an acetyl group were unsuccessful, for either (i) the compound proved to be extremely stable and was recovered unchanged, or (ii) the acetyl group was hydrolysed quickly, so that no protection was obtained.

The mechanism of the acid oxidation of carbazole was thought to be closely allied to that of the corresponding oxidation of diphenylamine (IX) to diphenylbenzidine (X), (Wieland, Ber., 1913, 46, 3296).



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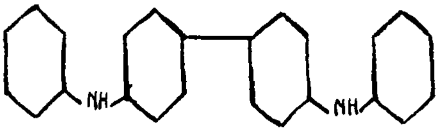


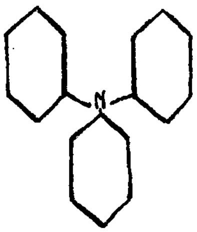
X

Two theories of the mechanism of the diphenylamine oxidation have been put forward.

(1) That the benzene nuclei unite directly, without the formation of an intermediate product, (Wieland).

(2) That the primary attack occurs at the :NH group, with the formation of an intermediate compound, which subsequently undergoes transformation (Marqueyrol and Muraour, Bull. Soc. Chim., 1914, <u>15</u>, 191).

(1) In support of this assumption Wieland has shown that tetraphenylbenzidine (XII) is formed by the oxidation of triphenylamine (XI).



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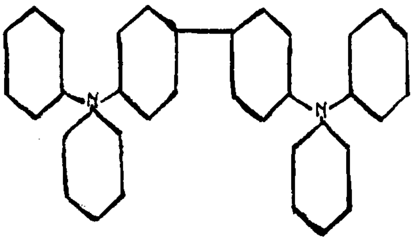
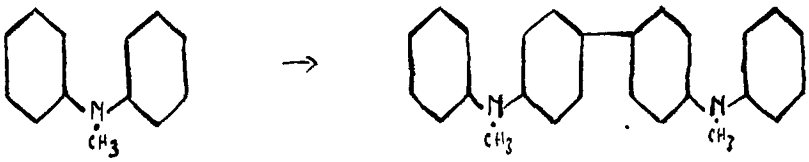


XII

Marqueyrol and Muraour, however, state that this evidence is not conclusive, since the oxidation is effected in acetic acid solution, whilst in the case of diphenylamine the presence of sulphuric acid is necessary. They state further that N-acetyldiphenylamine is not oxidised by sodium dichromate and acetic acid to diacetyldiphenylbenzidine.

In order to eliminate any effect caused by the introduction of the acid phenyl radicle into diphenylamine, we oxidised the N-methyl derivative (XIII), in the presence of sulphuric acid. The fact that we obtained dimethyldiphenylbenzidine (XIV) from this oxidation,



XIII XIV

supports Wieland's view, that all these oxidations proceed directly, and not via the N:N' derivative, or any other intermediate compound, which subsequently undergoes transformation.

(The constitution of dimethyldiphenylbenzidine (XIV) was proved by its preparation by direct methylation of diphenylbenzidine).

(2) Although tetraphenylhydrazine (XV) can be transformed into diphenylbenzidine (X) by the action of concentrated sulphuric acid (Wieland), very little transformation takes place under the

conditions of the diphenylamine oxidation, where a 40:1 acetic-sulphuric acid solution was used (Marqueyrol and Muraour),

XV X

and therefore tetraphenylhydrazine cannot be an intermediate product in the oxidation of diphenylamine (IX) to diphenylbenzidine (X).

Marqueyrol and Muraour find that diphenylamine when dissolved in concentrated sulphuric acid resists the attack of oxidising agents, whilst in a more dilute solution excellent yields of diphenylbenzidine are obtained. They are led therefore to the conclusion that the primary attack occurs at the :NH group, the sulphuric acid being only necessary in that it causes the transformation of the intermediate product (the constitution of which is unknown). In concentrated sulphuric acid the :NH group is so far protected that oxidation cannot occur.

Finally, they state that if the sulphuric acid protects the nitrogen and directs para oxidation, by increasing the amount, less unchanged diphenylamine should be obtained. In their experiments, however, more unchanged diphenylamine was obtained.

On repeating these experiments of Marqueyrol and Muraour, we obtained a very small amount of unchanged diphenylamine. It is quite possible that they allowed the temperature to rise, and that sulphonation took place in the 3- and 6- positions, with consequent prevention of the change, since the linking in diphenylbenzidine is through these positions. The sulphonic groups would come off in the subsequent steam distillation, and this would explain why such a large amount of unchanged diphenylamine was obtained.

These results of ours therefore disprove the theory of Marqueyrol and Muraour of the mechanism of the diphenylamine oxidation,and support that of Wieland.

In the analogous acid oxidation of carbazole, to give 3:3'-dicarbazyl (II), the evidence is against the intermediate formation of 9:9'-dicarbazyl (I). McLintock and Tucker have treated 9:9'-dicarbazyl in various ways in order to see if it would be transformed into 3:3'-dicarbazyl, but the results have all been negative.

The fact that oxidation to the corresponding dicarbazyl proceeds easily when the nitrogen of carbazole is protected by an alkyl group, suggests that the two carbazole nuclei unite directly, without the formation of an intermediate product.

We have already stated (p.1) that, in all the acid oxidations of carbazole and its derivatives, brightly coloured substances are produced. We suggest that these substances possess a quinonoid structure, by analogy with the corresponding oxidation of diphenylamine.

In his original experiment, Wieland oxidised diphenylamine, in a mixture of acetic and sulphuric acids, with a concentrated solution of sodium dichromate in water. The intense blue colour, which developed immediately, was removed by the addition of zinc dust to the solution.

Wieland has accepted the explanation of Kehrmann and Micewiez (Ber., 1912, 45, 2641 - 2653), that the blue colour is due to the formation of a quinonoid derivative of diphenylbenzidine (XVI).

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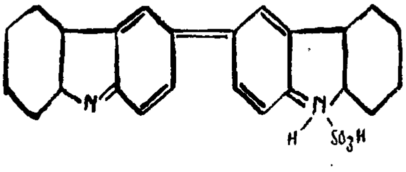
X

We suggest formulae (XVII), (XVIII), (XIX) for the coloured substances formed during the oxidation of carbazole, N-methyldiphenylamine and 9-methylcarbazole.



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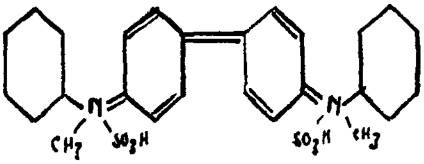

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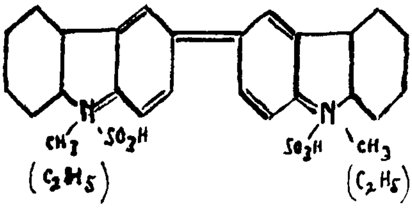


XIX

In all the oxidations, with one notable exception, the coloured substances were produced immediately on the addition of the oxidising agent; that is to say, the dicarbazyl or diphenylbenzidine, or derivatives of these two, were formed first, but were immediately attacked by the acid present, giving the quinonoid compounds. The exception was in the case of N-methyldiphenylamine. No coloured substance was produced until the theoretical amount of oxidising agent was exceeded.

EXPERIMENTAL.

I.

9-METHYL CARBAZOLE.

This substance remained unchanged when treated in boiling acetone with potassium permanganate. A similar result was obtained by the action of potassium dichromate on a cold acetic acid solution.

OXIDATION WITH POTASSIUM DICHROMATE IN BOILING ACETIC ACID.

To methyl carbazole (1 gram) in acetic acid (50 ccs.) was added powdered potassium dichromate (2 grams) and the mixture boiled for 15 minutes. The solution turned green, then brown and finally became green again. The brown sticky mass, obtained on pouring into water, was extracted with ether to remove unchanged methyl carbazole. The residue, after drying, was dissolved in benzene, in which it was very soluble. On addition of alcohol to this solution a brown amorphous powder, m.p. 228 - 280 was obtained. All attempts at crystallisation were fruitless. This oxidation was repeated seven times, varying the amount of dichromate and acetic acid, without any better result.

OXIDATION WITH POTASSIUM PERMANGANATE IN ACETIC ACID.

A few experiments on the small scale were performed but this method of oxidation was too vigorous, even in the cold, as tars were obtained.

OXIDATION BY WIELAND'S METHOD.

(a) To methyl carbazole (16 grams) dissolved in a mixture of acetic acid (640 ccs.) and sulphuric acid (16 ccs.) was added during one minute, under ice, sodium dichromate (6·5 grams., 1½ times theory) in the smallest quantity of water. The solution turned bluish-green immediately, and a precipitate came down. After leaving for ten minutes, finely powdered zinc was added. The blue tint disappeared quickly but the solution was still coloured green. A large amount of zinc was added, and, after some time, the solution became reddish-yellow, when it was filtered. The white flocculent precipitate, obtained by pouring the filtrate into water, was washed and dried. Weight, 6·2 grams., m.p. 150 - 200°. The zinc residue was washed with cold water, dried thoroughly, and extracted three times with benzene. The benzene solution on evaporation gave a brown substance (7·8 grams., m.p. 188 - 198°.) (On purification these two products were shown to be the same). The mixed products were crystallised three times from benzene with charcoal purification, and slightly pink needles of 9:9'-dimethyl 3:3'-dicarbazyl, m.p. 200 - 202°, were obtained.

Found: C, 86·4; H, 5·6; N, 7·8.

$C_{26}H_{20}N_2$ requires C, 86·7; H, 5·6; N, 7·8.

Molecular Weight, freezing point in benzene;

Found 380, 375; theory 360.

(Using excess of sodium dichromate, one gram to one of methyl carbazole, a small quantity of white crystals, m.p. 280 - 288° was obtained, but this substance was not examined further).

(b). Modified Method. 5 grams. used.

After the addition of the oxidising agent and leaving to stand for ten minutes, the solution was reduced by pouring into the same bulk of strong sodium bisulphite solution in water, and heated on a water bath until the colour disappeared. The green precipitate obtained, after washing and drying, weighed 5·2 grams and melted 60 - 100°. After extraction with benzene a residue (0·5 gram.), which contained chromium, was obtained. The hot benzene solution was poured into twice its volume of hot alcohol. The light brown crystalline mass, deposited overnight, melted about 185°. It was dissolved in hot acetic anhydride, acetic acid added, and then zinc dust. After boiling for ten minutes, the dark-brown solution lightened. After filtration, it was poured cautiously into ammonia solution (concentrated ammonia diluted with its own bulk of water). The slightly coloured mass deposited was recrystallised from benzene (charcoal).

II.

9-ETHYL CARBAZOLE.

A number of small oxidations were performed at the boil with different quantities of sodium dichromate and acetic acid. Indefinite brown powders melting 60 - 120°, 150 - 200°, and 200 - 260° were obtained; but after ineffectual attempts at crystallisation the examination of these products was discontinued.

OXIDATION BY WIELAND'S METHOD.

(a) To ethyl carbazole (5 grams.) dissolved in a mixture of acetic acid (250 ccs.) and sulphuric acid (5 ccs.) was added during one minute, under ice, sodium dichromate (2·3 grams., $1\frac{1}{2}$ times theory) in the smallest quantity of water. The procedure was the same as for the methyl derivative. The flocculent precipitate weighed 2·8 grams.; and extraction of the zinc residue with benzene gave a brown substance, m.p. 148 - 180° (2 grams.). The mixture was purified from benzene (charcoal). Cream-coloured prisms of

9:9'-diethyl 3:3'-dicarbazyl, m.p. 188 - 190°, were obtained.

(b) Ethyl carbazole (20 grams). Acetic acid (1 litre). Sulphuric acid (25 ccs). Sodium dichromate (12·8 grams).

Ten minutes after the addition of the oxidising agent, the solution was poured in a litre of strong sodium bisulphite solution, and heated on a water bath till the colour disappeared. The brown precipitate, obtained after washing and drying, weighed 19 grams and melted 140 - 160°. After extraction with benzene a residue (2 grams), which contained chromium, was obtained. The benzene solution was concentrated and poured into hot alcohol (400 ccs). The brown crystalline mass deposited overnight (16 grams) melted 174 - 176°. It was purified in the same way as described under methyl carbazole (b).

Found: C, 86·5; H, 6·4; N, 7·2; M, by Rast's Method, 342, 391

$C_{28}H_{24}N_2$ requires C, 86·6; H, 6·2; N, 7·2; M, 388.

In the preparation of the alkylated dicarbazyls by oxidation, excellent yields of the crude products, melting over a range of ten degrees, were obtained, but great difficulty was experienced in isolating the pure dicarbazyls. It was thought that a dicarbazyl possessing a linkage other than the 3:3' might be present, and much time was spent on this problem. Fractional crystallisation from benzene, toluene, xylene, acetic anhydride, pyridine, in which the dicarbazyls are very soluble, and also from acetic acid, alcohol, acetone, in which they are sparingly soluble, was tried. Benzene was found to be the best solvent,but the pure product was only obtained after many crystallisations. Crystallisation from mixed solvents, benzene and alcohol, benzene and acetone, was tried without avail. The diethyldicarbazyl was sublimed in vacuum, but the slight colour remained, and the melting point was not raised. Slight oxidation or further reduction of the crude product cleaned it up somewhat. The oxidation was carried out in acetone solution with potassium permanganate, and the reduction with zinc in a mixture of acetic anhydride and acetic acid.

In no case did we encounter any isomer.

III.

CARBAZOLE.

Carbazole is difficultly soluble in cold acetic acid. If it is not all in solution before adding the sodium dichromate, a large amount remains unchanged. A huge volume of acetic acid had to be used.

OXIDATION BY WIELAND'S METHOD.

To 5 grams of pure carbazole, dissolved in a mixture of acetic acid (1250 ccs.) and sulphuric acid (30 ccs.) was added, during one minute, under ice, sodium dichromate (3·2 grams, twice theory). A deep green colour developed immediately. After leaving for 10 minutes, the solution was poured into a concentrated solution of sodium bisulphite (1 litre), and the whole heated on a water bath until the colour disappeared. After further dilution, the solution was left to stand overnight, when the greater part of the liquid was siphoned from the light brown flocculent precipitate. After filtration and washing with water, the precipitate was dried at 160° (4·5 grams). It was then extracted with anisole (500 ccs.) and the green insoluble residue (1 gram) filtered off. The dark brown filtrate was boiled with a large amount of charcoal and concentrated, when 3:3'-dicarbazyl (1·7 grams) m.p. over 300°, was obtained.

The acetyl derivative was prepared, and shown to be identical with the acetyl derivative of the synthetic 3:3'-dicarbazyl prepared by Tucker.

IV.

METHYLATION OF 3:3'-DICARBAZYL. (STEVENS AND TUCKER'S METHOD, J., 1923, 123, 2140).

To the dicarbazyl (0·8 gram) suspended in acetone (40 ccs.) was added methyl sulphate (2 ccs.) and then powdered potassium hydroxide (2 grams). Water was added drop by drop until the potash formed a layer. After boiling for 10 minutes, the solution was poured into water, the precipitate washed, dried and recrystallised from benzene three times. White needles, m.p. 198 - 200°.

V.

ETHYLATION OF 3:3'-DICARBAZYL.

To the dicarbazyl (0·4 gram) suspended in acetone (30 ccs.) was added ethyl sulphate (5 ccs.), and potassium hydroxide (10 grams) added in small quantities at the boil. On pouring into water, an oil was obtained (due to the large amount of potash acting on the acetone). After steam distilling, the solid residue was recrystallised four times from benzene. Small cream-coloured prisms, m.p. 186 - 188°.

VI.

OXIDATION OF N-METHYLDIPHENYLAMINE.

N-methyldiphenylamine (Gibson & Vining, J. 1923, 835) (5 grams) was dissolved in excess of dilute sulphuric acid (50% water by volume). The pale yellow solution was cooled and a solution of sodium dichromate (1·4 gram) in water (8 c.c.) added. A reddish-violet coloration was produced, and almost immediately a white precipitate separated. It was only when the last few drops of the dichromate solution were added that the mauve colour persisted. The colour was removed by treating the solution with a few drops of aqueous sulphurous acid. The cream coloured compound obtained on filtration was washed and dried (nearly 5 grams). Crystallisation gave leaflets possessing a green tint, which was very difficult to remove. It was finally effected, with considerable diminution of yield, by crystallisation from ethyl acetate or acetone,in both of which it is sparingly soluble,giving violet fluorescing liquids. White, nacreous plates, m.p. 167 - 168° of N:N'-dimethyldiphenylbenzidine.

Found: C, 85·9; H, 6·8; N, 7·9; M, by Rast's Method, 386.

$C_{26}H_{24}N_2$ requires C, 85·7; H, 6·6; N, 7·7; M, 364.

The compound also crystallises from carbon tetrachloride, benzene, toluene, xylene, and acetic acid, but from the last the separating crystals are deep green. It is soluble in chloroform, insoluble in alcohol or light petroleum.

Oxidation by means of an acetone solution of potassium permanganate gave an oil from which, on standing, a small amount of N:N'-dimethyldiphenylbenzidine was obtained.

VII.

METHYLATION OF DIPHENYLBENZIDINE. (Gibson and Vining's method of methylation J. 1923, 835)

The diphenylbenzidine (1 gram) was dissolved in methyl sulphate (10 ccs.) by warming on the water bath for 15 minutes. A solution of sodium carbonate in water (35 grams in 200 ccs.) was added during one hour, the temperature being kept between 50° and 60°. An oil separated and solidified on cooling. After washing and drying, the solid was extracted with benzene. The concentrated benzene solution deposited greyish crystals, which were obtained almost colourless by further crystallisation, m.p. 165°.

VIII.

OXIDATION OF 9-ACETYL CARBAZOLE.

Five experiments on the small scale were performed. The acetyl carbazole was dissolved in acetic acid and oxidised at the boil with, firstly, sodium dichromate, and secondly, with chromic anhydride. The starting product, slightly impure, was recovered.

Oxidation by Wieland's method was also tried. No colour was developed on the addition of the oxidising agent, and all that could be isolated from the solution was some carbazole, which had been formed by the action of the sulphuric acid on the acetyl carbazole.

This paper has been sent to the Chemical Society for publication.

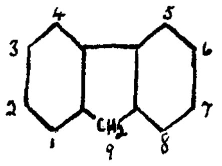
Part II.

The Condensation of Fluorene with Acetone.

--------oOo--------

This reaction was discovered during preliminary experiments on fluorene, with a view to preparing difluoryls, for comparison with the dicarbazyls.

Fluorene (I) has been condensed with many aromatic aldehydes (Thiele, Ber., 1900, 33, 851 - 853; Thiele and Heule, Annalen, 1906, 347, 290 - 315). The condensations were carried out with alcoholic sodium ethoxide or alcoholic alkali hydroxide. Water was always split off in the condensation and the unsaturated compound formed (II). Thiele states that fluorene does not react with aliphatic aldehydes or with aliphatic or aromatic ketones under these conditions.



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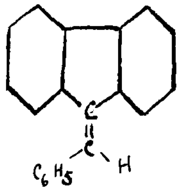
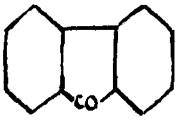


II

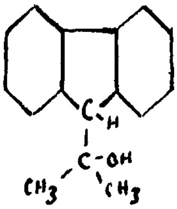
Sieglitz (Ber., 1920, 53 (B), 1232 - 1241) has shown that the introduction of two bromine atoms into the fluorene molecule increases its reactivity as regards condensation with aromatic aldehydes. This reaction, like that of Thiele, is not capable of extension to aliphatic aldehydes or to aliphatic or aromatic ketones.

We find, however, that, when powdered potassium hydroxide is added to fluorene in acetone, the solution turns brown, goes through red to black, and finally, as it boils, becomes a brilliant bluish-green in colour, at the same time thickening up into a paste, from which has been isolated a white crystalline product, which melts 74 - 78°, and which appears to be the only product formed. This substance has been subjected to a variety of reactions in order to determine its constitution. On vigorous oxidation it gave fluorenone (III), which proved that the side chain was attached to the centre carbon atom.

It was thought, at first, that one molecule of fluorene and one of acetone had undergone aldol condensation to yield (IV); but a study of its simple substitution derivatives suggested that some more complicated condensation, such as (V), had occurred.

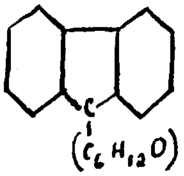


III



$(C_{16}H_{16}O)$

IV



$(C_{19}H_{20}O)$

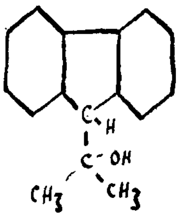
V

Simple analysis does not convincingly distinguish between (IV) or (V), as their analytical data are very close. The molecular weight determinations, however, support (V).

The acetone was actually involved in the reaction, for, in a similar experiment performed in alcoholic solution, the fluorene was obtained back unchanged.

There are many possible arrangements of the side chain $C_6H_{12}O$. These will be discussed in the conclusion.

In the table below is set down the evidence in favour of $C_{16}H_{16}O$ and $C_{19}H_{20}O$. We suggest that the condensation product is really $C_{19}H_{20}O$, the derivatives of $C_{16}H_{16}O$ being formed by the splitting off of part of the side chain. This also will be discussed in the conclusion.



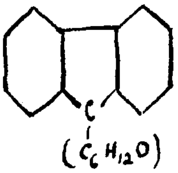
Found:

$$C\left\{\begin{array}{l}85\cdot7\\85\cdot8\\85\cdot7\end{array}\right. \quad H\left\{\begin{array}{l}7\cdot4\\7\cdot5\\7\cdot7\end{array}\right.$$

$C_{16}H_{16}O$ requires

C, 85·7; H, 7·2.

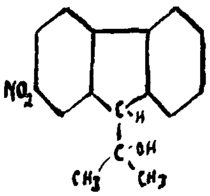
Molecular weight.
Found, 259, 262.
$C_{16}H_{16}O$ requires
224.



$C_{19}H_{20}O$ requires

C, 86·4; H, 7·6.

Molecular Weight.
Found, 259, 262.
$C_{19}H_{20}O$ requires
264.

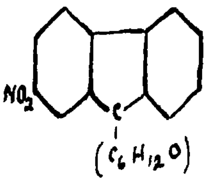


VI

Found:

$$N\left\{\begin{array}{l}5\cdot27\\5\cdot27\end{array}\right.$$

$C_{16}H_{14}OH\cdot NO_2$
requires N, 5·2.



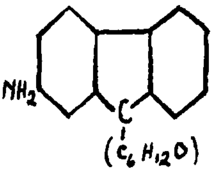
VII

Found:

C, 74·1; H, 6·4;
N, 4·6.

$C_{19}H_{18}OH\cdot NO_2$
requires C, 73·8;
H, 6·1; N, 4·5.

(The reactive positions in fluorene are the 2 and 7 positions.)

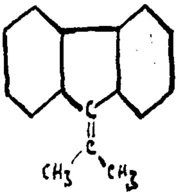


VIII

Found:

C, 81·7; H, 7·2; N, 5·2.

$C_{19}H_{18}OH\cdot NH_2$
requires
C, 81·7; H, 7·5; N, 5·0.

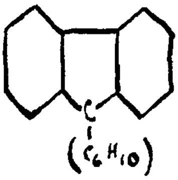


IX

Found:

C	93·18	H	6·7
	93·05		6·7

$C_{16}H_{14}$
requires
C, 93·2; H, 6·8.

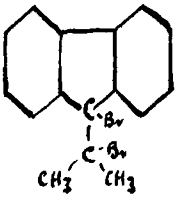


X

Found:

	92·3		7·2
C	92·1	H	7·2
	92·1		7·4

$C_{19}H_{18}$
requires
C, 92·7; H, 7·3.

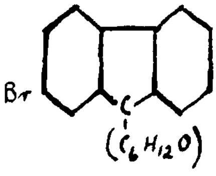


XI

Found:

Br 43.16
43·26

$C_{16}H_{14}Br_2$
requires 43·71



XII

Found:

C, 65·6; H, 5·7;
Br, 23·5.

$C_{19}H_{19}OBr$
requires C, 66·5;
H, 5·5; Br, 23·3.

The condensation product gave three bromine derivatives containing (a) 23·5% (XII), (b) 34·2%, (c) 48·1% bromine respectively.

(1). Nitration of the condensation product gave a most peculiar result. At first a nitro compound, which, on analysis, gave a nitrogen in agreement with $C_{16}H_{14}OH \cdot NO_2$ (VI) was obtained in very good yield. Without confirming this result by performing a carbon-hydrogen estimation, preliminary experiments on the reduction to the amine were carried out with it. On repeating the nitration three times the same nitro compound was obtained. The fourth time a different nitro compound, which on analysis gave carbon, hydrogen and nitrogen in agreement with $C_{19}H_{18}OH \cdot NO_2$ (VII), was obtained, also in very good yield. There was no sign of the formation of the first nitro compound.

This problem was attacked with vigour. Each nitration took about one hour to work up. Over seventy experiments were performed, varying the conditions, in an attempt to hit upon those necessary for the formation of the first compound. All these experiments gave the second nitro-compound, and no sign of the first could be detected.

(2). The method of preparation of the original condensation product was then investigated fully. Modifications were introduced, and the product isolated and nitrated; but the first nitro-compound has never been obtained again.

(3). We attempted to prepare the nitro-derivatives by condensing 2-nitrofluorene with acetone by means of potassium hydroxide, but without success.

(4). The nitro-compound, $C_{19}H_{18}OH{\cdot}NO_2$, gave on reduction the corresponding amine, $C_{19}H_{18}OH{\cdot}NH_2$ (VIII). At the present moment we are attempting to remove the amino group.

(5). In an attempt to prepare an unsaturated compound from the condensation product, three methods were tried, (a) action of anhydrous zinc chloride, (b) action of various strengths of sulphuric acid, (c) action of molecular potassium in benzene. By the last method an unsaturated compound, $C_{16}H_{14}$ (IX) was obtained, along with 30% of fluorene. The unsaturated compound absorbed bromine easily, and gave a derivative $C_{16}H_{14}Br_2$ (XI).

(6). If the condensation product possesses an OH group, it is a tertiary alcohol, and should therefore acetylate. The action of acetic anhydride (in the presence of catalysts) and of acetyl chloride was tried, but the substance remained unchanged. An attempt to methylate gave a similar result. The substance reacted with thionyl chloride, but no crystalline substance could be isolated.

(7). The condensation product did not respond to any of the tests for the C:O group, or to any of the tests for the presence of a double bond.

(8). The product reacted with hydrobromic acid, and gave an unstable substance, which evolved hydrobromic acid spontaneously. By heating this substance, an unsaturated compound $C_{19}H_{18}$ (XI), free from bromine, was obtained. The formation of this compound will be discussed in the conclusion.

(9). The product was heated in order to see if it would distil, but it passed into a tar about 200°. It was also heated at 120° and 160° (when it begins to darken) in the hope that water would be eliminated and an unsaturated compound formed. The product was recovered unchanged.

(10). By the action of bromine on the condensation product,we have isolated three compounds melting 83 - 85°, 102 - 104°, and 173 - 175°, and which contain 23·5%, 34·3%· and 48·1% bromine respectively. The last two being remarkably similar, in melting point and percentage of bromine, to mono- and dibromofluorene, these derivatives were prepared, but proved to be different.

Bromine derivative	m.p. 102 - 104°,	34·3% Br:
Bromine derivative	m.p. 173 - 175°,	48·1% Br.
Monobromofluorene	m.p. 101 - 102°,	32·5% Br:
Dibromofluorene	m.p. 165°,	49·0% Br.

None of the bromine derivatives of the condensation product agrees with any bromine derivative of

$C_{16}H_{16}O$ (III). The first, however, is in fair agreement with a monobromo derivative of $C_{19}H_{20}O$ (V).

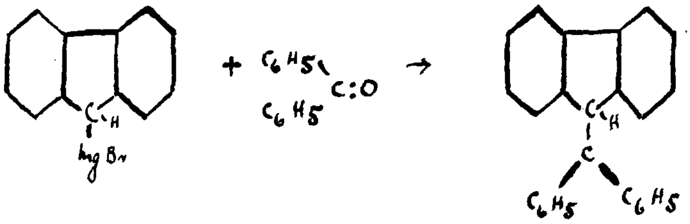
(11). We attempted to prepare these bromine derivatives by the condensation of the bromine derivatives of fluorene with acetone in the presence of potassium hydroxide; but Hodgkinson (1885, P. 36 - 37) has shown that the bromine derivatives of fluorene are affected by potassium hydroxide, the bromine being split off. In the attempted condensation, the green product he describes was observed.

(12). The bromo-compound m.p. 83 - 85° was reduced with sodium in alcoholic solution. The minute quantity of white crystals, isolated from the sticky mass obtained, melted about 90°, was free from bromine, and was certainly not the original condensation product. The side-chain of the bromo-compound, however, may have been reduced at the same time. This problem is being investigated.

(13). The iodo-derivatives of the condensation product, whether obtained by direct substitution, or by replacing the bromine in the bromo-derivatives with iodine, were quite unsuitable for any comparative purposes.

(14). Chlorine was found to have very little action on the condensation product, even in the presence of catalysts.

(15). An attempt was made to synthesise $C_{16}H_{16}O$ (III) by means of the Grignard compound of fluorene. Grignard and Courtot (Comptes Rendus, 1911, 152, 1493 - 1495) isolated fluorene magnesium bromide (XIII), and prepared various compounds from it, the most important, from our point of view, being the substance obtained by the action of benzophenone.



XIII

Numerous attempts to make acetone react in the same way having met with failure, we tried many times to repeat Grignard's work with benzophenone, but without success. The actual Grignard compound appeared to be formed however.

(16). In the original condensation of fluorene with acetone, the intense green colour took a few minutes to develop, after the addition of the potassium hydroxide. We thought that, at first, the potash might oxidise the fluorene to fluorenone (VI), and that this substance would then react with the acetone. This led us to try the action of potash on fluorenone in acetone solution. The intense green colour developed immediately on the addition, but only a black tar could be isolated.

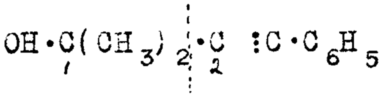
(17). In order to find out if the condensation proceeded via the sodium compound of acetone, this compound was prepared (by the action of sodium on acetone), and then fluorene in acetone added. No colour developed, and the fluorene was recovered. If, however, the sodium is added directly to fluorene in acetone, the green colour develops, and a minute quantity of the condensation product may be isolated in this way.

(18). Methyl ethyl ketone was condensed with fluorene under the same conditions as in the original condensation with acetone. A glue-like mass was obtained.

CONCLUSION.

It is unlikely that the product obtained by the condensation of fluorene with acetone is a mixture of the compounds represented by the empirical formulae $C_{16}H_{16}O$ and $C_{19}H_{20}O$. If it were, a quantity of each derivative would be obtained on nitration. Actually, however, a very good yield of the one or the other nitro-compounds was obtained.

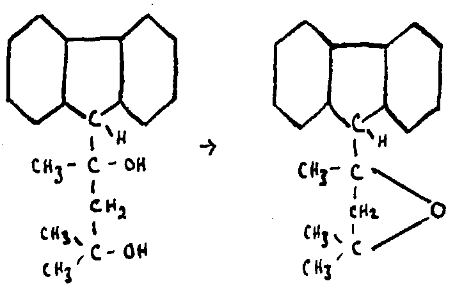
It is thought that the condensation product is really $C_{19}H_{20}O$, and that the derivatives of $C_{16}H_{16}O$ are formed by the removal of part of the side chain. The sulphuric acid would cause this in the process of nitration, and the molecular potassium in the preparation of the unsaturated compound $C_{16}H_{14}$ (IX). It will be recalled that, in the latter experiment, fluorene itself was obtained from the condensation product. In this connection it is of interest to note that Skossarewsky (J. Russ. Phys. Chem. Soc., 1905, <u>37</u>, 645 - 647) has performed a similar condensation of acetone with phenylacetylene by means of solid potassium hydroxide, obtaining from the reaction phenylacetylenyldimethylcarbinol.



$$\mathrm{OH\cdot\underset{1}{C}(CH_3)_2\,\vdots\,\cdot\underset{2}{C}\vdots C\cdot C_6H_5}$$

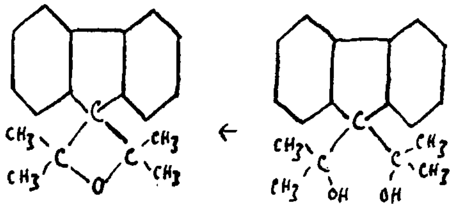
He has shown that the bond between carbon atoms 1 and 2 can be easily broken by boiling the compound with dilute caustic potash solution, the result being the regeneration of phenylacetylene and acetone.

Of the many possible arrangements of the side chain, we need only consider two (A and B), for the remainder possess either a C:O group, an OH group, or a double bond, and the condensation product does not respond to the tests for these two groups or for unsaturation.



A′

A



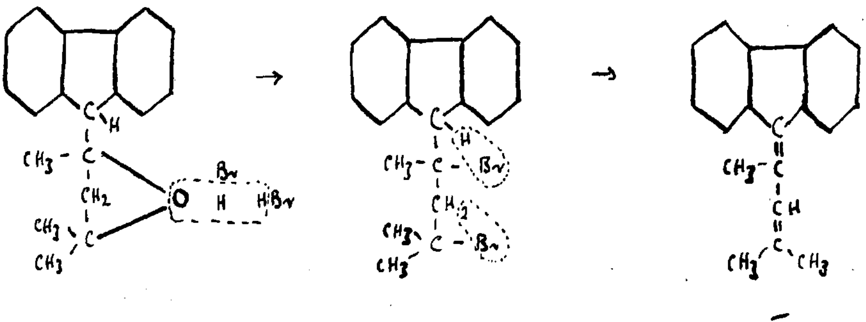
B

B′

A and B may be formed by the elimination of one molecule of water from the product obtained by the double aldol condensation of two molecules of acetone with one molecule of fluorene (A' and B').

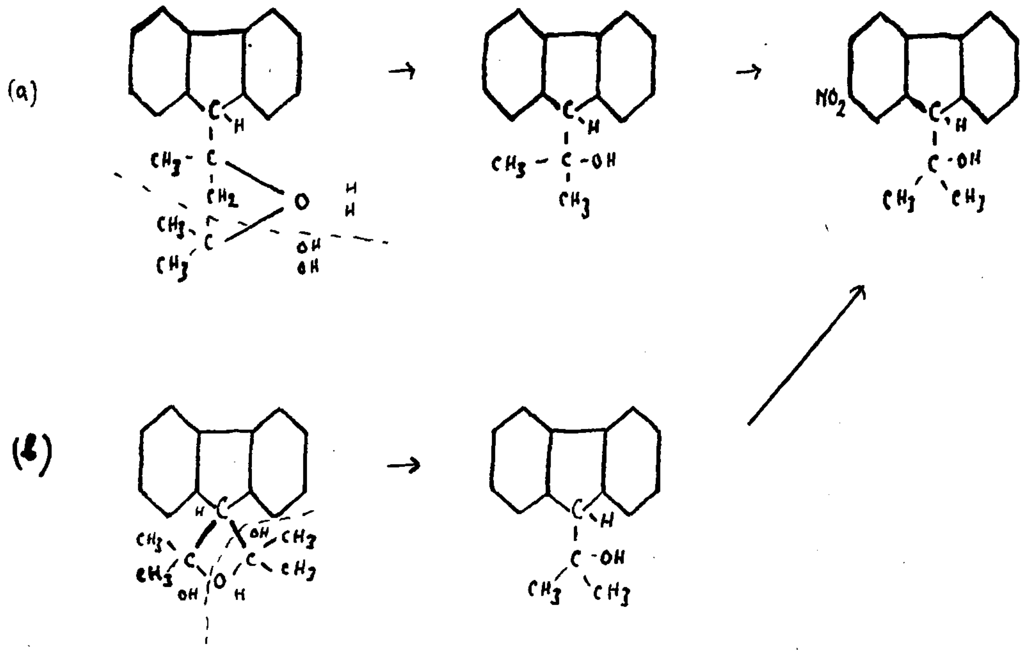
It must be admitted, however, that neither of these formulae readily explains every one of the reactions discussed in the previous pages.

The reaction with hydrobromic acid (8) is better explained by (A).



X

Neither formula explains the formation of the nitro derivative of $C_{16}H_{16}O$, unless we assume that fission of the propylene-oxide ring takes place ((a) and (b)).



The difficulty here is not to account for the breaking of the bond between the carbon and the oxygen, but between two carbon atoms, in a compound which has neither a C:O nor a C = C linkage.

In phenylacetylenyldimethylcarbinol the breaking of the bond is accounted for by the presence of the ·C⋮C· linkage.

Finally, neither formula gives any satisfactory explanation of the formation, by the action of finely divided potassium on the condensation product in the absence of water, of the unsaturated compound $C_{16}H_{14}$ (IX) and fluorene.

EXPERIMENTAL.

I.

CONDENSATION PRODUCT.

Fluorene (20 g.) was dissolved in cold acetone (240 c.c.) in a large beaker, and powdered potassium hydroxide (80 g.) was added during one minute with vigorous stirring. The solution turned brown, went through red to black, and finally, as the acetone boiled, became brilliant green, and almost immediately thickened up. After leaving for ten minutes, water was added until a green oil separated. The lower layer containing the potassium hydroxide was run off and discarded. The green oil, on pouring into watercontaining a few drops of sulphuric acid, changed to a light reddish-brown oil, which solidified to an oily mass in ice. After washing and removing most of the oil, the solid was crystallised twice from alcohol (charcoal), when it was deposited as white needles, m.p. 74 - 78°. The oil was steam distilled, and more of the condensation product was obtained from the residue. (The oil was formed by the action of potassium hydroxide on acetone.) The product is very soluble in all the usual solvents, and crystallises well from light petroleum. From pyridine, it crystallises with solvent of crystallisation in beautiful hexagons, which, however, give off pyridine on leaving to stand in the air. Yield, 15 g.

$$\text{Found C} \left\{ \begin{matrix} 85{\cdot}7 \\ 85{\cdot}8 \\ 85{\cdot}7 \end{matrix} \right. ; \quad \text{H} \left\{ \begin{matrix} 7{\cdot}4 \\ 7{\cdot}5 \\ 7{\cdot}7 \end{matrix} \right. ; \quad \text{M, } 259, 262.$$

$C_{16}H_{16}O$ requires C, 85·7 ; H, 7·2 ; M, 224.

$C_{19}H_{20}O$ requires C, 86·4 ; H, 7·6 ; M, 264.

II.

ACTION OF POTASSIUM HYDROXIDE ON ACETONE.

Powdered potassium hydroxide (80 g.) was added during one minute to cold acetone (240 c.c.), and the mixture allowed to boil for ten minutes. The oily liquid was poured off, and the acetone removed. The oil remaining was heated with fluorene, alone at first, and then in the presence of potassium hydroxide. No colour developed, and the fluorene was recovered.

III.

OXIDATION OF THE CONDENSATION PRODUCT.

Potassium permanganate in acetone was found to be too mild, and the same substance in glacial acetic acid to be too vigorous an oxidising agent. Sodium dichromate in glacial acetic acid was therefore used.

The condensation product (5 g.) was dissolved in glacial acetic acid (200 c.c.), sodium dichromate (40 g.) added, and the solution boiled for five hours, after which it was poured into water. The chloroform extract was steam distilled, and a yellow substance, which was proved to be fluorenone, came over.

IV.

NITRATION OF THE CONDENSATION PRODUCT.

(a) The condensation product (2 g.) was dissolved in glacial acetic acid (8 c.c.) and 12 c.c. of a mixture of concentrated nitric and sulphuric acids (4 c.c. : 1 c.c.) was added during five minutes, keeping the temperature down. One minute after the addition, the solution was poured into water. The yellow sticky mass adhered to the glass rod and the sides of the beaker and was washed, by decantation, with water and then cold alcohol, and crystallised from alcohol twice. Yellow plates, m.p. 98 - 100°. Yield, 1 - 7 g.

Found N, 5·27, 5·27.

$C_{16}H_{14}OH\cdot NO_2$ requires N, 5·2.

(b) This method of preparation now gives an excellent yield of a substance crystallising in light yellow needles, m.p. 110 - 114°.

Found C, 74·1 : H, 6·4 : N, 4·6.

$C_{19}H_{18}OH\cdot NO_2$ requires C, 73·8 ; H, 6·1 : N, 4·5.

V.

ATTEMPT TO PREPARE NITRO-DERIVATIVES FROM 2-NITROFLUORENE.

2-nitrofluorene (1 g.) prepared according to Hodgkinson P.1885, 37 was dissolved in cold acetone (10 c.c.) and powdered potassium hydroxide (4 g.) added during one minute. The solution became green in colour, and after a few minutes it was poured into water. A dirty green oil separated. On neutralising the solution with dilute sulphuric acid, a reddish flocculent precipitate separated. All attempts to obtain this substance in a crystalline form were unsuccessful.

VI.

REDUCTION OF NITRO-COMPOUND, m.p. 110 - 114°.

Reduction with zinc in glacial acetic acid gave a substance crystallising in brownish prisms, m.p. about 220°. This substance was not an amine, and was thought to be the acetyl derivative of the amine; but an attempt to hydrolyse it was unsuccessful.

The reduction with tin and hydrochloric acid in alcoholic solution proceeded smoothly, and gave a colourless solution, but a tin-free product could not be obtained.

The nitro-compound (12 g.) was dissolved in alcohol (600 c.c.) and sodium sulphide (60 g.) in water (150 c.c.) added. The solution was boiled for three hours, more water being added occasionally to prevent bumping. The yellow solid, obtained on pouring into water, was dried and dissolved in alcohol. An equal bulk of concentrated hydrochloric acid was added, together with a few pieces of tin, and the whole boiled for a few minutes. The clear solution obtained was decanted from the tin into excess of strong potassium hydroxide. The precipitate obtained was redissolved in concentrated hydrochloric acid, and again poured into strong potassium hydroxide solution. The light coloured solid was washed and dried, and crystallised twice from alcohol (charcoal). Cream coloured needles, m.p. 143 - 146°. Yield, 8 g.

Found C, 81·7 ; H, 7·2 ; N, 5·2

$C_{19}H_{18}OH{\cdot}NH_2$ requires C, 81·7 ; H, 7·5 ; N, 5·0.

VII.

UNSATURATED COMPOUND $C_{16}H_{14}$.

This compound was isolated in attempting to prepare a potassium derivative of the condensation product.

Freshly cut potassium (1·7 g.) was molecularised in boiling dry benzene (250 c.c.), and the condensation product (10 g.), in benzene, added. The solution immediately became red. After boiling for 16 hours it was filtered from the potassium hydroxide formed. The benzene was distilled off, the last traces being removed from the brown solid by hot air.

The residue was subjected to steam distillation for three hours. The solid which came over was proved to be crude fluorene. The residue was extracted with chloroform in order to separate it from the water. The chloroform was distilled off, and the solid remaining crystallised twice from alcohol, when it was obtained in the form of yellow needles, m.p. 110 - 114°. The colour was removed by steam distilling the yellow needles, white needles coming over extremely slowly. m.p. 112 - 116°.

$$\text{Found C,}\begin{cases}93{\cdot}18\\93{\cdot}05\end{cases};\quad \text{H,}\begin{cases}6{\cdot}7\\6{\cdot}7\end{cases}$$

$C_{16}H_{14}$ requires C, 93·2 ; H, 6·8

$C_{19}H_{18}$ requires C, 92·7 ; H, 7·3.

Previous to the discovery of this method other methods had been tried.

ACTION OF ANHYDROUS ZINC CHLORIDE ON THE CONDENSATION PRODUCT.

The condensation product (1 g.) was heated with the same bulk of powdered anhydrous zinc chloride for five minutes about 200°. When cold the mass was taken up in alcohol, and poured into dilute hydrochloric acid. The oily solid which came down overnight was crystallised three times from alcohol - nacreous yellow plates, m.p. 124 - 131°. The alcoholic residues deposited white crystals, m.p. 80 - 94°. Neither of those substances could be obtained pure.

ACTION OF SULPHURIC ACID.

The condensation product remained unchanged when boiled with sulphuric acid in water (10%, 30% and 50%).

VIII.

BROMINE DERIVATIVE OF $C_{16}H_{14}$.

The pure unsaturated compound (0·7 g.) was dissolved in carbon disulphide (7 c.c.) and bromine (0·54 g.) in carbon disulphide (5·4 c.c.) added gradually, keeping the temperature down. A small amount of hydrobromic acid was evolved, but it was evident that most of the bromine was absorbed. The carbon disulphide was removed by air current, and the solid obtained crystallised twice from light petroleum. Slightly green prisms, crushing to a white powder, and melting 126 - 127° to a green liquid, were obtained.

Found Br, 43·16, 43·26.

$C_{16}H_{14}Br_2$ requires Br, 43·71.

IX.

ACTION OF HYDROBROMIC ACID ON THE CONDENSATION PRODUCT.

The condensation product (5 g.) was dissolved in glacial acetic acid (50 c.c.) and dry hydrobromic acid (prepared from bromine and tetralin) was passed in until the solution started to deposit crystals (1 hour). After leaving overnight, the white crystalline mass was filtered off and a melting point taken immediately, 80 - 104°. The substance evolved hydrobromic acid spontaneously. It was therefore heated at 100° to drive off all the gas. The residue was steam distilled, when it came over as white crystals, free from bromine. On crystallising from alcohol, it was obtained as white rods, m.p. 75 - 78°.

$$\text{Found}\quad C,\left\{\begin{array}{l}92\cdot3\\92\cdot1\\92\cdot1\end{array}\right.\quad;\quad H,\left\{\begin{array}{l}7\cdot2\\7\cdot2\\7\cdot4\end{array}\right.$$

$C_{19}H_{18}$ requires C, 92·7 ; H, 7·3.

X.

BROMINE DERIVATIVES.

(1) The condensation product (10 g.) was dissolved in carbon disulphide (100 c.c.) and bromine (7 g., theoretical for $C_{16}H_{14}OH{\cdot}Br$) in carbon disulphide (70 c.c.) added during one minute. After five minutes the solution cleared, and hydrobromic acid was evolved. The solvent was removed by air current, and the residue dissolved in petroleum ether (160 c.c.). Large stout rods (6 g.), m.p. about 80° came down first, and on recrystallisation melted 83 - 85°. The filtrate on concentration deposited white needles, m.p. about 100°, which were proved to be identical with the bromine derivative

prepared by method (2) below.

Found C, 65·6 ; H, 5·7 ; Br, 23·5.

$C_{19}H_{18}OH\cdot Br$ requires C, 66·5 ; H, 5·5 ; Br, 23·3.

(2) The condensation product (4 g.) was dissolved in carbon disulphide (40 c.c.) and bromine (3·9 g.) in carbon disulphide (20 c.c.) added gradually at the boil. The solution was slightly coloured with bromine even after boiling for half an hour. After evaporation by air current, the oily residue was taken up in excess of hot alcohol (56 c.c.), which prevents it from coming down as an oil. The solution on standing deposited a white semi-crystalline mass, m.p. 80 - 100°. After three crystallisations from alcohol it melted 102 - 104°. (The filtrate on standing for some weeks deposited a small quantity of a white substance, m.p. 144 - 148°, which has not been analysed yet).

Found C, 58·3 ; H, 4·8 ; Br, 34·3.

(3) The condensation product (4 g.) was dissolved in carbon disulphide (40 c.c.) and bromine (10·5 g.) in carbon disulphide (60 c.c.) added. The addition was started in the cold, and the temperature was raised as the bromine became more difficult to absorb. After boiling for an hour, the bromine coloured solution was evaporated by air current. The sticky solid obtained was crystallised from alcohol (520 c.c.). Plates came

down first and then needles, but these were found to be the same substance. After two more crystallisations, the substance was obtained in the form of stout white needles, m.p. 173 - 175°.

Found, Br, 48·1.

XI.

ATTEMPTS TO OBTAIN IODINE DERIVATIVES.

(a) By direct iodination.

Some twenty experiments on the small scale were performed in these attempts. In the potassium iodide-potassium iodate method, even by using half the theoretical quantity for a mono-substituted derivative, the iodine colour could not be discharged. By means of the nitric acid method, however, the iodine was easily taken up, but an oily product was obtained. Other oxidising agents were tried in place of nitric acid - hydrogen peroxide, ammonium persulphate, mercuric oxide - but all gave negative results.

The condensation product (0·9 g.) was dissolved in glacial acetic acid (20 c.c.), finely powdered iodine (0·5 g.) added, and the mixture raised to the boiling point, when 1·5 c.c. of a nitric acid solution (2 c.c. nitric acid made up to 10 c.c. with glacial acetic acid) were added, a few drops at a time, with shaking. The iodine colour was just discharged. The hot solution, on cooling, deposited an oil. After separation of this oil, the residual solution was poured into water, when a sticky mass was obtained. All attempts at crystallisation from the usual solvents, and from mixed solvents, proved fruitless.

(b) From the bromine derivatives.

The bromo compound (2 g.) was dissolved in hot acetone and a solution of sodium iodide (6 g.) in acetone (40 c.c.) added, and the mixture boiled for three hours. Iodine was deposited, and a white substance came out of solution. After leaving to stand overnight, the solution was filtered. The hard pale yellow substance obtained was washed with hot water to remove any sodium salt. It melted 210 - 220° with decomposition, and, after crystallisation twice from toluene, melted at 226° to a black liquid, with first evidence of charring at 220°.

The acetone filtrate from above, which was strongly coloured by iodine, was evaporated to dryness. The sticky mass obtained was heated with dilute caustic soda to extract the iodine, filtered and washed with hot water. After extraction with alcohol, in which part of it was soluble, the residue melted about 210° (decomp.). After crystallising twice from acetone it melted at 217,° with evidence of charring at 200°.

Both compounds contained halogen. The substance m.p. 226° contained both bromine and iodine; the other, iodine alone.

The bromo-compound m.p. 83 - 85° was treated in the same way, but the product obtained was not homogeneous.

XII.

REDUCTION OF BROMO-COMPOUND m.p. 83 - 85°.

The bromo-compound (4 g.) was dissolved in alcohol (200 c.c.) and sodium added in small pieces until there was no more action. The solution was poured into water. A yellow oil was extracted from the resulting mixture by means of chloroform. A small amount of white crystals m.p. 80 - 90°, free from bromine, was obtained from the oil by crystallisation from alcohol.

XIII.

ATTEMPTS TO OBTAIN CHLORINE DERIVATIVES.

The action of chlorine on the condensation product was tried using acetic acid, chloroform, carbon disulphide and carbon tetrachloride as solvents. The chlorine was passed into the cold solution and also into the boiling solution. A very small amount of hydrochloric acid was evolved in each case. Iodine, red phosphorus, iron filings, aluminium chloride, aluminium mercury couple and antimony pentachloride were all tried as catalysts. The last named was found to be the best. When chlorine was passed through a solution of the condensation product in carbon tetrachloride, very little action took place, but, on the addition of antimony pentachloride, hydrochloric acid was evolved. Great difficulty was experienced in getting rid of the antimony pentachloride. Successive treatment of the alcoholic hydrochloric acid solution with sulphuretted hydrogen gave an uncrystallisable uninviting product.

XIV.

CONDENSATION OF FLUORENE WITH METHYL ETHYL KETONE.

Fluorene (2 g.) was dissolved in warm methyl ethyl ketone (24 c.c.) and powdered potassium hydroxide (8 g.) added, and the mixture heated on a water bath for half an hour. An intense blue colour developed a few minutes after the addition of the potash. Water was added until a blue oil separated. The lower layer was run off and discarded. The blue oil, on pouring into water containing a few drops of sulphuric acid, changed to a light reddish-brown oil. This oil was steam distilled. About 1 g. of fluorene came over along with some oil. The glue-like residue in the flask could not be obtained in a crystalline state.