STUDIES IN THE AROMATIC POLYCYCLIC HYDROCARBONS

BY

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Thesis presented for the Degree of Doctor of Philosophy.

University of Edinburgh

July, 1964

To my parents and Catherine

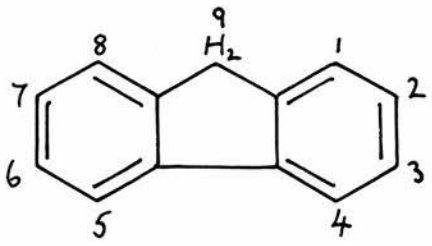
I N D E X

I N T R O D U C T I O N

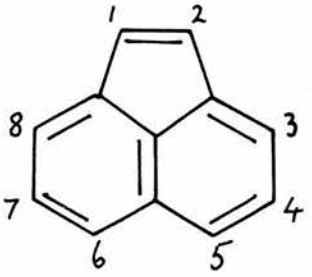
FLUORENE AND FLUORANTHENE

NUMBERING CONVENTIONS

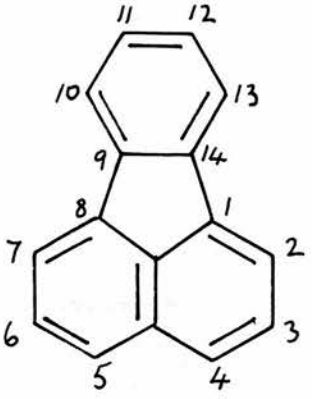
FLUORENE



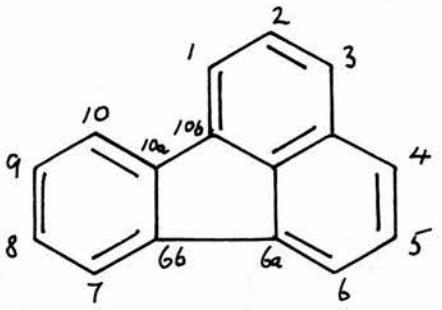
ACENAPHTHYLENE



FLUORANTHENE



Old (von Braun)

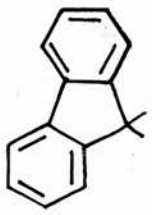


New (Patterson)

The Patterson numbering and orientation, used in Chemical Abstracts, has now been adopted by the Chemical Society. In this Thesis, the new numbering is used (although the old orientation has been retained for the sake of symmetry), so that care should be exercised when comparing with pre-1960 British papers.

All other systems are numbered according to the I.U.P.A.C. Rules (1960).

FLUORENE



I

Fluorene was first isolated by Berthelot[1] from crude anthracene oil in 1867, and the structure established[2,3] as diphenylenemethane I. Since then, it has been the subject of considerable research and its chemistry has been reviewed up to 1937.[4,5] More recent work has still to be summarised, and in fact it was not until 1954 that the question of the stereochemistry of the fluorene molecule was finally resolved. The detailed X-ray analysis[6,7] showed that it has a planar structure, at least in the solid state. Strain is relieved by abnormal bond lengths and angles, and not by inclination of the planes of the 6-membered rings to that of the 5-membered ring. Thus no possibility of optical isomerism exists, despite earlier claims to this effect.

Synthesis:

Fluorenes may be synthesised by several general routes, but these will be discussed with reference to 3-substituted fluorenes in a following review.

Reactions:

One of the more striking properties of fluorene is the reactivity of the 9-methylene group. Relative to methanol, fluorene has a pK of about 25, roughly the same as that of acetylene.[8] Consequently, alkali metal derivatives can be formed and used to good effect in synthesis, as can 9-fluorenylmagnesium bromide. These derivatives are often prepared by exchange with the corresponding derivatives of less acidic hydrocarbons.

The methylene group also condenses with some carbonyl compounds, particularly aromatic aldehydes, giving derivatives of the type $(C_6H_4)_2C{=}CHR$, with activated double bonds in the Michael reaction, and with certain esters in the Claisen condensation: for instance ethyl formate in the presence of sodium ethoxide yields 9-formylfluorene. All these reactions have proved particularly useful in the synthesis of fluoranthenes (q.v.).

When fluorene is oxidised, it gives fluoren-9-one, which, through the normal reactions of the carbonyl group, can be used to prepare many 9-substituted derivatives of fluorene. Fluorenone reacts with hydroxylamine and hydrazine, undergoes Reformatsky and Stobbe condensations, and reacts with Grignard reagents to give substituted fluorenols.

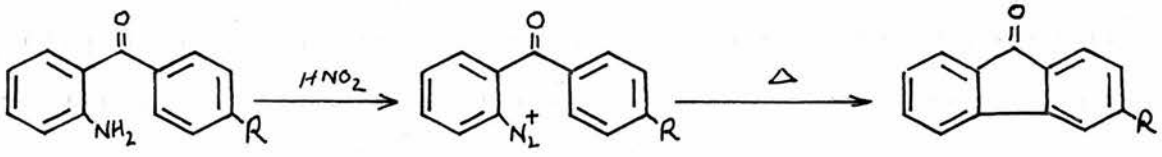
Substitution:

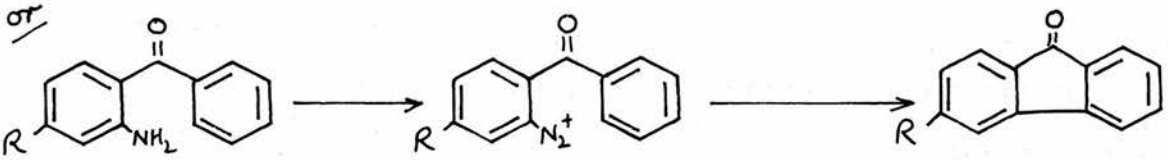
Direct substitution by electrophilic reagents in fluorene always involves the 2-position.[4,9] With an electron-attracting group in position 2, further substitution occurs in the 7-, and to some extent in the 5-, position. On the other hand, an electron-releasing group directs a second substituent into the 7-, 3- and 1-positions, in varying order of quantitative importance. Only the 2-monosubstituted and the 2,7- and 2,3-disubstituted derivatives are readily available in useful yields from the hydrocarbon itself: compounds with substituents at other carbon atoms must be synthesised by more elaborate methods.

3-Substituted fluorenes:

Fluorenes or fluorenones with a substituent in the 3-position have been synthesised in several ways, many of which are not necessarily specific for 3-isomers:

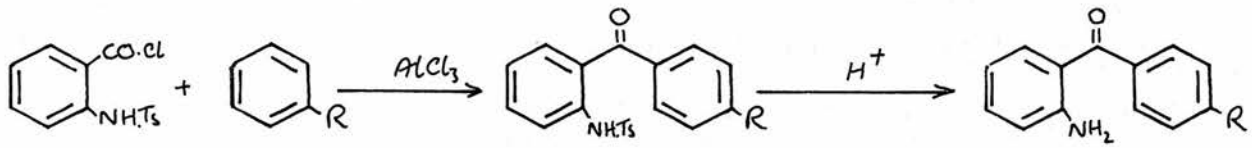
(1) From 2-aminobenzophenones by a Pschorr-type (Ullmann) Reaction.





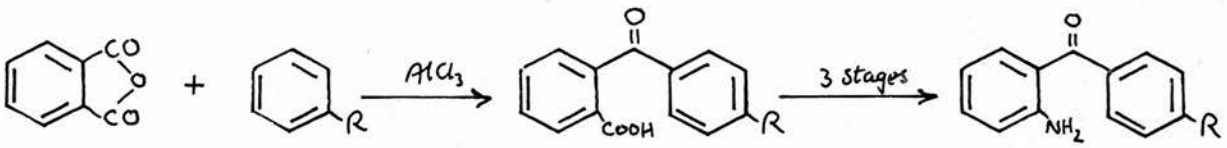
This synthesis is the subject of an excellent review by deTar.(10) Unfortunately, it cannot be applied to the direct synthesis of fluorenes from o-benzylanilines since the tetrahedral configuration of the methylene-group means that the phenyl rings are non-planar, and cyclisation is not favoured. The intermediates themselves are obtained in at least three ways:

Friedel-Crafts reaction with a protected anthranilic acid:(11)

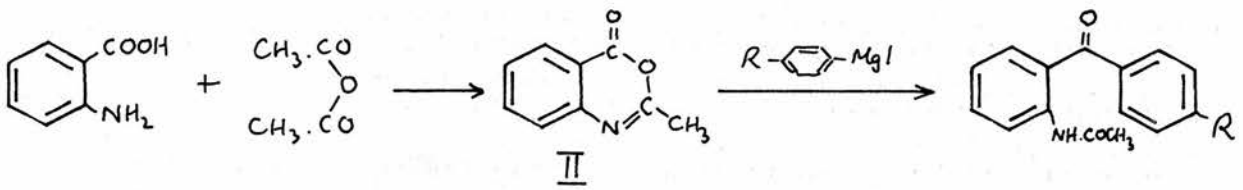


[Ts = $-SO_2-C_6H_4-CH_3$]

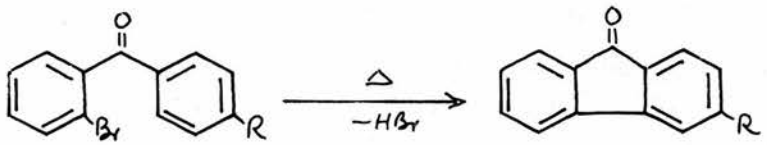
Friedel-Crafts with phthalic anhydride, followed by Hoffman degradation of the amide of the resulting o-benzoylbenzoic acid.(11)



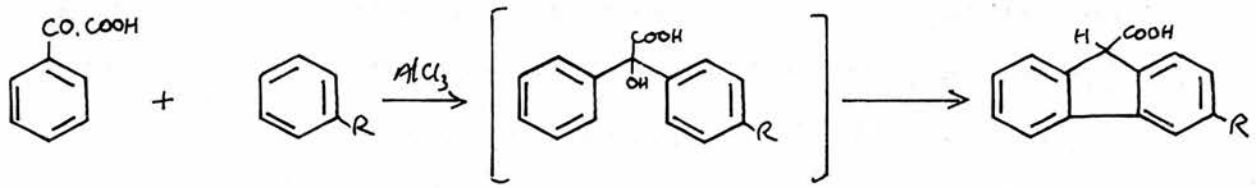
Inverse addition of a Grignard reagent from a p-substituted iodobenzene to 6-oxo-2-methyl-4,5-benz-1,3-oxazine II, itself readily available from acetic anhydride and anthranilic acid.(12)



(2) By elimination of hydrogen bromide from o-bromobenzophenones.(13)



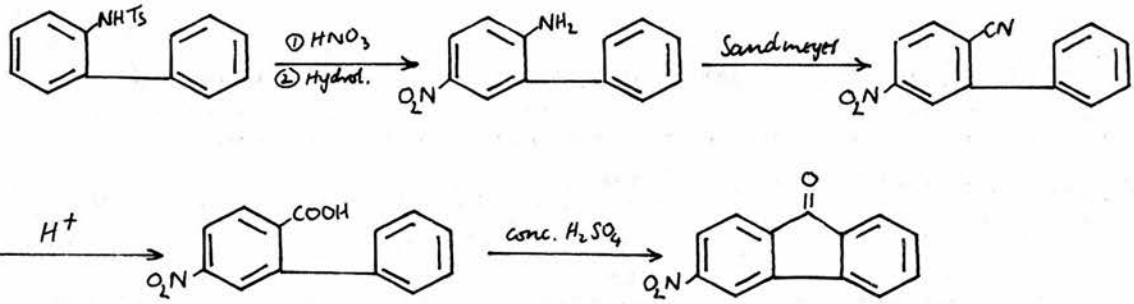
(3) Via a remarkable reaction in which benzoylformic acid condenses with substituted benzenes in the presence of aluminium chloride to produce fluorene-9-carboxylic acids.(14)



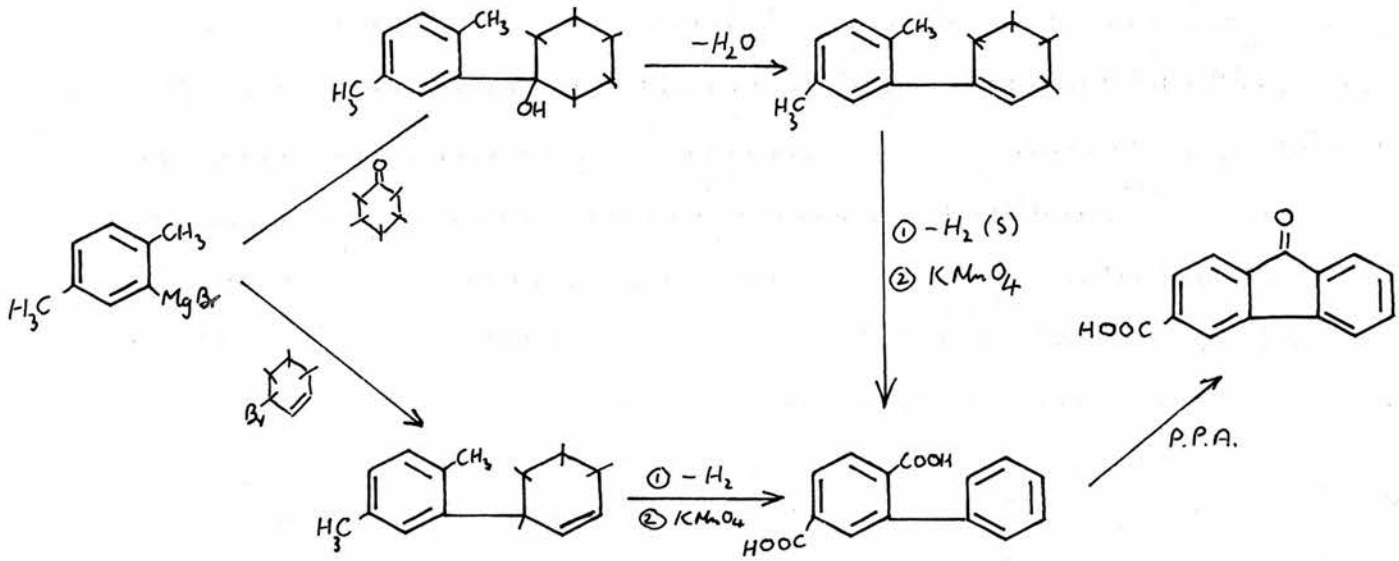
So far the method has only been applied to the synthesis of the 3-methyl derivative, but there seems no reason why it could not be extended to others.

④ From o-carboxybiphenyl derivatives by ring closure.

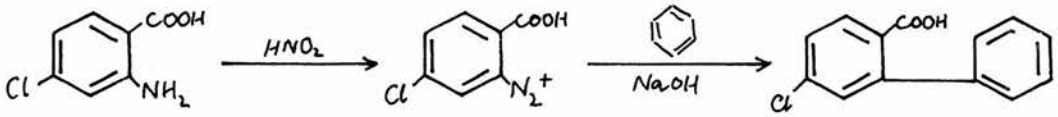
3-Nitrofluorenone was synthesised by nitration of o-tosylaminobiphenyl, followed by hydrolysis, conversion to the nitrile by the Sandmeyer reaction and hydrolysis to the carboxylic acid.(15,16)



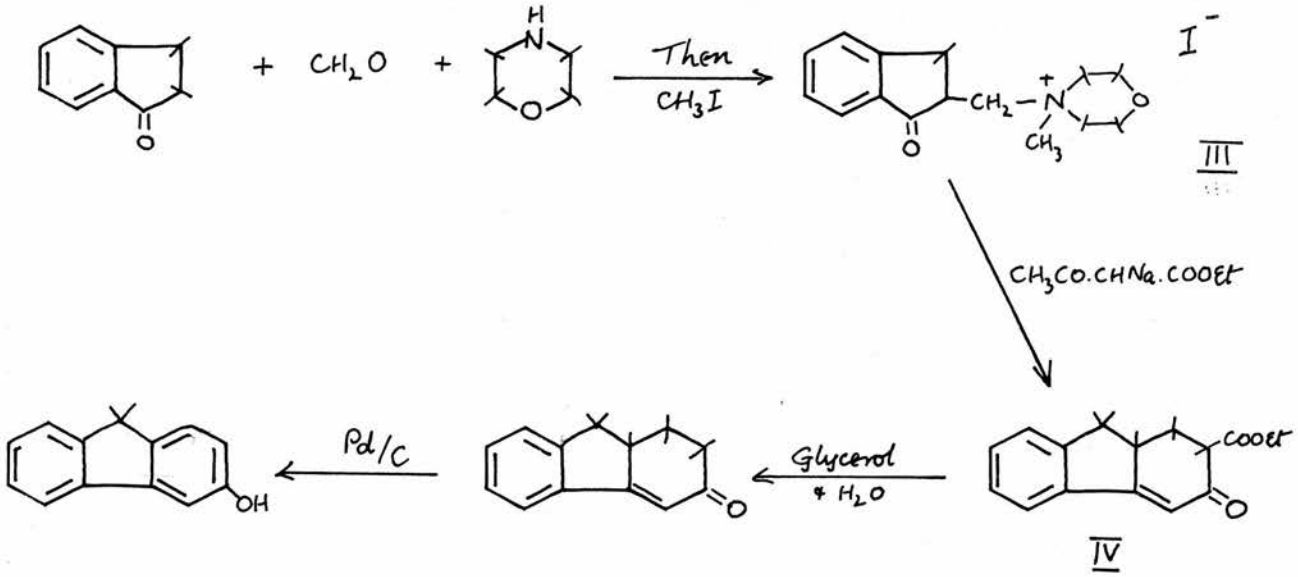
Fluorenone-3-carboxylic acid was obtained(17) by the following interesting route: the isomeric 1- and 3-(2,5-xylyl)-cyclohexenes were prepared from 2,5-xylylmagnesium bromide with cyclohexanone and 3-bromocyclohexene respectively. Dehydrogenation yielded 2,5-dimethylbiphenyl which was oxidised to 2,5-biphenyl-dicarboxylic acid and ring-closed.



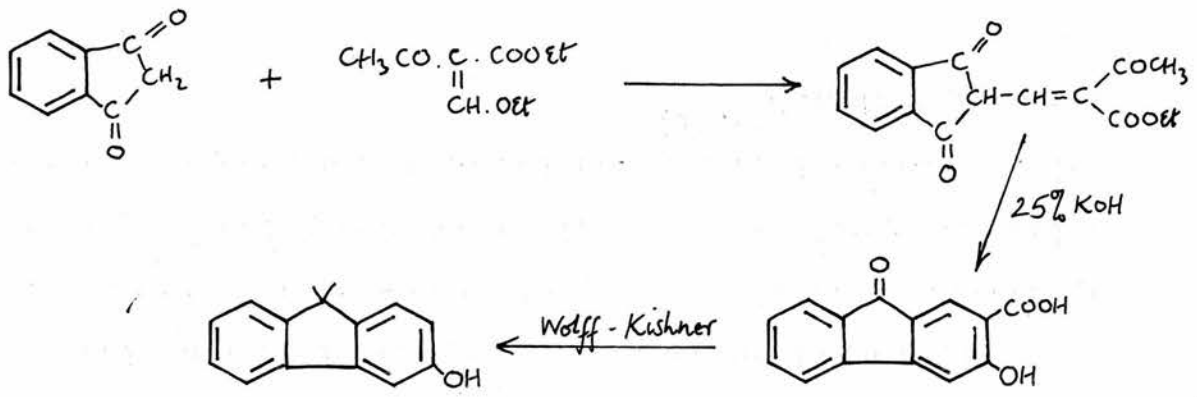
The required o-carboxybiphenyls have also been prepared by a Gomberg reaction with substituted anthranilic acids.(18)



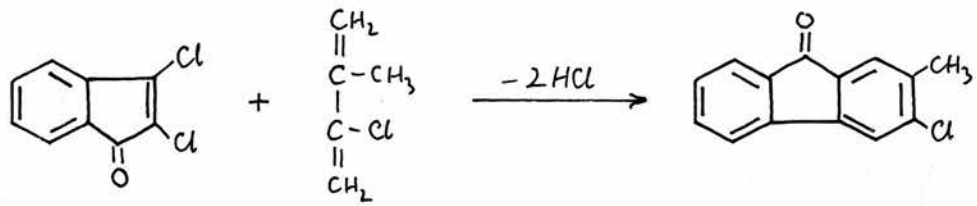
(5) The fluorene ring system may be built from indane derivatives: Indan-1-one gave, by the Mannich reaction, the salt III which in turn reacted with sodio-acetoacetate to give the keto-ester IV. This was decarboxylated and aromatised to 3-hydroxyfluorene.(19)



3-Hydroxyfluorene was also synthesised from indan-1,3-dione by condensation with ethoxymethylene-acetoacetic ester, giving V, which was cyclised by alkali to 3-hydroxyfluorenone-1-carboxylic acid. Wolff-Kishner reduction of the carbonyl also effected decarboxylation.(20,21)



Bergmann and Barshai[22] have used 2,3-dichloroindenones in a neat Diels-Alder synthesis with substituted butadienes. Simultaneous elimination of hydrogen chloride provided 2,3-disubstituted fluorenones directly.



Only the isomer shown was obtained, presumably due to mutual repulsion of the chlorine and the carbonyl. The corresponding reaction would perhaps occur with 2-chlorobutadiene, giving 3-chlorofluorenone, but this was not reported.

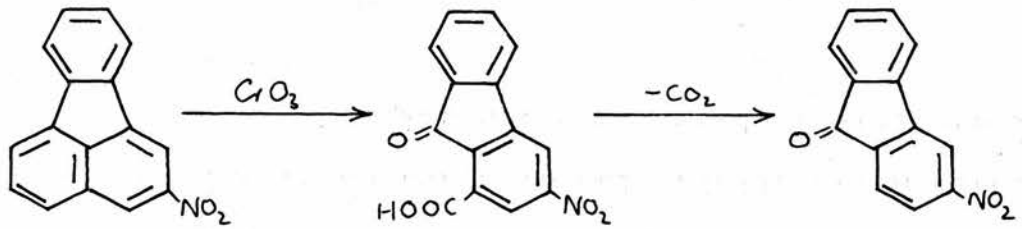
(6) Elimination of the 2-substituent in 2,3-disubstituted fluorenones:

This is the simplest, and often the best, route to 3-substituted fluorenones, although the reduction to the corresponding fluorenes is not always practicable. When 2-acetamidofluorenone is nitrated,[23] brominated,[24] or chlorinated,[25] the product is easily deaminated by hydrolysis, diazotisation, and treatment

with hypophosphorous acid. Curiously, 2,3-disubstituted fluorenes are resistant to deamination. Despite claims by Bardout,[26] later workers have been unable to effect the deamination of 2-amino-3-nitrofluorene by any of the usual methods.[27] Apparently the methylene group is responsible, as certain diphenylmethane derivatives are equally resistant.[28]

⑦ Finally, 3-substituted fluorenones may be obtained by oxidation of suitably substituted fluoranthene derivatives to 3- or 6-substituted fluorenone-1-carboxylic acids, which may then be decarboxylated.

Kloetzel, King and Menkes[29] obtained 2-nitrofluoranthene and oxidised it to 3-nitrofluorenone-1-carboxylic acid. Decarboxylation yielded 3-nitrofluorenone.

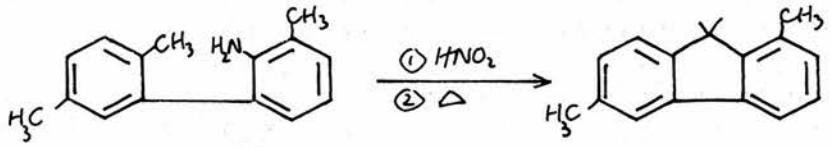


The degradation of 3,8-disubstituted fluoranthenes to 6-substituted fluorenone-1-acids and their decarboxylation to 3-substituted fluorenones, is described in this thesis.

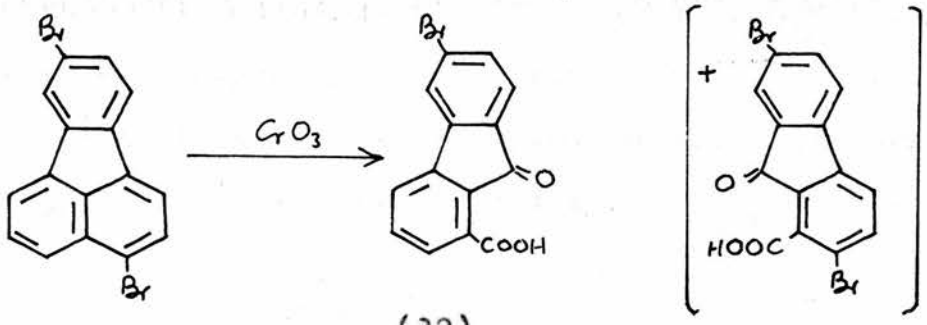
1,6-Disubstituted fluorenes.

Very few fluorenes substituted in both the 1- and 6-positions have been reported. In many cases they have only been obtained as constituents of mixtures.

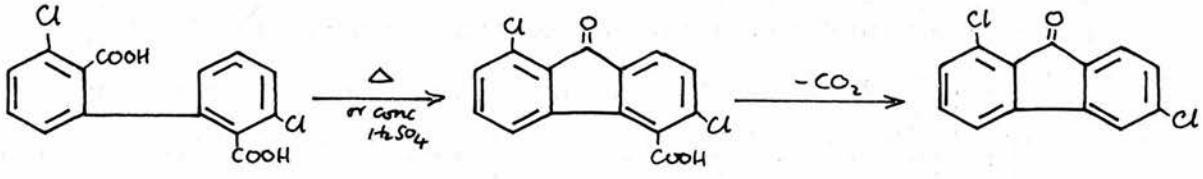
1,6-Dimethylfluorene was synthesised by Longo and Pirona by a coupling reaction:[30]



6-Bromofluorenone-1-carboxylic acid was shown to be one of the products of oxidation of 3,8-dibromofluoranthene:[31]

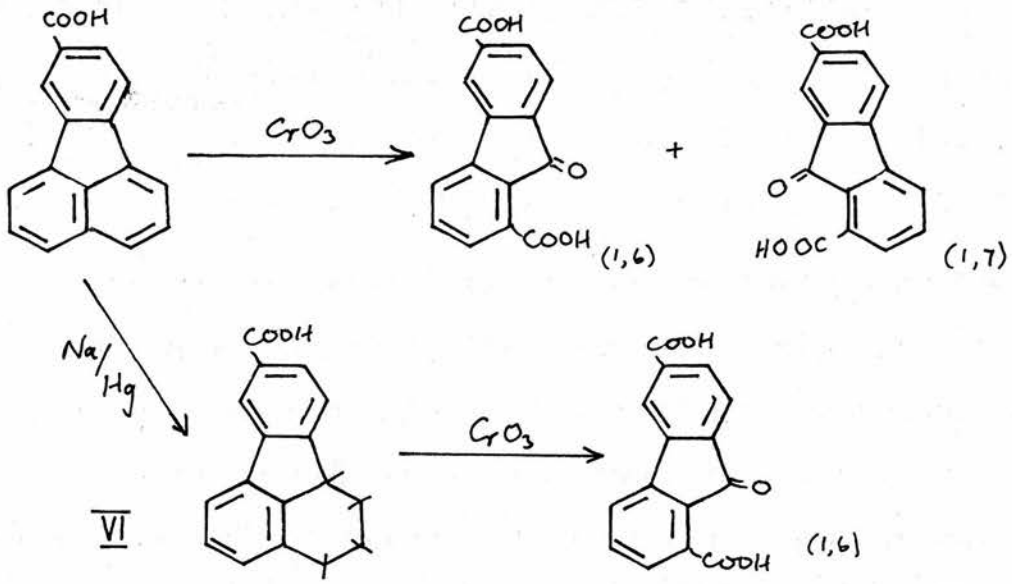


Huntress and Cliff[32] prepared 1,6-dichlorofluorenone by cyclisation of 3,3'-dichlorobiphenic acid, but depending on the reaction conditions, a number of products could be obtained, due to rearrangements and migrations. The designation of structures and postulation of mechanism for these appear reasonable, but in view of the high temperatures involved, the synthesis cannot be regarded as reliable.



Fluorenone-1,6-dicarboxylic acid was obtained as one of the oxidation products of fluoranthene-8-carboxylic acid, but

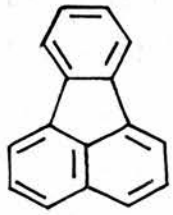
also specifically by the oxidation of 1,2,3,10b-tetrahydrofluoranthene-8-carboxylic acid VI.[33]



Tucker and Whalley[34] isolated a trace of an acid, either 6- or 7-methylfluorenone-1-carboxylic acid, from the oxidation of 8-methylfluoranthene.

It is apparent that, as yet, no satisfactory unambiguous route to 1,6-disubstituted fluorenones has been developed.

FLUORANTHENE



VII

Isolated as early as 1877 by Goldschmiedt,[35] fluoranthene is now obtained commercially from coal tar. Its derivatives are used to some extent in the dyestuff industry and have been isolated from everything from tobacco smoke to barnacles and Zulu snuff.

The structure proposed by Fittig and Gebhart[36] in 1877, involving two 5-membered rings, was corrected in 1929 by von Braun and Anton.[37] They pointed out the inherent strain in the original structure, suggested the 1,2-benzacenaphthene formulation VII, and confirmed this synthetically.

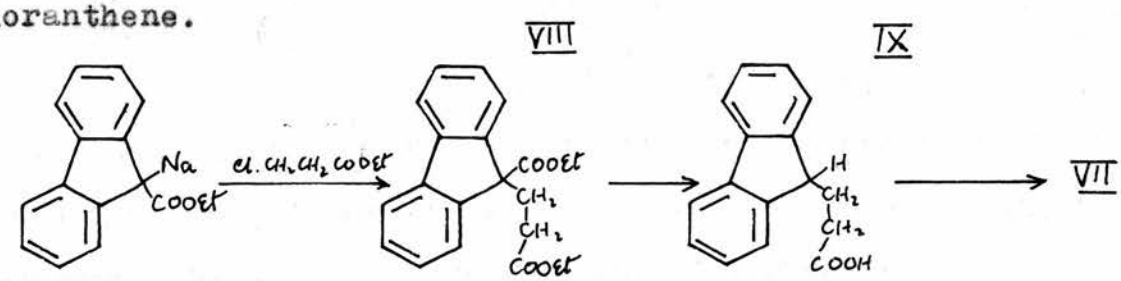
The detailed crystallographic analysis of fluoranthene has not yet been reported, although the unit cell has been determined.[38]

Synthesis:

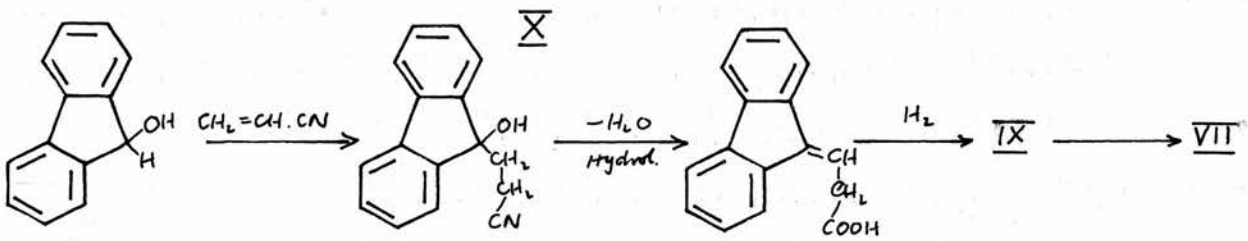
The molecule may be regarded as containing the fluorene, naphthalene or acenaphthylene structures, and the three main synthetic routes to fluoranthene and its derivatives reflect these relationships.

(1) From Fluorene.

The original synthesis of von Braun and Anton[37] started from ethyl fluorene-9-carboxylate. It was condensed with ethyl β-chloropropionate and the product VIII hydrolysed then decarboxylated to β-(9-fluorenyl)propionic acid IX). Ring closure, reduction of the carbonyl and dehydrogenation gave fluoranthene.

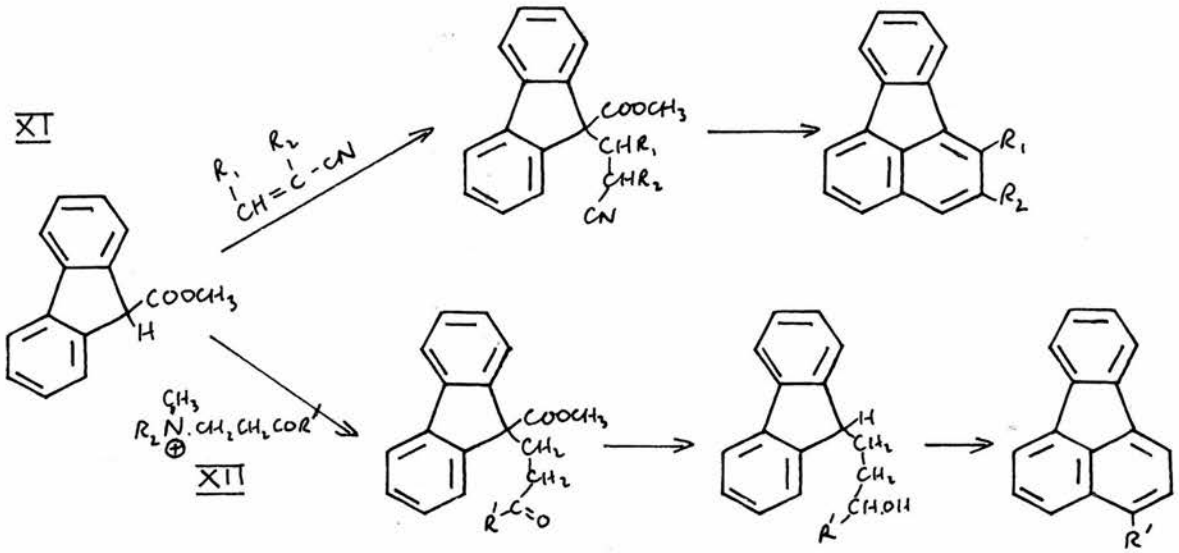


Campbell and Fairfull[39] found that fluoren-9-ol reacted with acrylonitrile in a Michael addition to give β-(9-hydroxy-9-fluorenyl)propionitrile X, which was hydrolysed, dehydrated and reduced to IX - an intermediate in von Braun's synthesis.



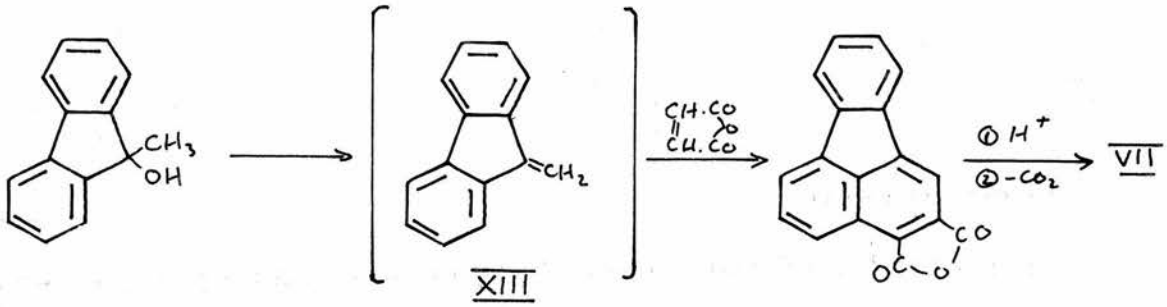
These two syntheses were neatly combined and extended by Tucker and co-workers: methyl fluorene-9-carboxylate XI was reacted with acrylonitrile[41] and the product hydrolysed with concomitant decarboxylation to IX. Crotononitrile[40] and 2-methylacrylonitrile[43] were similarly employed in the reaction

to prepare 1- and 2-methylfluoranthenes respectively, and Mannich bases[42] of the type XII to obtain 3-substituted fluoranthenes.

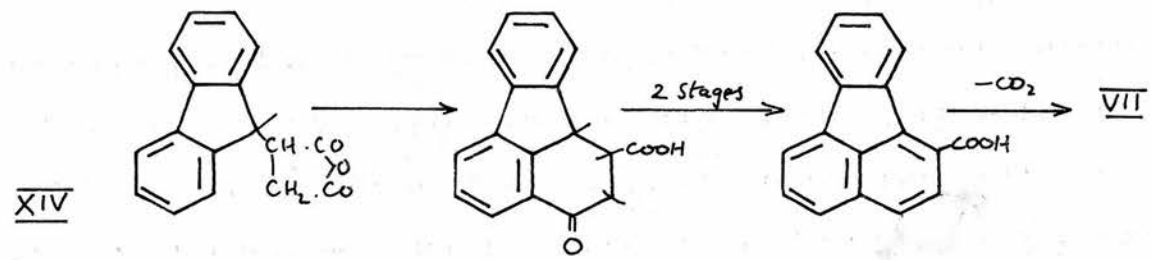


The use of nuclear-substituted fluorenes in the above reactions has only been touched upon: 2-chloro-, 2,7-dichloro-[44] and 2,7-dibromofluorenes[45] gave rise to the corresponding 8- and 3,8-substituted fluoranthene derivatives; and methyl 2-nitrofluorene-9-carboxylate reacted with acrylonitrile in low yield,[46] leading to 8-nitrofluoranthene.

An interesting route[47] from the fluorene nucleus starts from 9-hydroxy-9-methylfluorene, which was found to react with maleic anhydride to produce fluoranthene-2,3-dicarboxylic acid, presumably by Diels-Alder addition to the intermediate XIII. Similarly, 9-hydroxy-9-ethylfluorene gave rise to 1-methyl-fluoranthene.



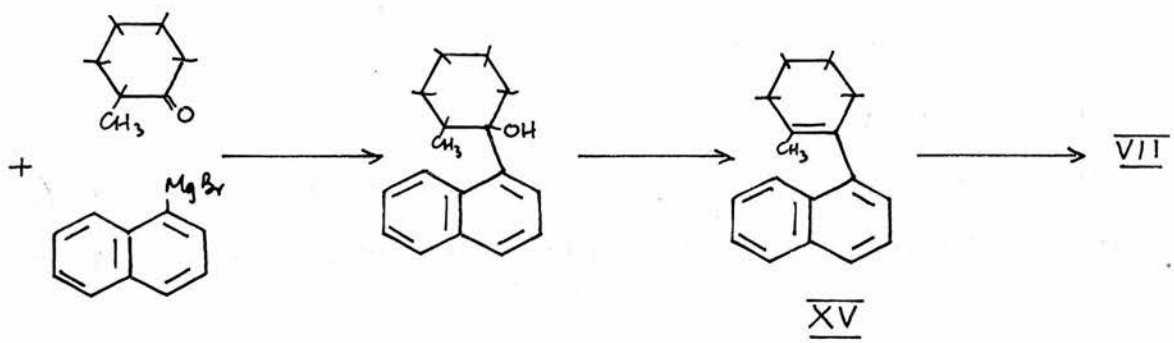
Bergmann and Orchin's synthesis[48] employed an initial condensation between fluorene and maleic anhydride. The resulting adduct XIV was cyclised and converted to fluoranthene in three stages.



This method has been extended to a few 2- and 2,7-halogenofluorenes;[49,50] and in the one case in which decarboxylation was attempted,[50] debromination occurred at the same time.

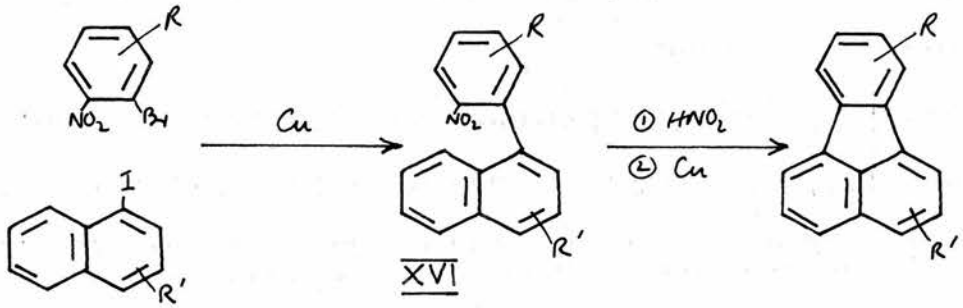
(2) From Naphthalene:

Cook and Lawrence[51] reacted α-naphthylmagnesium bromide with 2-methylcyclohexanone. Dehydration of the resulting alcohol to XV, followed by cyclisation and dehydrogenation, afforded fluoranthene in poor yield.



Better yields were obtained by Orchin and Reggel[52] using cyclohexanone itself. The dehydrated product was cyclodehydrogenated to fluoranthene.

In a series of papers,[53-59] Tucker and co-workers described the synthesis of several methyl- and methoxy-fluoranthenes by coupling α-iodonaphthalenes with o-bromonitrobenzenes in a crossed Ullmann reaction. The products XVI were reduced, diazotised and cyclised with copper bronze.

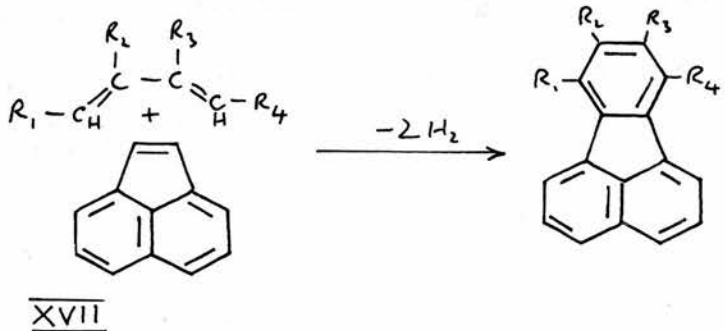


XVI

The synthesis is to some extent limited by inaccessibility of starting materials.

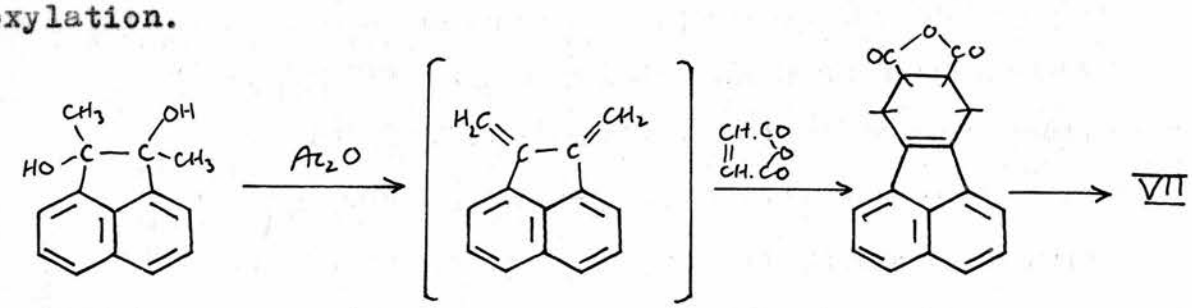
(3) From the Acenaphthene nucleus:

Acenaphthylene XVII undergoes the Diels-Alder reaction with certain dienes to give substituted fluoranthenes: 1-Phenylbutadiene yields 7-phenylfluoranthene;[60] sorbic acid gives 7-methylfluoranthene-10-carboxylic acid[61] and methylbutadienes afford 7- and 8-methylfluoranthenes.[62]



XVII

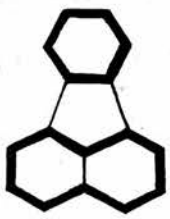
Campbell and Gow[63] condensed trans-1,2-dimethyl-acenaphthene-1,2-diol XVIII with maleic anhydride to give, presumably via a diene created in situ, the adduct XIX which was converted to fluoranthene by dehydrogenation and decarboxylation.



XVIII

Substitution:

The substitution of fluoranthene is a relatively unexplored field, which is surprising in view of the fact that the molecule poses an interesting problem in the application of the Molecular Orbital theory to aromatic substitution. The extension of Hückel's "4n+2" rule to polycyclic hydrocarbons, normally successful, is not applicable to fluoranthene which has only 16π-electrons.[64] It is classed as a non-alternant hydrocarbon, and may be regarded as a 6-electron and 10-electron system with "cross-links" XX.



XX

The effect of these links, however, is by no means negligible, so that attempts to rationalise the substitution in terms of the constituent systems are invalid; neither does the LCAO-MO treatment in its present forms adequately describe its reactivity. In any case, the accumulated experimental data is neither sufficient nor detailed enough to present a full picture. The results obtained so far are as follows:

(1) Monosubstitution:

Normally the 3-isomer is obtained as the major product, with a small amount of the 8-isomer as a by-product,[65] but a notable exception is the Friedel-Crafts reaction in which the 8-position is the preferred point of attack.[66]

A recent careful examination[67] of the products of nitration, however, revealed four isomers in all, the relative yields obtained depending on the reaction conditions. The intensities of selected bands in the infra-red spectra corresponding to each isomer were measured, and correlated by computer to give the yield distribution:

Isomer	In Ac_2O at 0°C	In AcOH at 50°
1	11.1%	2.3%
3	43.5	69.6
7	18.4	5.0
8	27.0	23.1
(2	0	0)

Acetic acid is seen to be the more selective solvent, but in both cases the order of reactivities is 3>8>7>1>2. Calculations based on cation localisation energies gave the order as 3>7>8>1>2, so that only the 7-position is out of line. This is the first report of any isomers other than 3 or 8 in monosubstitution; obviously much more work along these lines is desirable.

(2) Disubstitution:

Dibromination was shown to give 3,8-dibromofluoranthene,[31] while sulphonation[68] and the Friedel-Crafts reaction[69] yielded the 3,9-disubstituted derivatives.

In order to study the effect of a substituent already present on the position of attack of another reagent, Campbell and Keir[68] brominated 3-carboxy-, 3-carbomethoxy-, 3-cyano, and 3-nitrofluoranthene. In all cases the bromine entered the 9-position.

Kloetzel, King and Menkes[29] showed that 3-acetamidofluoranthene nitrates in the 2-position, and suggested that the acetamido-function so activates the ring to which it is attached that substitution occurs in the same ring. This work has recently been supplemented by Charlesworth and Blackburn,[70] who have proved that bromination also occurs in the 2-position.

The question remaining unanswered is that of the effect of a weaker electron-releasing group than acetamido- on further

substitution. The only evidence so far available is that a bromine in the 3-position directs a second bromine into position 8. Section I of this thesis concerns the investigation into the effect of such substituents.

③ Trisubstitution:

Only the tribromo-derivative has been orientated: It was shown to be the 3,8,9-isomer.[71] In addition, 3,8-dibromofluoranthene was found to acetylate in the 9-position. Trinitro- and trichlorofluoranthene have been obtained but not orientated.[35,36]

D I S C U S S I O N

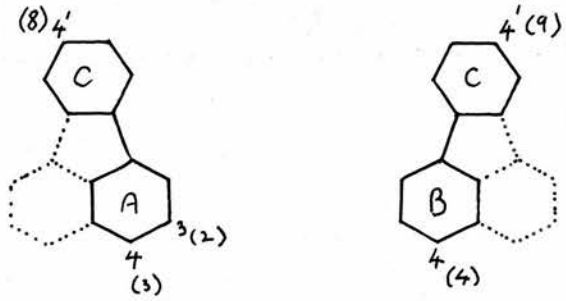
SECTION I

Part 1: The nitration of 3-methoxyfluoranthene

Campbell and Craig[72] nitrated 3-methoxyfluoranthene and obtained a mixture of mononitromethoxyfluoranthenes, from which they isolated a pure mononitro-derivative as well as an unresolvable mixture. Both the pure compound and the mixture gave the same dinitromethoxyfluoranthene almost quantitatively on further nitration. Hence there are two monosubstitution products, each of which nitrates to give the same dinitro-isomer.

Investigating the nitration of 4-methoxybiphenyl, Bell and Kenyon[73] found that a mixture of mononitro-derivatives was formed: 3- and 4'-nitro-4-methoxybiphenyl, each of which on further nitration yielded 3,4'-dinitro-4-methoxybiphenyl.

By the rough analogy, suggested by Campbell and Keir[68] on the basis of their disubstitution experiments, that fluoranthene may be considered as a double biphenyl compound, thus -



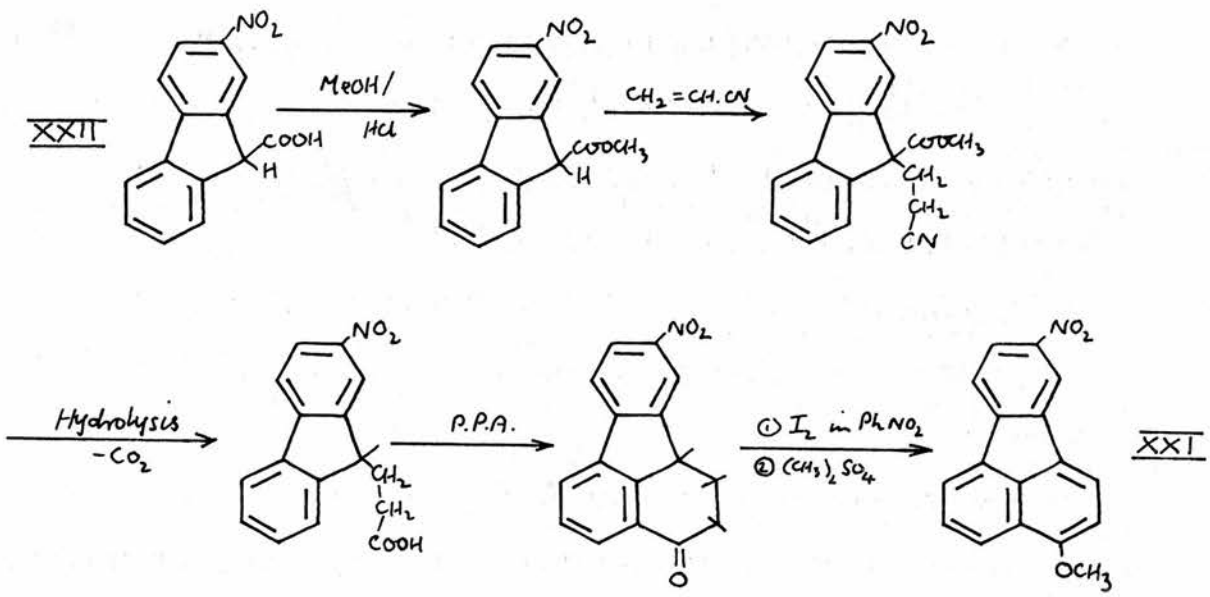
(Fluoranthene positions in parentheses)

it was expected that 3-methoxyfluoranthene would give the corresponding isomers viz. 3-methoxy-2-nitro- and 3-methoxy-8-nitrofluoranthene.

Campbell and Nichol[74] prepared the former isomer by boiling

the diazonium salt of 3-amino-2-nitrofluoranthene with ethanolic alkali, and methylating the resulting nitrophenol. It was shown to be identical with the pure compound obtained in the nitration of 3-methoxyfluoranthene, and gave the same dinitro-isomer on further nitration. Thus one of the nitro-groups in the latter is in the 2-position; The other is probably in the 8-, but possibly 9-, position.

Campbell, Craig and Nichol[75] synthesised 3-methoxy-9-nitrofluoranthene XXI from 2-nitrofluorene-9-carboxylic acid XXII by a modification of Campbell and Tucker's fluoranthene synthesis:-[41]



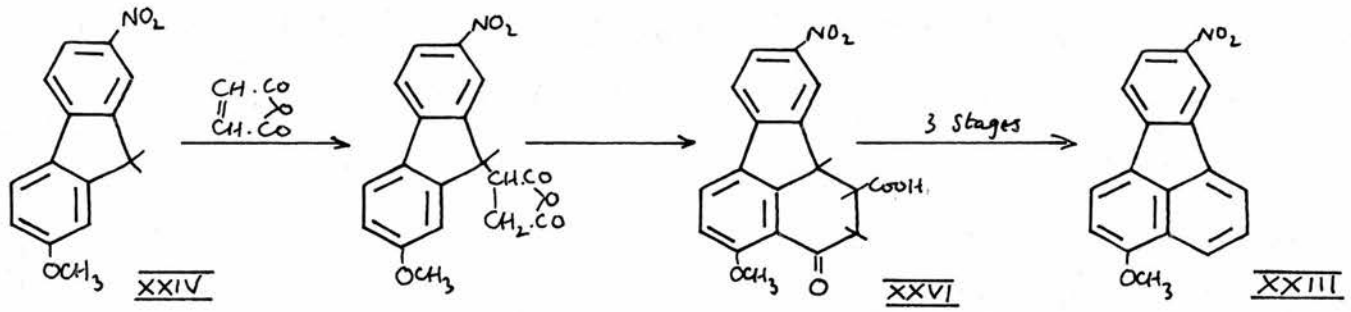
On further nitration, this gave 3-methoxy-2,9-dinitrofluoranthene, which proved to be different from the dinitration product of 3-methoxyfluoranthene.

Several attempts were made by these workers to synthesise 3-methoxy-8-nitrofluoranthene XXIII, but all failed. The following section describes the successful synthesis of this isomer.

Synthesis of 3-methoxy-8-nitrofluoranthene

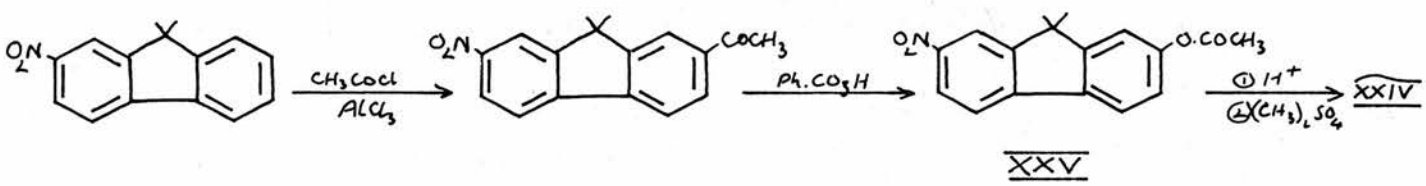
(1) From 2-methoxy-7-nitrofluorene XXIV:

The following scheme, based on Bergmann and Orchin's synthesis of fluoranthene,[48] was envisaged:



Previous preparations of XXIV involved selective reduction of 2,7-dinitrofluorene to 2-amino-7-nitrofluorene, followed by diazotisation, hydrolysis and methylation. As the yields obtained were very low, an alternative synthesis seemed desirable.

2-Nitrofluorene was acetylated to give 2-acetyl-7-nitrofluorene and this was treated with perbenzoic acid in tetrachlorethane.[76] The ester XXV was formed, which on hydrolysis and methylation gave XXIV, in higher overall yield than the previous method.

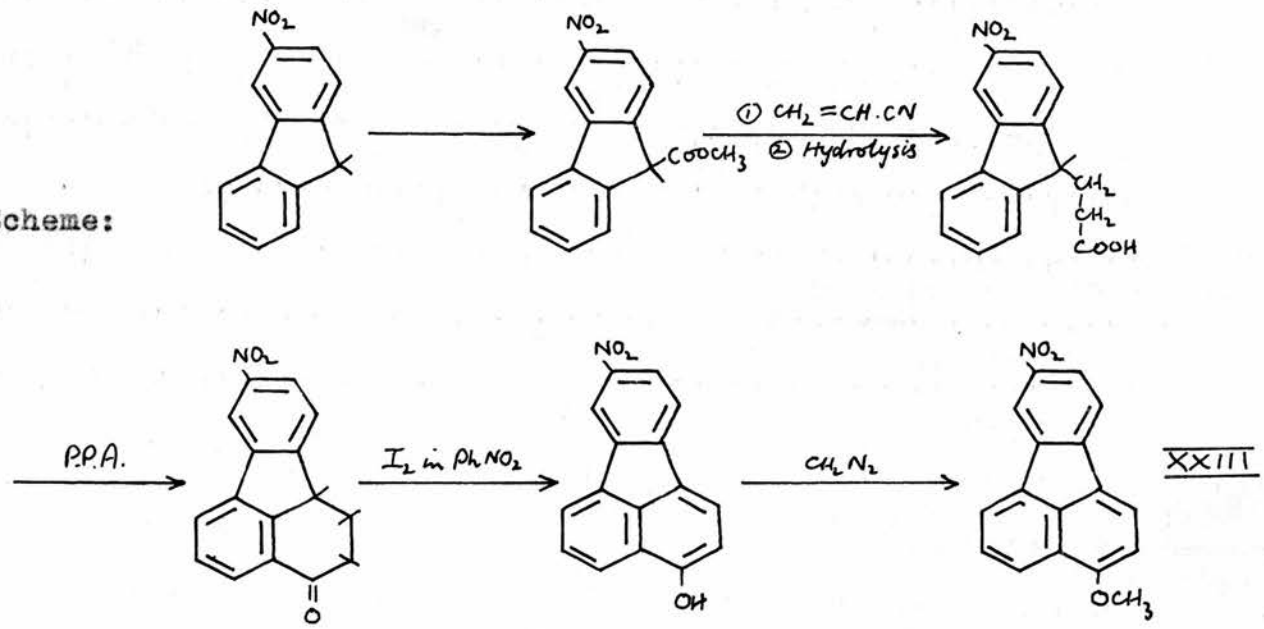


However, attempts to react this with maleic anhydride were unsuccessful. The possibility of effecting the condensation

with 2-acetylfluorene, followed by nitration of the product, was considered, but a trial nitration of 2-acetylfluorene gave no 2-acetyl-7-nitrofluorene; nor did 2-acetylfluorene condense with maleic anhydride. Other attempts to introduce a side-chain into the 9-position of XXIV had also failed,[75] and since the reduction of the carbonyl of XXVI would be difficult owing to the presence of the nitro-group (c.f. p.25), this approach was abandoned.

(2) From 3-nitrofluorene:

Scheme:



This synthesis is directly analogous to that of 3-methoxy-9-nitrofluoranthene XXI, except that 3-nitrofluorene is much less accessible than the 2-isomer: There is no report of its having been prepared in quantity.

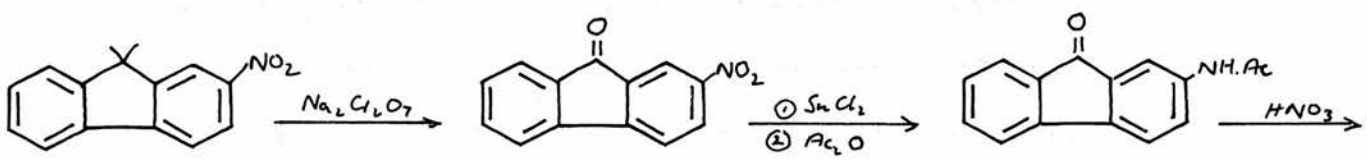
Nitration of 2-acetamidofluorene led to a mixture of nitro-amines which were separated by means of their different

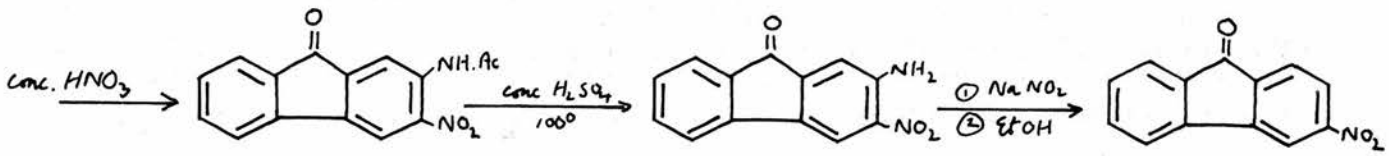
basicities;[77] and 2-amino-3-nitrofluorene obtained in about 30% yield. The deamination of this compound, reported by Bardout,[26] was attempted, but only a trace of 3-nitrofluorene was isolated. The red amorphous material mentioned by Stafford and Nichol[27] was the main product. Diazotisation in tetrahydrofuran[78] produced no better results, and this approach was discontinued.

3-Nitrofluorenone was then synthesised in the hope that a means of reducing it to the fluorene would be found.

Arcus and Coombs' method[16] (Introd.p.5) was repeated but although found to be generally satisfactory, the yield obtained at the Sandmeyer stage was much lower than that reported, even when freshly prepared cuprous cyanide was used. Bradsher and Jackson[79] encountered similar difficulties and showed that the original authors' product must have been impure; They modified the synthesis by first making the bromo-derivative with cuprous bromide and converting to the nitrile by the Rosenmund-von Braun reaction. The whole synthesis seems unnecessarily involved, and the following route is much to be preferred.

In contrast to the deamination of 2-amino-3-nitrofluorene, the deamination of the corresponding fluorenone occurs smoothly and in high yield[23] (Introd.p.8). Accordingly, 3-nitrofluorenone was prepared as shown:



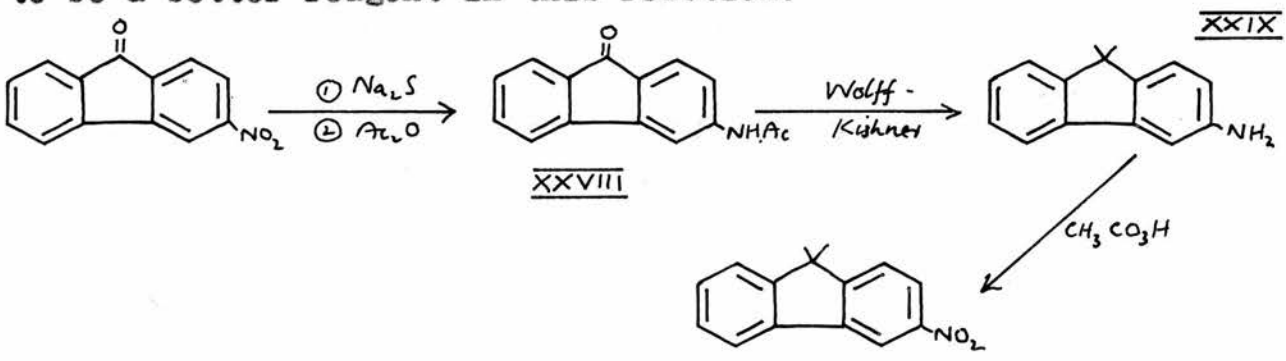


In an attempted short-cut, the work of Schultz[80] on the nitration of fluorenone was repeated. As reported, two products were obtained: One, m.p. 290°, was 2,7-dinitrofluorenone. The other, m.p. 219-220°, Schultz designated as 2-nitrofluorenone (lit. m.p. 222-223°). However, a mixed melting-point with an authentic sample of 2-nitrofluorenone showed a distinct depression, the infra-red spectra were different and analysis indicated that it was in fact a dinitrofluorenone. Chromatography on alumina raised the melting-point to 241°, and a mixture with 2,5-dinitrofluorenone XXVII (m.p. 241°) showed no depression. Under the conditions employed (fuming nitric acid), Schultz's compound was more likely to be a dinitro- than a mononitro-fluorenone. It is interesting to note that Huntress and Cliff[81] obtained a "new", unidentified dinitrofluorenone m.p. 213-214° along with 2,7-dinitrofluorenone, by nitrating 9-acetamido-fluorene; It seems probable that this, too, was impure XXVII.

The next step was to reduce 3-nitrofluorenone to 3-nitro-fluorene but, since carbonyl-reducing agents invariably attack the nitro-group, this proved to be impossible: Wolff-Kishner reduction produced only a red, intractable tar; Sodium boro-hydride in methanol gave a high-melting, yellow solid,

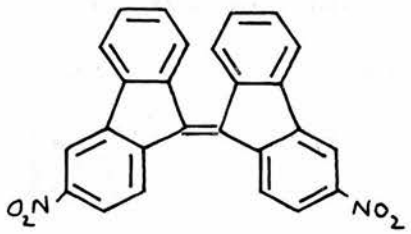
paralleling Fletcher's attempt[82] to reduce 2-nitrofluorenone by this method. (The action of borohydride on aromatic nitro-compounds has recently been discussed[83]). 3-Nitrofluoren-9-ol has been prepared by the Meerwein-Ponndorf method,[16] but attempts to carry the reduction further were unsuccessful.[84]

Emmons[85] has shown that peracetic acid can be used to oxidise amines to nitro-compounds, and the reaction has been successfully applied to the oxidation of some bromo-amino-fluorenes.[86] 3-Nitrofluorenone was therefore reduced to 3-aminofluorenone with sodium sulphide and acetylated to give XXVIII. The Wolff-Kishner reaction smoothly reduced and hydrolysed XXVIII to 3-aminofluorene XXIX.[87] On treatment with peracetic acid, XXIX gave a 20% yield of 3-nitrofluorene along with some red tar (probably containing azoxycompounds). In contrast, 2-nitrofluorene was obtained in 60% yield from the corresponding amine, and was largely free from contaminant. Nevertheless, this route provides a means of preparing 3-nitro-fluorene in quantity, and should be capable of improvement: For instance, peroxytrifluoro-acetic acid has sometimes proved to be a better reagent in this reaction.



XXVIII XXIX

The synthesis broke down at the next stage: 2-Nitrofluorene has been converted to 2-nitrofluorene-9-carboxylic acid by condensation with dimethyl oxalate, in about 24% yield.[46] This work was repeated, and the yield confirmed, but when 3-nitrofluorene was employed, the initial condensation failed. Only a red material, insoluble in acetic acid, was obtained; and the filtrate, on hydrolysis and peroxide oxidation, gave 3-nitrofluorenone instead of the desired acid. The red compound melted above 340° and separated from nitrobenzene as an amorphous solid. Its nitrogen analysis and molecular weight suggested that it was perhaps 3,3'-dinitro-9,9'-bifluorenylidene XXX.



XXX

Campbell and Nichol[88] obtained a similar (perhaps identical) compound from the attempted condensation of 3-nitro-9-bromofluorene with ethoxymagnesium malonic ester, although the mechanism which they postulated for its formation cannot apply in this case since it ihvolves dehydrobromination.

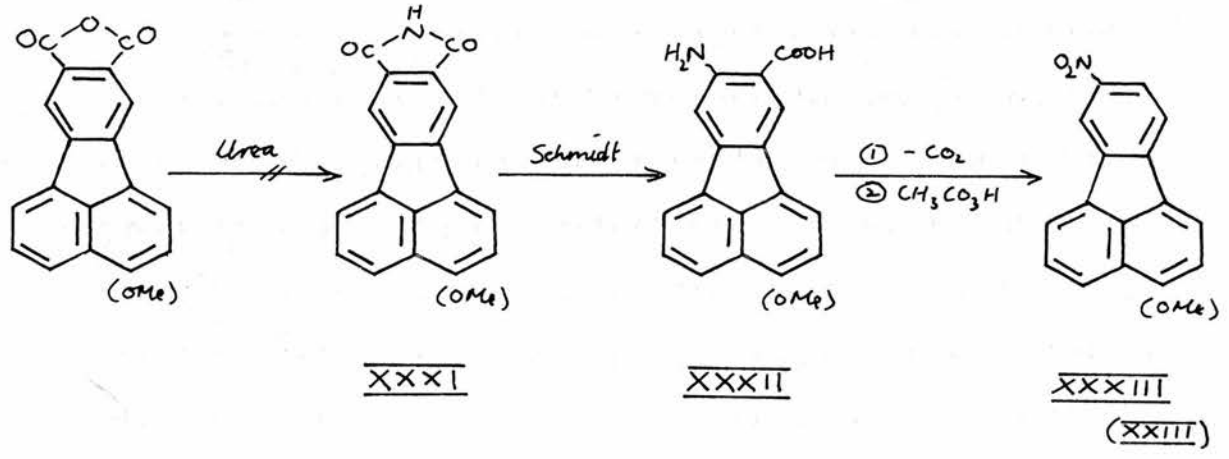
Another way of introducing the carboxyl group into the 9-position of fluorene is via the 9-lithium derivative: This can be prepared either by exchange with phenyllithium,[89] or directly, with lithium in tetrahydrofuran.[90] Neither method, applied to

2-nitrofluorene or to 2-aminofluorene, produced any 9-carboxylic acid, and since 3-nitrofluorene was not expected to behave differently, this method was not further investigated.

(3) From acenaphthene derivatives.

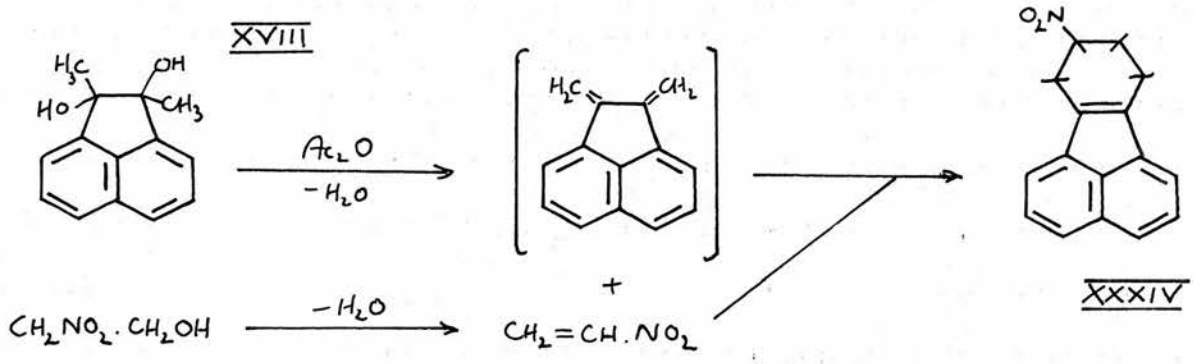
A few trial experiments were carried out in an attempt to synthesise an 8-nitro or 8-aminofluoranthene from acenaphthene-quinone, with a view to applying this to 5-methoxy-acenaphthene-quinone thereby obtaining 3-methoxy-8-nitrofluoranthene XXIII. Although the route is patently ambiguous, the 3,8- might be formed in preference to the 3,9-isomer, and its structure proved by degradation or comparison with the known 3-methoxy-9-nitrofluoranthene XXI.

Fluoranthene-8,9-dicarboxylic anhydride was prepared by the method of Campbell and Gow (Introd.p.16). It was intended to convert this to the imide XXXI which could be degraded by the Schmidt reaction to the amino-acid XXXII. Decarboxylation and peracetic oxidation would afford 8-nitrofluoranthene XXXIII.



However, an attempt to produce the imide by heating the anhydride with urea at 280° resulted in decomposition.

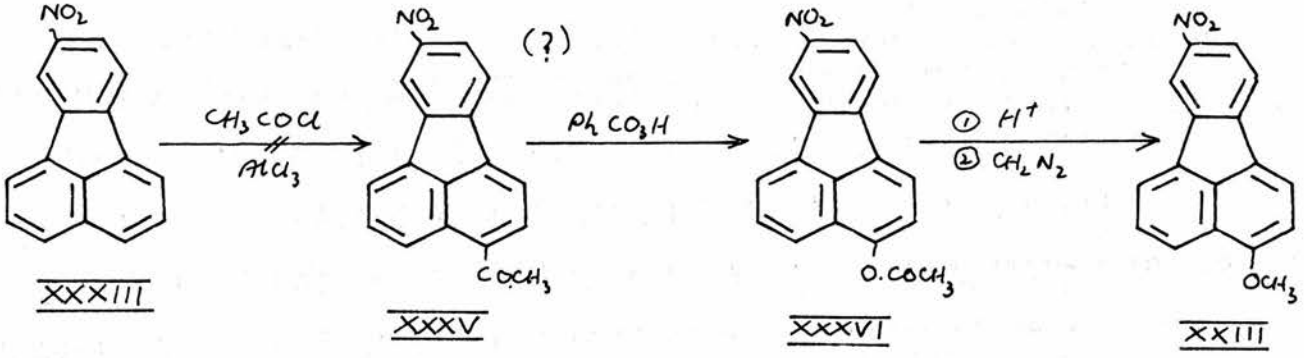
Nitroethylene has been used in the Diels-Alder reaction,[91] and since it may be prepared by the dehydration of 2-nitroethanol with phthalic anhydride,[92] it was of interest to combine this with the dehydration of 1,2-dimethylacenaphthene-1,2-diol as in Campbell and Gow's synthesis. A diene and dienophile would be created in situ, and subsequent 1,4-addition would give 7,8,9,10-tetrahydro-8-nitrofluoranthene XXXIV.



In the event, however, no pure product could be isolated from the reaction.

(4) From fluoranthene derivatives.

Acetylation of 8-nitrofluoranthene, by comparison with that of 2-nitrofluorene, might be expected to give 3-acetyl-8-nitrofluoranthene XXXV, although the possibility of the 3,9-isomer cannot be excluded. Perbenzoic acid oxidation, hydrolysis of the resulting ester XXXVI to the phenol and methylation would afford XXIII.



XXXIII XXXV XXXVI XXIII

The reaction was attempted with acetyl chloride in various solvents and under different conditions, but only traces of material showing a carbonyl absorption in the infra-red were isolated.

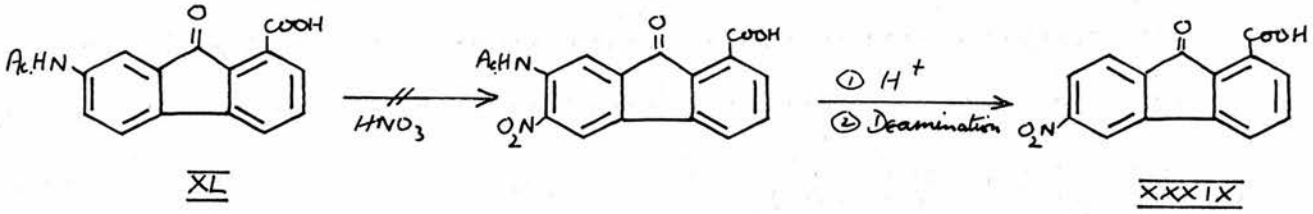
Now Bell and Kenyon[73] found that whereas 4-methoxybiphenyl gave on nitration the mixture of isomers mentioned previously (p.20), 4-toluenesulphonyloxybiphenyl nitrated mainly, if not exclusively, in the 4'-position. By the usual analogy, 3-tosyloxyfluoranthene XXXVII might be expected to yield 8-nitro-3-tosyloxyfluoranthene XXXVIII as the main product.

3-Hydroxyfluoranthene was synthesised,[93] tosylated and nitrated in acetic acid. Chromatography of the product on alumina gave essentially one band, yielding after crystallisation from benzene, about 30% of a pure compound m.p. 189-190°. On hydrolysis and methylation this provided a nitromethoxy-fluoranthene m.p. 208-209° which was different from the 2- and 9-nitro-3-methoxyfluoranthenes already prepared. On further nitration, it gave the same dinitro-isomer as that obtained from the dinitration of 3-methoxyfluoranthene, and must therefore be

the other constituent of the mixture obtained in the mono-nitration of the latter compound.

Meanwhile it was found that 3-hydroxyfluoranthene could be oxidised by alkaline permanganate to fluorenone-1-carboxylic acid, which gave fluorenone on decarboxylation with copper bronze in 4-methylquinoline. The nitrotosyloxy-compound m.p. 189-190° was hydrolysed to the nitrophenol with alcoholic potassium hydroxide, and the above procedure applied. A new nitro-carboxylic acid was formed which melted 30° higher than 7-nitrofluorenone-1-carboxylic acid m.p. 245-6° (which would have resulted from 3-hydroxy-9-nitrofluoranthene). Furthermore, on decarboxylation, this time by heating with copper acetate in a small sublimation apparatus, a yellow sublimate was formed which was shown, by comparison with an authentic specimen, to be 3-nitrofluorenone. Hence the new acid is 6-nitrofluorenone-1-carboxylic acid XXXIX m.p. 275-6°. (The other acid which would have decarboxylated to 3-nitrofluorenone viz. 3-nitro-fluorenone-1-carboxylic acid, melts at 204-5°[29]). An attempt to synthesise the new acid by another route failed: The 7-nitro-analogue, prepared by nitration of fluorenone-1-carboxylic acid, was reduced and acetylated to give 7-acetamidofluorenone-1-carboxylic acid XL.[94] Nitration of this in mixed acid afforded an amorphous red material which deflagrated violently on heating and resisted attempts at deamination. The insolubility of XL in acetic acid and acetic anhydride made nitration in these solvents

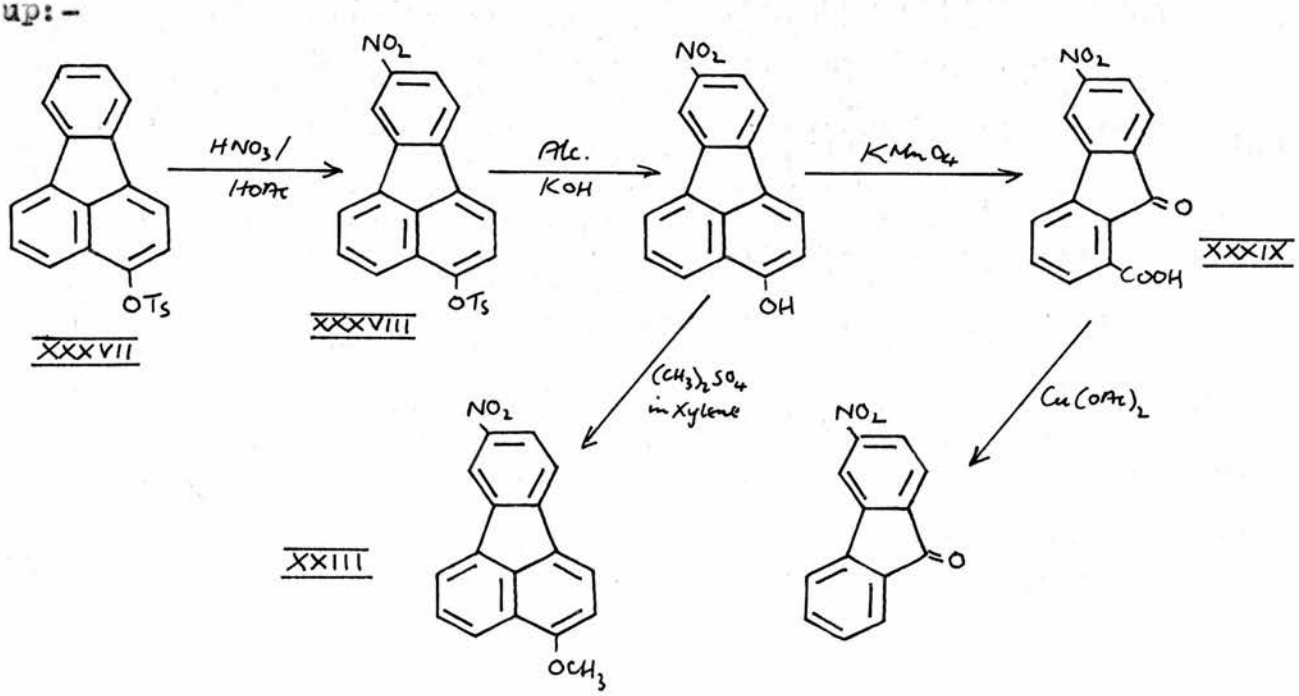
unsatisfactory, and no pure product was isolated.



XL XXXIX

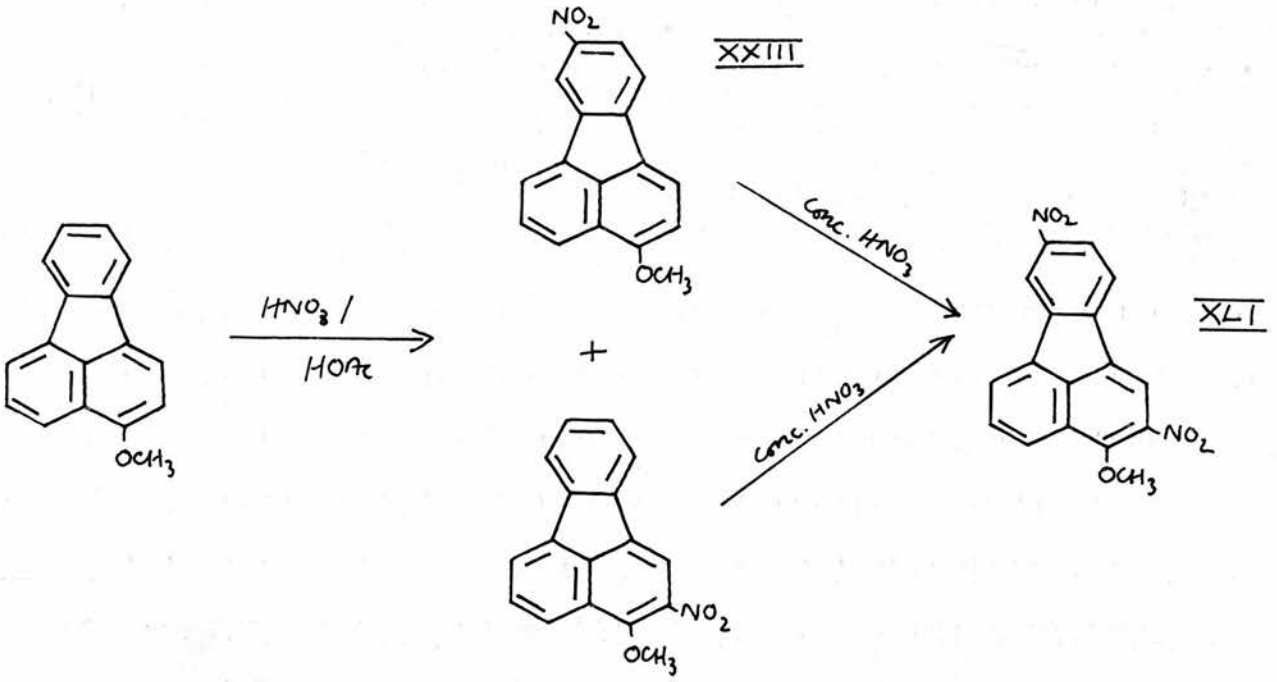
The failure of this synthesis renders the former one all the more valuable since it provides a new route to the hitherto rather inaccessible 1,6-disubstituted fluorenones (Introd.p.8). Both the nitro- and carboxyl-functions are capable, at least in theory, of many interconversion reactions.

The main outcome of the isolation of XXXIX, however, is that it indicates that the nitro-group in the nitro-3-tosyloxy-fluoranthene m.p. 189-190° is in the 8-position, i.e. it is XXXVIII, as predicted. Consequently, the nitromethoxy-isomer m.p. 208-9° must be 3-methoxy-8-nitrofluoranthene XXIII. The flow diagram for its synthesis and orientation can now be drawn up:-



XXXVII XXXVIII XXXIX XXIII

The dinitromethoxy-compound must therefore be 2,8-dinitro-3-methoxyfluoranthene XLI, so that the course of nitration of 3-methoxyfluoranthene postulated by Campbell and Craig has been shown to be correct:



Although the nitration of 3-tosyloxyfluoranthene was shown to give mainly the 8-nitro-isomer XXXVIII, when the mother liquor from its crystallisation was evaporated, an oil was left from which, by chromatography and crystallisation, another isomer was obtained m.p. 226-30°. Analysis indicated that it was not quite pure, and insufficient material was available for a degradation, but it is almost certainly 2-nitro-3-tosyloxy-fluoranthene.

Nitration of 3-acetoxyfluoranthene was also carried out, but considerable hydrolysis to nitrophenols occurred, and only

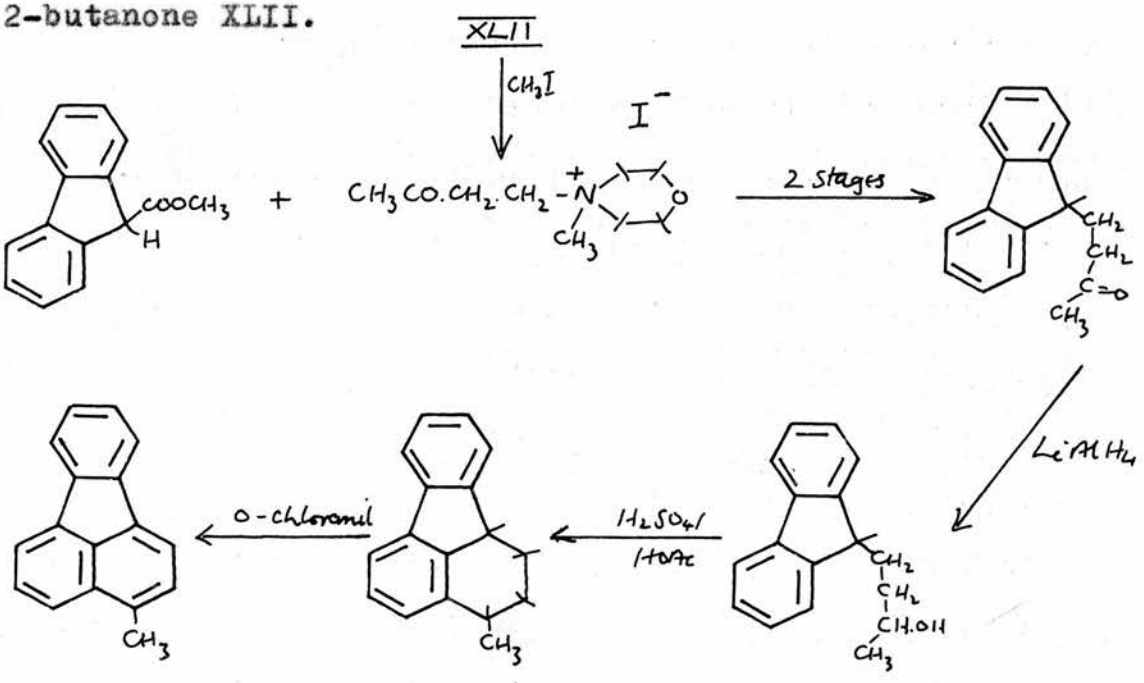
about 10% of an acetoxynitro-compound m.p. 208-210° could be isolated. This was converted in the same manner as XXXVIII to 3-methoxy-8-nitrofluoranthene XXIII, showing that it is 3-acetoxy-8-nitrofluoranthene. Once again, the corresponding reaction in the biphenyl series is closely analogous: 4-acetoxybiphenyl nitrates in the 4'-position, but the main reaction is hydrolysis.[95] An attempted Fries rearrangement of 3-acetoxyfluoranthene also resulted in hydrolysis rather than migration of the acetyl-group, although a trace of material was obtained whose I.R. spectrum showed a carbonyl stretching band in the region of o-chelated ketones, suggesting that an o-Fries rearrangement had occurred to some extent.

Nitration of 3-hydroxyfluoranthene gave inconclusive results, owing to extensive decomposition.

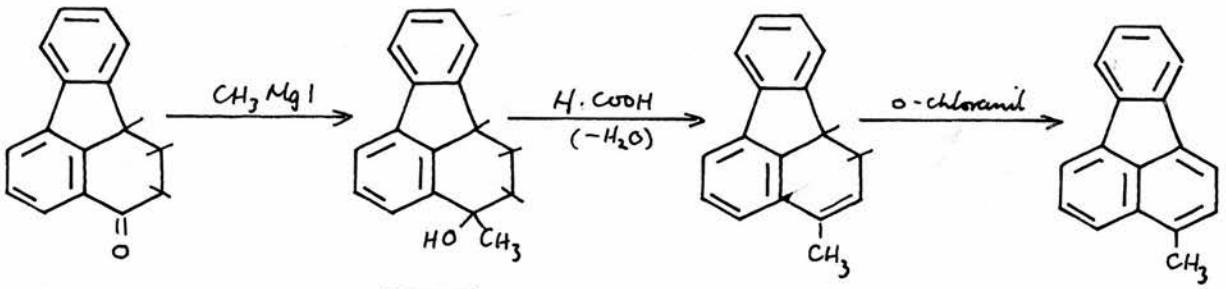
Part 2: The nitration of 3-methylfluoranthene

The course of nitration of 3-tosyloxyfluoranthene suggested that another weak o,p-director, the alkyl group, would also direct further substitution into the 8-position. Again, comparison may be made with the corresponding biphenyl compound: Nitration of 4-methylbiphenyl gives a mixture of 2-, 3'-, and 4'-nitro-4-methylbiphenyls, with the latter predominating (43%).[96]

3-Methylfluoranthene was synthesised by two routes:
(1) The synthesis of Stubbs and Tucker[42] was carried out with only minor modifications, with the Mannich base 4-morpholine-2-butanone XLII.



(2) 1,2,3,10b-Tetrahydro-3-oxo-fluoranthene was treated with methylmagnesium iodide to give the alcohol XLIII, which was dehydrated and dehydrogenated to 3-methylfluoranthene.[97]



XLIII

The nitration, carried out in acetic acid at room temperature with nitric acid (D. 1.42), gave a quantitative yield of crude material. This was chromatographed on alumina with benzene as eluant, and a single band obtained which afforded a yellow solid. Recrystallisation from a benzene-petrol mixture gave yellow needles m.p. 178-180° in about 50% yield. The mother-liquor was rechromatographed, this time with benzene-petrol (1:1) as eluant, providing after several recrystallisations two more isomers. One crystallised as square plates m.p. 180-3°, and the other as needles m.p. 165-75° (obviously impure). Neither was obtained in sufficient yield for orientation purposes, but both analysed for mononitromethylfluoranthenes.

On further nitration in concentrated nitric acid, the isomers A m.p. 178-80° and B, m.p. 180-3° each gave the same dinitro-derivative m.p. 280°. Dinitration of 3-methylfluoranthene itself under the same conditions proved rather difficult, but eventually some material was isolated m.p. 280°, which was shown by I.R. and mixed melting-point to be identical with that obtained from the mononitro-compounds. Nitration of the third

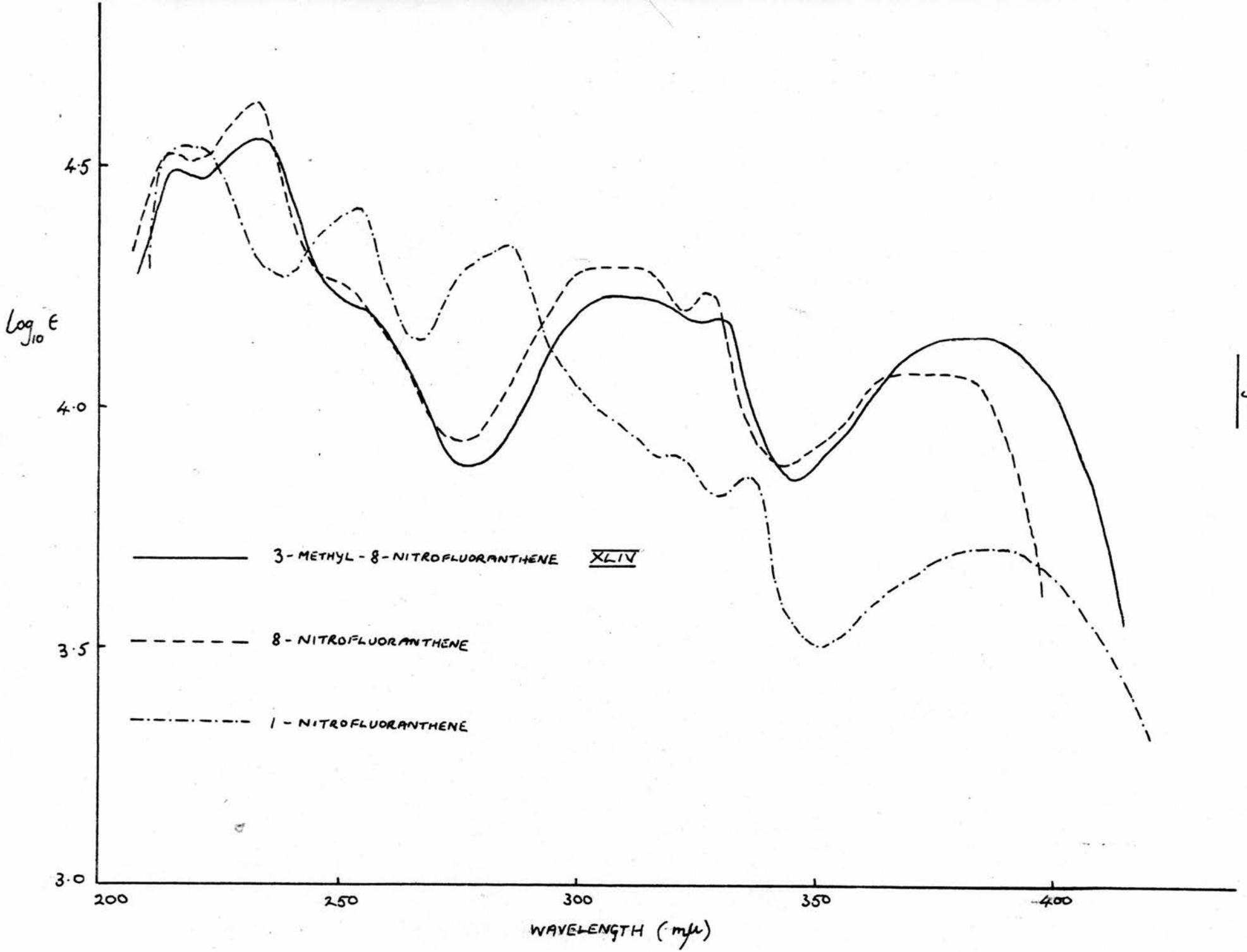

4·5
4·0
3·5
3·0
$\log_{10} \epsilon$
200
250
300
350
400
WAVELENGTH (mμ)
3-METHYL-8-NITROFLUORANTHENE XLIV
8-NITROFLUORANTHENE
1-NITROFLUORANTHENE

FIG. 1

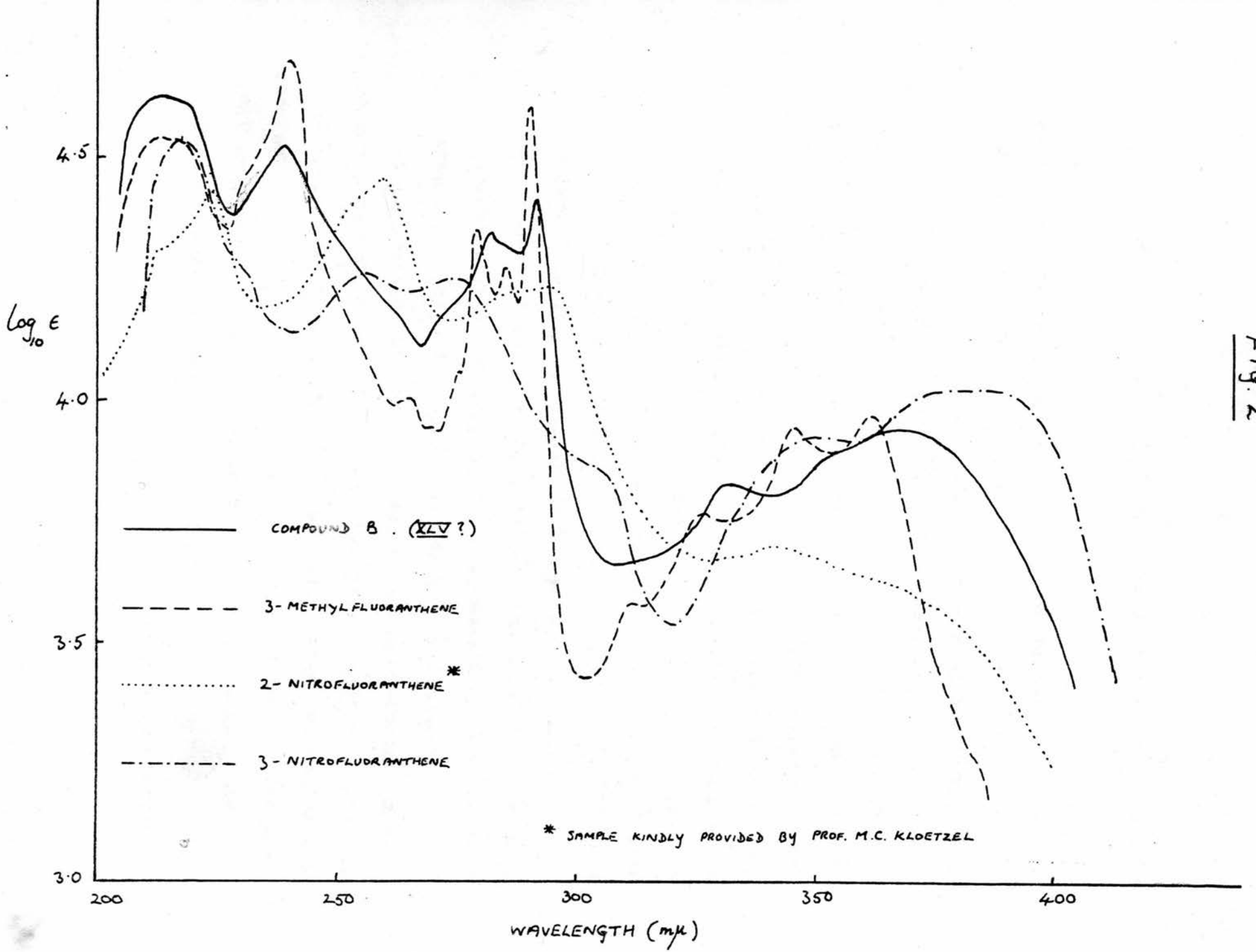

4·5
4·0
3·5
3·0
Log10 ε
200
250
300
350
400
WAVELENGTH (mμ)
COMPOUND B . (XLV ?)
3- METHYL FLUORANTHENE
2- NITROFLUORANTHENE *
3- NITROFLUORANTHENE
* SAMPLE KINDLY PROVIDED BY PROF. M.C. KLOETZEL

FIG. 2

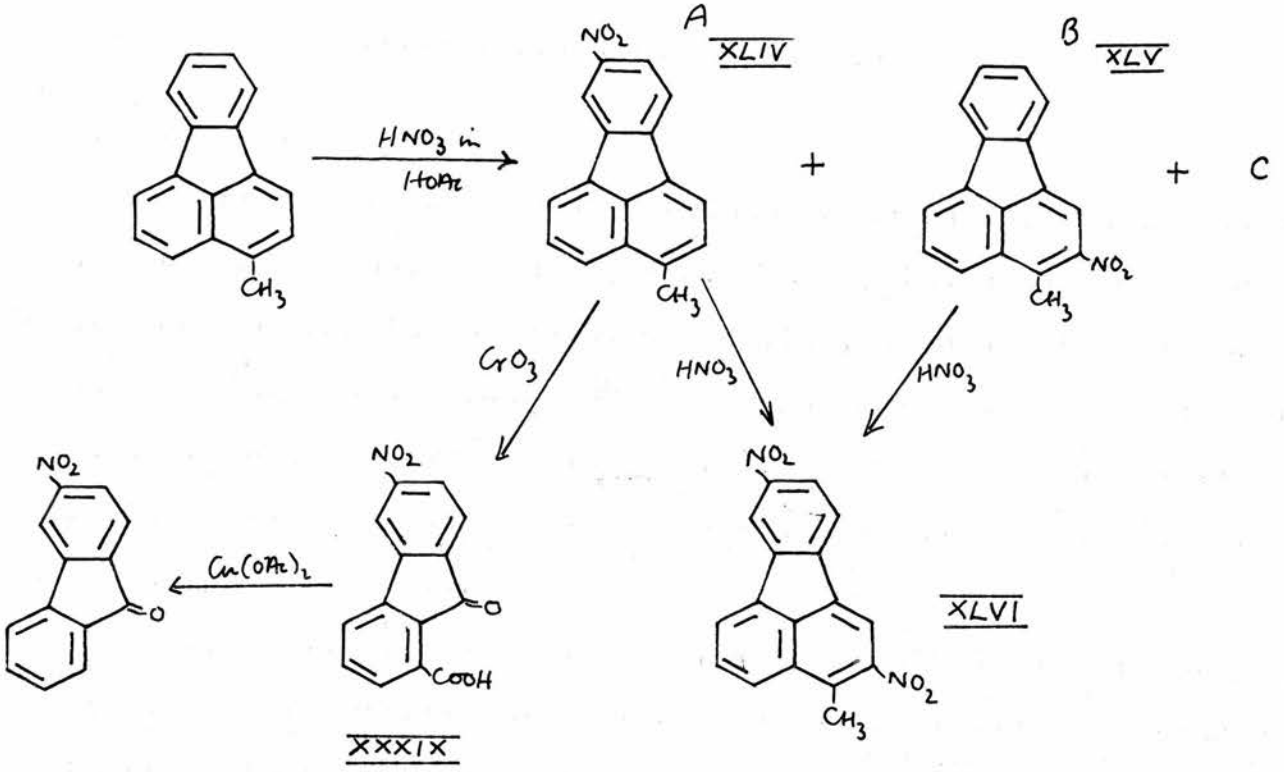
isomer C was inconclusive owing to its impurity.

Orientation of A

A comparison of the ultra-violet spectrum of A with those of some nitrofluoranthenes (Figs.1 and 2) indicated that the nitro-group was in the "benzenoid" ring, probably in the 8-, but possibly 9-position: Its spectrum is almost identical to that of 8-nitrofluoranthene (Fig.1). That the main product of nitration was indeed 3-methyl-8-nitro-fluoranthene XLIV was shown by degradation.

Oxidation with permanganate, either in aqueous suspension or in aqueous acetone solution, gave no nitrofluoranthene-3-carboxylic acid (c.f. attempted oxidation of 3-n-propylfluoranthene[98]). However, chromic acid or sodium dichromate in acetic acid ruptured the ring containing the methyl group, giving 6-nitrofluorenone-1-carboxylic acid XXXIX, identical with that obtained from the oxidation of 3-hydroxy-8-nitrofluoranthene. Decarboxylation yielded 3-nitrofluorenone.

The general form of the spectrum of B (Fig.2) suggests that the nitro-group is in the "naphthalene" system, most probably position 2, although the similarity to the spectrum of 2-nitrofluoranthene is not as close as it might be. Thus 3-methylfluoranthene nitrates to give 3-methyl-8-nitrofluoranthene XLIV and a small amount of 3-methyl-2-(?)nitrofluoranthene XLV, each of which gives 3-methyl-2(?),8-dinitrofluoranthene XLVI on further nitration.

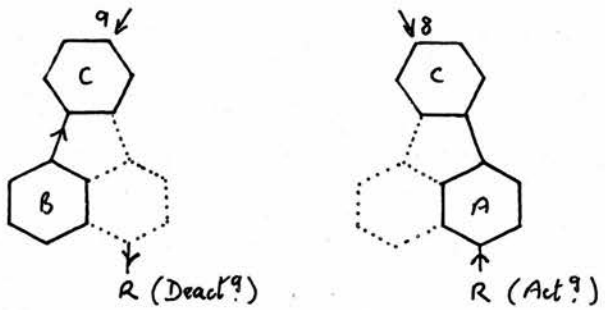


The value of I.R. and U.V. spectra in characterising nitrofluoranthenes is worth considering at this point: Streitwieser and Fahey[67] have used certain peaks in the "fingerprint" region of the infra-red to identify all the possible isomers. Their results were confirmed in the case of 1-, 3- and 8-nitrofluoranthene, but the ultra-violet spectra were found to display much more striking differences. In particular, the spectra of the "benzenoid"-nitrofluoranthenes (Fig.1) are very different from those of the "naphthenoid"-type (Fig.2). The only effect of a methyl group is a slight shift of the whole spectrum to the visible. The latter observation has been made previously by Stubbs and Tucker,[58] who also noted that a methoxy-group in the benzenoid ring has much less effect on the fluoranthene spectrum than the same group in

a naphthenoid ring. They concluded that "p-Absorption in fluoranthene is located in the naphthalene system." However, it is apparent from Figs.1 and 2 that in the case of the nitro-group the position is reversed: It is the benzenoid nitro-group which has the greatest effect on the spectrum of fluoranthene. The spectrum of 3-methyl-2(?)-nitrofluoranthene (compound B) is remarkably similar to that of 3-methyl-fluoranthene itself.

Summary

It was mentioned at the beginning of this section that fluoranthene may be regarded as two biphenyl units. When a substituent is present in the 3-position, however, the molecule is no longer symmetrical, and further substitution will occur at position 8- or 9-, depending on the relative directing influences of rings A and B on ring C. This in turn will depend on whether the substituent is activating or deactivating.



In the absence of a satisfactory quantum-mechanical explanation, the substitution pattern of fluoranthene is best predicted on the basis of this theory. However unsoundly based theoretically, it is amply justified by the experimental facts, which may now be summarised as follows:

Substitution type	Group at position 3	Second substituent	Position	Ref.
(1)	$-SO_3H$	$-SO_3H$	9	68
	$-COCH_3$	$-COCH_3$	9	69
	$-NO_2$	-Br	9	
	-CN	"	9	68
	-COOH	"	9	
	$-COCH_3$	"	9	
(2)	$-NHCOCH_3$	$-NO_2$	2	29
	"	-Br	2	70
(3)	$-OCH_3$	$-NO_2$	2, 8	This thesis
	-OTs	"	mainly 8	"
	$-O.COCH_3$	"	" 8	"
	$-CH_3$	"	" 8	"
	$-OCH_3$	-Br	2(?), 8	"

In type (1), the substituents deactivate ring A, so that substitution in ring C is directed by ring B to position 9. In (2), the acetamido-group so strongly activates ring A that substitution occurs in the same ring, at position 2 (ortho). In (3), the substituents are less strongly activating, so that ring A directs substitution in ring C to position 8. The methoxy-group displays both type (2) and (3) characteristics.

The case of dibromination has been omitted: It appears

to be the exception which proves the rule, since the first bromine should deactivate ring A, allowing ring B to direct the second bromine into the 9-position. In fact, it is the 3,8-dibromo-isomer which is formed,[31] indicating that the +T effect of the halogen is operating, overriding the -I effect. There is no justification, however, in invoking tautomeric effects to explain the substitution of fluoranthene in terms of electronic displacements from the 3- to the 8-position, since there is little evidence for the transmission of polar activation by a substituent beyond the aromatic ring in which it resides. For instance, in naphthalene, an α-substituent in one ring does not alter the normal tendency for the α-position in the other ring to be attacked, and all three nitrobiphenyls undergo further nitration in the other ring, at positions 2' and 4'. In the hydrocarbons biphenyl, fluorene and fluoranthene the phenyl group, whether substituted or not, is the dominant directing influence; and in fluoranthene a substituent in the 3-position alters the balance between the alternative directing rings.

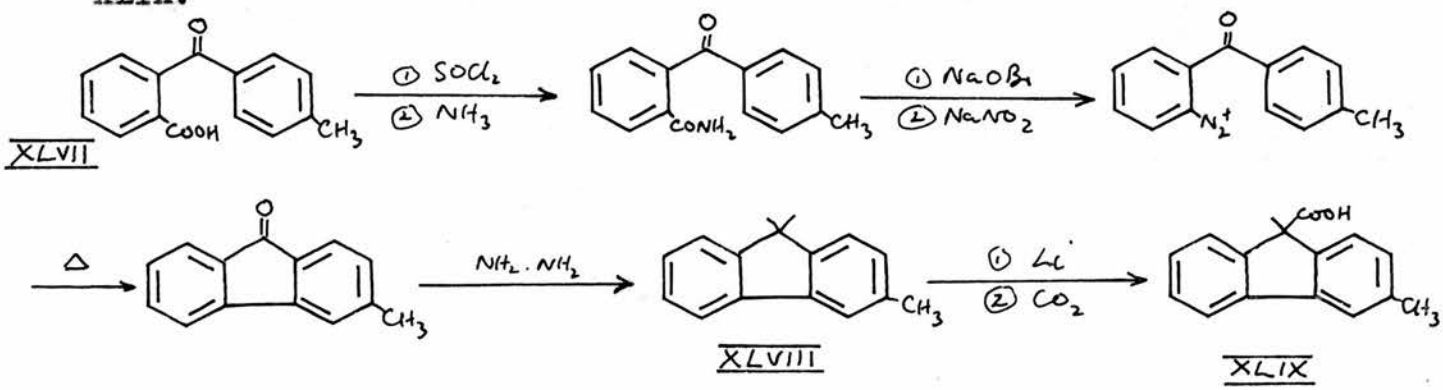
SECTION II

Part 1: Attempted synthesis of 8-methyl-3-methoxyfluoranthene; Formation of 2,4-disubstituted fluoranthenes.

The failure of a synthetic route to 8-nitro-3-methoxy-fluoranthene from fluorene derivatives prompted an investigation into the generality (or otherwise) of this type of synthesis from 3-substituted fluorenes.

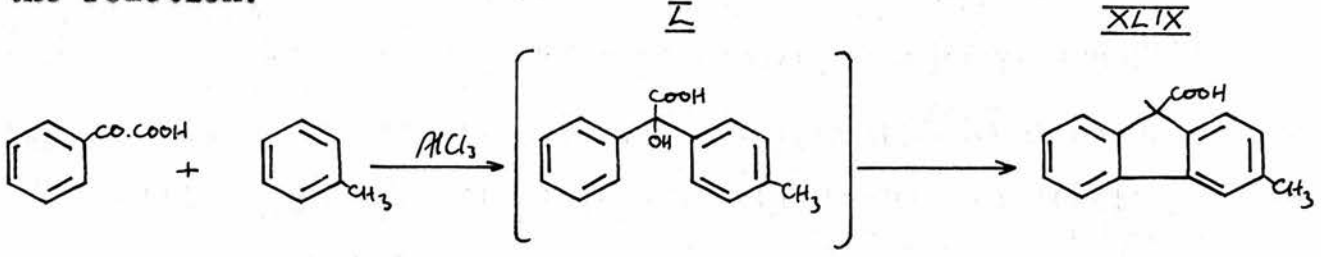
3-Methylfluorene should not be expected to differ markedly from fluorene in its reactions. It was synthesised as follows.

2-(4'-Toluyl)benzoic acid XLVII, from the Friedel-Crafts reaction of phthalic acid on toluene, was converted to its amide and degraded by the Hoffman reaction to 2-(4'-toluyl) aniline. It is interesting to note in this connection that freshly-made hypobromite solution was found to give low yields of the amine, but when Kippenberg's injunction[99] to use "old" solutions (i.e. sodium hyprobromite left at 0° for 10 days) was complied with, 64% of the pure amine was obtained. Diazotisation and pyrolysis gave 3-methylfluorenone with its curious daffodil-like odour.[24a] Wolff-Kishner reduction (see p.58) yielded 3-methylfluorene XLVIII which was metalated directly with lithium in tetrahydro-furan, and carbonated to give 3-methylfluorene-9-carboxylic acid XLIX.



XLVII XLVIII XLIX

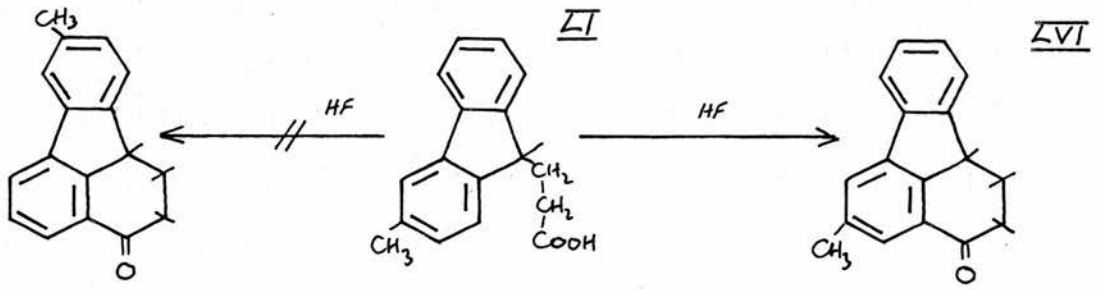
However, a much shorter route to XLIX was described by Vorlander and Pritzche in 1913:[14] Benzoylformic acid, obtained by the oxidation of mandelic acid,[100] reacted with toluene in the presence of anhydrous aluminium chloride to give XLIX directly. The intermediate is presumably phenyltolylglycollic acid L which undergoes cyclodehydration under the conditions of the reaction.



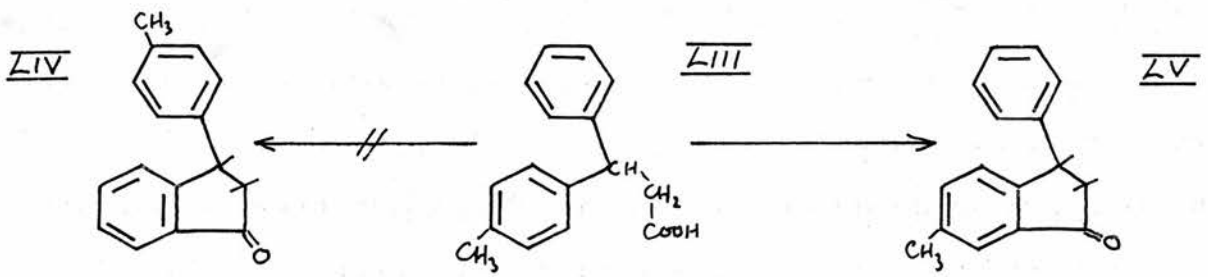
Although the yields obtained were fairly low, this method was nevertheless preferable to the 7-stage route.

The methyl ester of XLIX was successfully condensed with acrylonitrile c.f. Introd.p.12, then hydrolysed and decarboxylated to give 3-methyl-9-carboxyethylfluorene LI, which cyclised smoothly in anhydrous hydrogen fluoride to a methyl-1,2,3,10b-tetrahydro-3-oxofluoranthene. Wolff-Kishner reduction followed by dehydrogenation with o-chloranil, however, yielded not 8-methylfluoranthene as hoped, but the 2-methyl isomer LII. (P.46) It was identified by its melting-point (78-9°), and that of the picrate (164-5°), which correspond to the values given by Tucker.[43] The melting-point was depressed when the compound was mixed with an authentic specimen of 8-methylfluoranthene (m.p. 91-2°).

Hence cyclisation had taken place in the substituted ring. This was not unexpected, since, although the cyclisation position is meta- to the methyl group, its electron density is still higher than that of the alternative position in the unsubstituted ring.

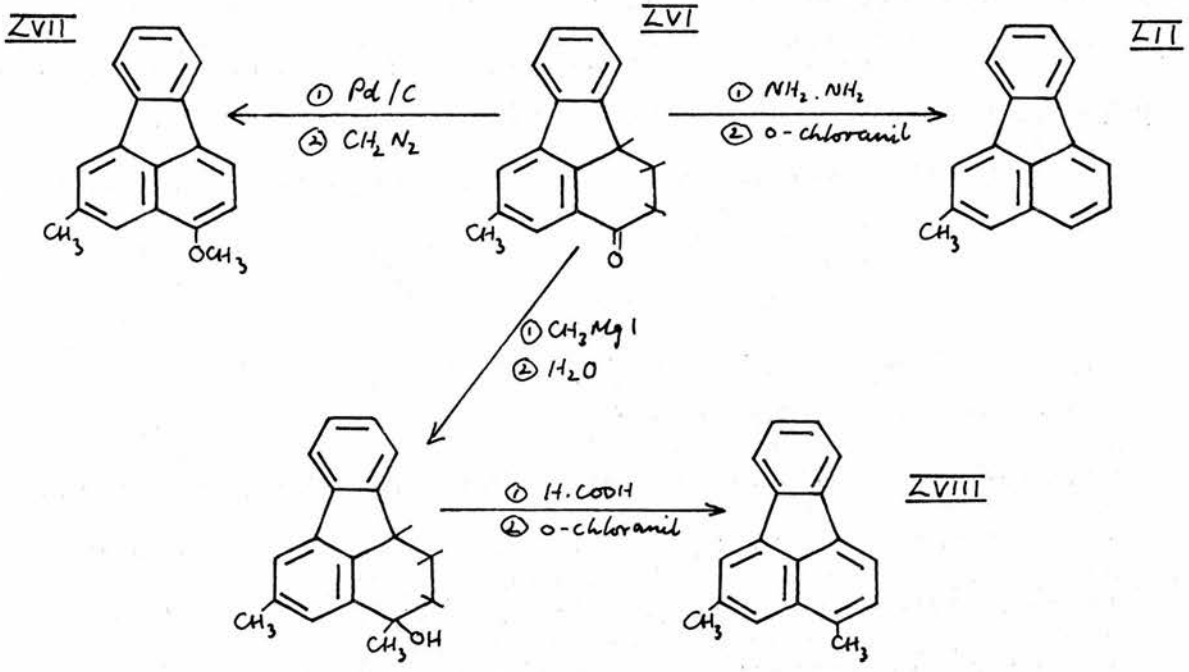


An interesting comparison is provided by the cyclisation of 2-phenyl-2-p-tolylpropionic acid LIII. von Braun's original contention[101] that cyclisation took place in the unsubstituted ring to give 3-p-tolylindanone LIV, was disproved by Pfeiffer and Roos[102] who showed that the product was in fact 6-methyl-3-phenylindanone LV: cyclisation had occurred meta- to the methyl group.



As a synthesis of 3,8-disubstituted fluoranthenes, this route had obviously failed, but instead a synthesis of 2,4-disubstituted fluoranthenes has been established: The ketone LVI was aromatised with palladium charcoal and methylated to

give 4-methoxy-2-methylfluoranthene LVII; and by a Grignard reaction with methylmagnesium iodide, followed by dehydration and dehydrogenation, yielded 2,4-dimethylfluoranthene LVIII.



Prior to this work, only two other 2,4-disubstituted fluoranthenes had been reported: 4-iodo-2-methyl-, prepared by iodination of 1,2,3,10b-tetrahydrofluoranthene with subsequent dehydrogenation, and 2-methyl-4-(o-nitrophenyl)-, obtained by means of a crossed Ullmann reaction of the iodo-compound with o-nitrobromobenzene.(103)

2,4-Dimethylfluoranthene is the first dimethylfluoranthene to be obtained in which the methyl groups are in different rings, the isomers so far reported being 1,3-, 2,3-, 7,10- and 8,9-.

Occasionally, it has been found that the conditions used in the cyclisation have controlled its direction, or at least

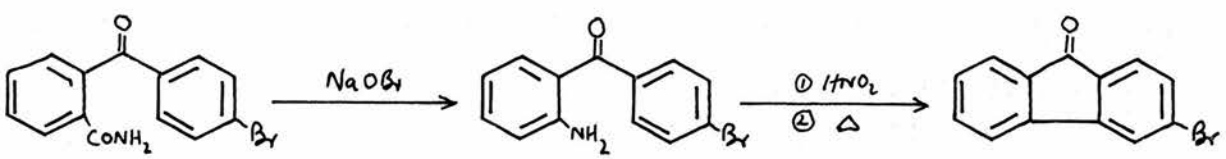
altered the relative proportions of isomers.[104] Accordingly, the cyclisation of LI was repeated with polyphosphoric acid and stannic chloride, but neither reagent gave a discernible amount of another isomer.

Part 2: Synthesis of 8-bromo-3-methoxyfluoranthene.

Clearly, in order that cyclisation should take place in the unsubstituted ring, an electron-withdrawing group must be present in the other. Bromine seemed to be a suitable choice, and if 8-bromo-3-methoxyfluoranthene could be obtained by an unambiguous route, then the corresponding 8-nitro-compound XXIII (p.32) could be converted into it, thus providing supplementary proof of the latter's orientation.

3-Bromofluorenone was synthesised by two routes, both of which provided unexpected though not uninteresting diversions.

Method (a): The synthesis described by Miller and Bachman,[11] already severely attacked on several counts by Stafford,[105] was carried out, and the latter's observations confirmed. One or two additional inaccuracies and misstatements were revealed. The method consists essentially in the formation of 2-(4'-bromobenzoyl) aniline LIX by the Hoffman degradation of 2-(4'-bromobenzoyl) benzamide LX (obtained from the corresponding acid via the chloride). Thermal decomposition of the diazonium salt from LIX gives the required 3-bromofluorenone LXI.



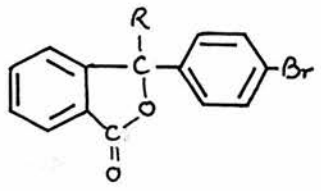
LX LIX LXI

The authors quote the melting-point of the chloride (prepared with phosphorus pentachloride) as 162-3°. Suzuki[106] obtained an oil, unpurified at this stage, with thionyl chloride. Bergmann and Barshai[107] using phosphorus pentachloride, also omitted purification at this point.

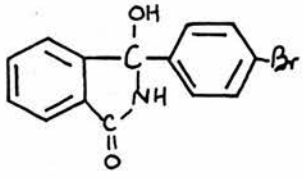
Repetition of Miller and Bachman's procedure indeed gave material melting at 165°, but a mixed-melting point with the original acid, m.p. 171° and a comparison of I.R. spectra, showed this to be impure starting material. With thionyl chloride, either without a solvent or in benzene solution, a clear oil was obtained which refused to crystallize. Treatment with methanol produced the methyl ester m.p. 112-113°, and when the crude chloride was reacted with ammonia in benzene solution, the amide LX was formed in good yield. It was insoluble in hot water, and melted at 212-214°, as reported by Suzuki. A sample recrystallised several times from xylene melted at 218°, but the figure of 224° given by Stafford was not realised. Miller and Bachman, however, reported 184.5-185° as the melting-point of LX. In fact, a compound m.p. 184-5° was obtained when the chloride was treated with conc. ammonia solution in the absence of a solvent, but it was soluble in hot water, giving the acid on acidification. It evolved a gas at its melting-point and was obviously the ammonium salt, confirmation being provided by its I.R. spectrum (Stafford suggested that it might be a mixture of amide and acid).

A complicating factor in this series of reactions is that the acid, chloride, ester and amide may exist in respective "pseudo"-forms LXIIa, b, c and LXIII.

LXII a : R = OH
b : R = OCH_3
c : R = Cl



LXIII



A study of the I.R. spectra showed that in this case, the acid, ester and ammonium salt were in the "normal"-form, whereas the chloride and amide showed only one carbonyl peak and were consequently in the "pseudo"-form. This is in accord with the findings of Graf and co-workers[108] who have studied several compounds of this type. Since the two forms in each case have different melting-points, confusion may arise when there is the possibility of different reaction conditions favouring the formation of different isomers. The reluctance of the chloride to crystallise, indeed, may have been due to the presence of some "normal"-form as an impurity. Miller and Bachman's melting-point of 162-3° seems very high for the chloride of an acid m.p. 171°, and their compound was undoubtedly unchanged acid; It is therefore not surprising that they obtained the ammonium salt at the next stage. However, they must have obtained some amide, since they were able to accomplish the Hoffman reaction on their product.

When Miller and Bachman's instructions for the latter

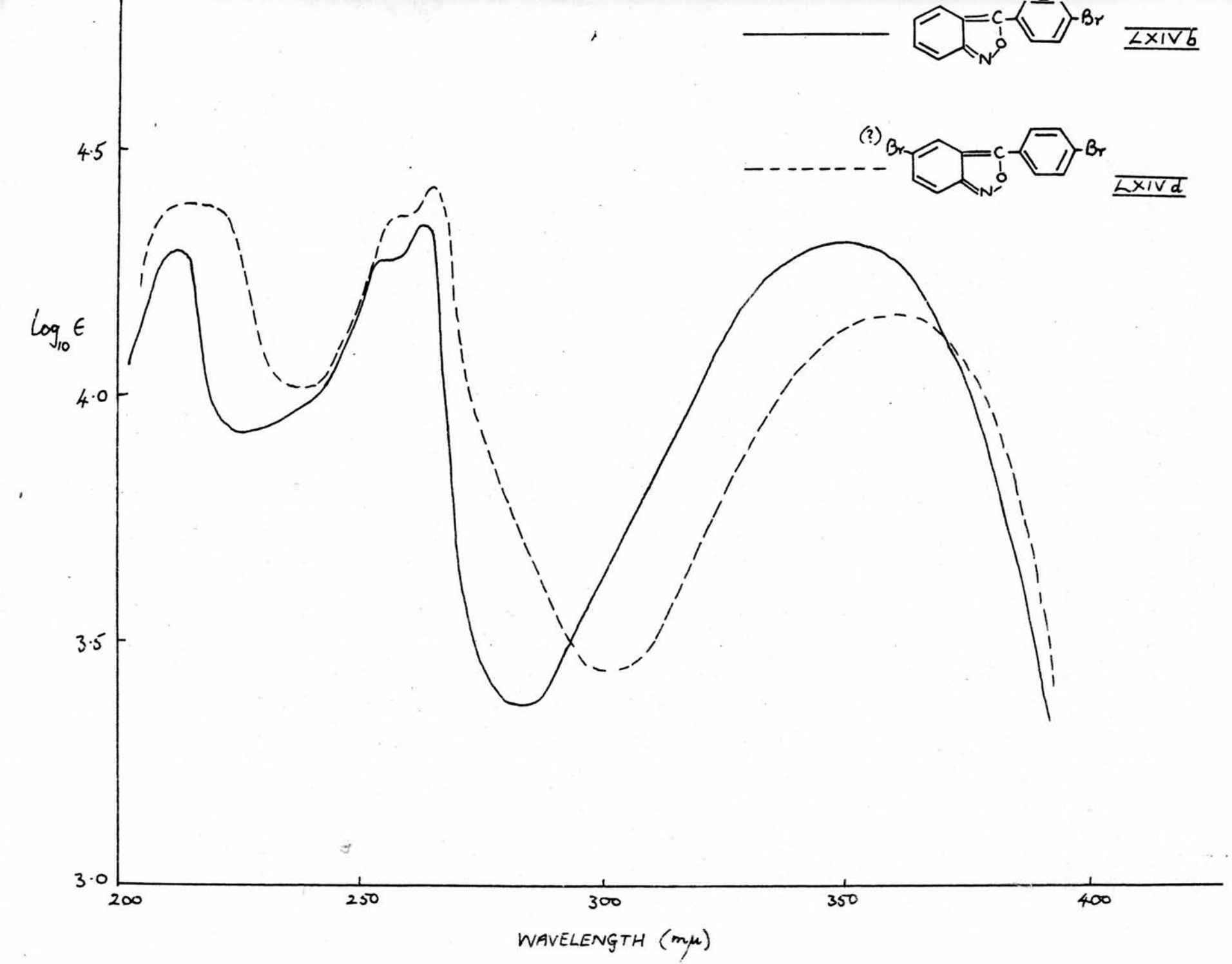

LXIVb
(?)
LXIVd
4·5
4·0
3·5
3·0
$\log_{10} \epsilon$
200
250
300
350
400
WAVELENGTH (mμ)

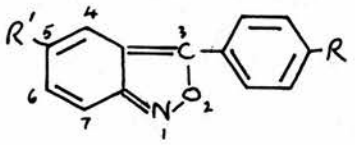
FIG. 3

reaction were closely followed, no amine was obtained, but it was subsequently discovered that the quantity of bromine quoted was twice the theoretical. When the correct amount (just over one mole per mole of amide) was employed, the amine LIX was formed in 80% yield.

The compound obtained in place of LIX when excess bromine was used was crystallised from alcohol as long, pale yellow needles m.p. 155°; and its analysis corresponded to the formula $C_{13}H_8NBrO$. Now Graf and co-workers found that in the Hoffman reaction of 2-(4'-chlorobenzoyl) benzamide, although the correct weight of bromine was employed, a substance m.p. 156-8° was formed instead of the required amine. They suggested that this was 3-(4'-chlorophenyl) anthranil LXIVa, giving its U.V. spectrum in evidence.

LXIV

a : R = Cl, R' = H
b : R = Br, R' = H
c : R = Cl, R' = Cl
d : R = Br, R' = Br



The U.V. spectrum of the unknown bromo-compound (Fig.3) corresponded almost exactly to that of the chloro-anthranil; and the I.R. spectra of both compounds showed no carbonyl absorption, only a C:C or C:N stretching band at ν_{max} = 1645cm.$^{-1}$ The compound m.p. 155° was therefore probably 3-(4'-bromophenyl) anthranil LXIVb.

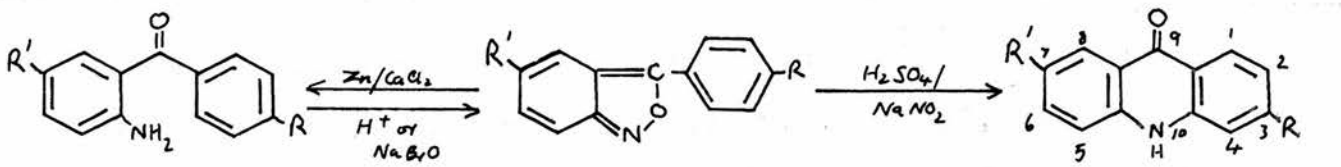
When the reaction with excess bromine was repeated on a

larger scale, a small amount of a higher-melting isomer (m.p. 220-222°) was isolated, which analysed for a dibromophenyl-anthranil. Its U.V. spectrum was of the same general form as that of the monobromo-compound (Fig.3), and since anthranils normally substitute in the 5-position, it was probably 5-bromo-3-(4'-bromophenyl) anthranil LXIVd. That the two new compounds were indeed anthranils was confirmed by the following reactions:-

Anthranils are known to give adducts with mercuric chloride:[109] LXIVb gave an adduct m.p. 222-3°, and LXIVd an adduct which melted with decomposition at 224-5°. (A mixed melting point showed a distinct depression). The complexes were decomposed by boiling their acetone solutions with charcoal, the anthranils being regenerated: Previously, potassium cyanide had been used for this purpose.[109]

The corresponding chloroanthranils LXIVa and c have been studied by Tanasescu:[110] LXIVa was isomerised by the "Bamberger reaction" (treatment with conc. sulphuric acid containing a trace of sodium nitrite)[111] to 3-chloroacridone LXVa, m.p. >350°. LXIVc similarly gave 2,6-dichloroacridone LXVc. When this procedure was applied to the new bromo-compounds, 3-bromoacridone LXVb and 2,6(?)-dibromoacridone LXVd were obtained. Both were yellow crystalline solids, subliming to yellow needles and melting above 350°. LXVb analysed correctly for a monobromoacridone, and had an I.R. spectrum similar to that of acridone itself.

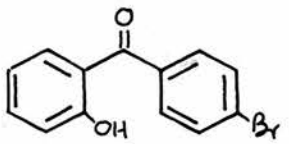
Tanasescu also found that LXIVa could be reduced with zinc and calcium chloride to 2-(4-chlorobenzoyl) aniline: Reduction of LXIVb similarly gave 2-(4-bromobenzoyl) aniline LIX, thus providing a means of recouping losses sustained due to anthranil formation during the Hoffman degradation of the amide LX.



LXIV a, b, c, d LXV a, b, c, d.

The anthranil LXIVb was encountered again during diazotisation of the amine LIX, since the strong acid conditions recommended by Miller and Bachman were sufficient to convert some of the amine into the anthranil. The acid strength was varied, and hydrochloric acid tried instead of the sulphuric acid used by the above authors, but in all cases some LXIVb was formed as a precipitate from the diazonium salt solution. In fact, when LIX was dissolved in concentrated sulphuric acid, then poured into water, almost quantitative conversion occurred. This reaction is remarkable in two ways:- Firstly, an oxidation has taken place, yet apparently no oxidizing agent is present: Presumably air, or an impurity in the sulphuric acid, is the cause. Secondly, o-benzoylaniline does not undergo the reaction: It is probable that the halogenophenylanthranils are more stable than 3-phenylanthranil itself.

Optimum acid-strength for the diazotisation (in order to keep anthranil formation to a minimum) was found to be about 2 normal, and the reaction was carried out in suspension. About 10% anthranil was formed and filtered off. The filtrate afforded 50% 3-bromofluorenone LXI on warming, along with another by-product in about 10% yield. The latter was isolated from the ethanol filtrate from the crystallisation of LXI, and was soluble in sodium hydroxide. It analysed correctly for 2-hydroxy-4'-bromobenzophenone LXVI.

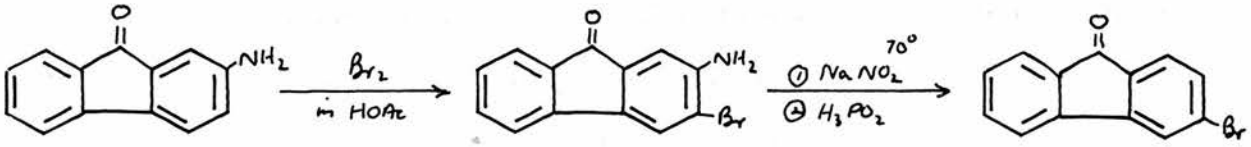


LXVI

The yield of 3-bromofluorenone (50%) compares with those achieved by both Suzuki and Stafford, but it is well below the 92% claimed by Miller and Bachman.

Method (b): As with 3-nitrofluorenone, the direct synthesis[24] (Introd.p.8) was found to be the more satisfactory method, once one serious problem had been overcome.

2-Aminofluorenone was brominated in acetic acid, then deaminated by diazotisation and treatment with hypophosphorous acid. The yields in all stages were high, giving an overall yield from fluorene of 27%.



LXI

In the initial experiments, the last stage afforded only 45% of 3-bromofluorenone LXI, but this was raised to 73% by carrying out the diazotisation at 70-80° in 6N hydrochloric acid. However, it was subsequently discovered that LXI obtained in this manner contained large amounts of 3-chlorofluorenone. (The latter was synthesised for comparison purposes by the method of Bell and Gibson,[25] which was analagous to the foregoing synthesis except at one point: The chlorination of 2-aminofluorenone gave low yields of the chloro-amino-compound, so that it was necessary in this case to chlorinate 2-acetamidofluorenone and hydrolyse the product, as reported by Bell and Gibson).

The difficulty was completely obviated by changing the acid used in the diazotisation to sulphuric acid of the same normality, good yields of fairly pure 3-bromofluorenone being obtained.

Two points of interest are raised in this connection: The extraordinary thermal stability of the diazonium salts of 3-chloro and 3-bromo-2-aminofluorenone, and the replacement of a bromine atom by chlorine during diazotisation in hydrochloric acid. The latter phenomenon is not new - Kornblum[112] has

warned against the use of hydrochloric acid for the deamination of o-bromoamines, since exchange can be quite extensive, particularly at high temperatures.

Before proceeding with the next stage - the reduction of 3-bromofluorenone to 3-bromofluorene - the various methods available were examined, and the literature on the subject reviewed.

Reduction of Fluorenones.

Until recently, the preferred method was the 2-stage reduction via the fluorenol. Several reagents have been used for the first stage, including zinc and ammonia,[113] zinc and calcium chloride,[24a] lithium aluminium hydride and aluminium chloride,[114] aluminium sec. butoxide,[115] and sodium borohydride.[82] The resulting fluorenols can then be further reduced with phosphorus and iodine,[116] or hydriodic acid.[117] Morrison[118] was able to reduce some fluorenone carboxylic acids straight to the fluorene acids with the latter reagents.

It is also possible to effect the reduction in one step: Miller and Bachman[116] claim to have obtained quantitative yields using the Clemmensen method and Bradlow and Vanderwerf support this. Other workers have found the method unsatisfactory, and Suzuki[119] has isolated and identified three other products from the reaction.

The Wolff-Kishner reduction, in particular the Huang-Minlon

modification,[120] has been used by several workers, and seems to be very satisfactory in most cases. However, Suzuki and Weisburger[86] found that with 2-amino-3-bromofluorenone, debromination occurred, giving 2-aminofluorene as the only product; but when alkali was omitted from the reactants, 2-amino-3-bromofluorene was obtained in good yield. Staudinger,[121] and Borsche[122] had previously discovered that fluorenone-hydrazones do not require alkali for their decomposition: Heating in a sealed tube was found to be sufficient.

Some of these methods were applied to the reduction of 3-bromofluorenone:

Reduction to the fluorenol was accomplished with zinc and ammonia in 56% yield, but sodium borohydride in methanol gave much better results. The reaction was clean and rapid, 97% conversion being achieved. 3-Bromofluorenol was then reduced with phosphorus and iodine to give 3-bromofluorene in 60-70% yields, but the reaction was capricious. In one experiment, the product was found to contain iodine, and from its analysis appeared to be 3-bromo-9-iodofluorene. In another, an unknown compound m.p. 115-117° was formed in addition to 3-bromofluorene (mixed m.p. with fluorene m.p. 113° was depressed). Similar results were obtained with hydriodic acid, but in no case was debromination observed, contrary to the findings of Miller and Bachman.

The Clemmensen method described by the latter authors was

repeated, but even after 22 hours refluxing, the only product isolated was 3-bromofluorenol.

The Wolff-Kishner reaction (with alkali) was found to result in debromination, giving a mixture of fluorene and 3-bromofluorene. In contrast, 2-bromofluorenone gave 2-bromofluorene in good yield, although a small amount of 2,2'-dibromobifluorenyl was also formed. The unusual reactivity of a bromine in the 3-position of fluorene has been observed before by Montagne and van Charante[13] who noted that reduction with sodium amalgam and alcohol removed the bromine atom from 3-bromofluorenone.

Then, following the results of Suzuki and Weisburger,[86] the Wolff-Kishner reduction was repeated without alkali, and a high yield of pure 3-bromofluorene was obtained. The reaction was so successful that an investigation was made into its generality: It was found that it does not apply to ketones other than fluorenones, such as benzophenone: Their hydrazones required alkali in refluxing diethyleneglycol for their decomposition. (In passing, it was discovered accidentally that hydrazones were also decomposed by sodium dichromate in acetic acid in the cold, but since the yield was poor this peculiar reaction was not investigated further). 2-Acetylfluorenone was an interesting case, since it contains both types of carbonyl: Without alkali, a hydrazone was formed; but when alkali was included, the product was 2-ethylfluorene.

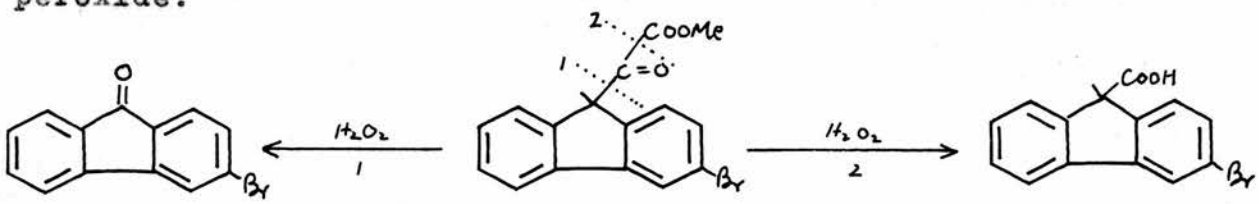
Nearly all other fluorenones examined gave the fluorene in good yield, and in all cases the reaction was cleaner when

alkali was omitted. One exception was 4-carbomethoxyfluorenone, which yielded a hydrazone-hydrazide. Dilute sodium hydroxide hydrolysed the hydrazide moiety to give the hydrazone-acid which required alkali in refluxing diethylene glycol (or sodium dichromate in acotic acid) for its decomposition to fluorene-4-carboxylic acid. As observed on p.25, the reaction is also unsuitable for nitrofluorenones. Otherwise, the Wolff-Kishner (Huang-Minlon) reaction without alkali appears to be a general one for fluorenones, and is recommended as the best available method for their reduction. Reduction to fluorenols is best accomplished with sodium borohydride.

In view of the lability of the bromine atom, 3-bromofluorene obtained as above was converted by the Rosenmund-von Braun reaction[123] into the hitherto unknown 3-cyanofluorene. This would have been employed in the subsequent reactions, had the bromine again proved troublesome; and incidentally provides a new route to fluorene-3-carboxylic acid.

Condensation of 2-bromofluorene with dimethyl oxalate, followed by hydrolysis and oxidative decarboxylation with peroxide, gave 2-bromo-9-carboxyfluorene (c.f. Tucker's synthesis of fluorene-9-carboxylic acid[41]), but the major product in the case of 3-bromofluorene was 3-bromofluorenone, only a small yield of the required acid LXVII being obtained. It is worth pointing out in this connection that Holbro[124]

was unable to prepare 2,7-dibromo-9-carboxyfluorene in this way. Since condensation apparently took place, the critical factor seems to be the relative strength of the carbon-carbon bonds in the keto-ester LXVIII. LXVII itself was stable to peroxide.

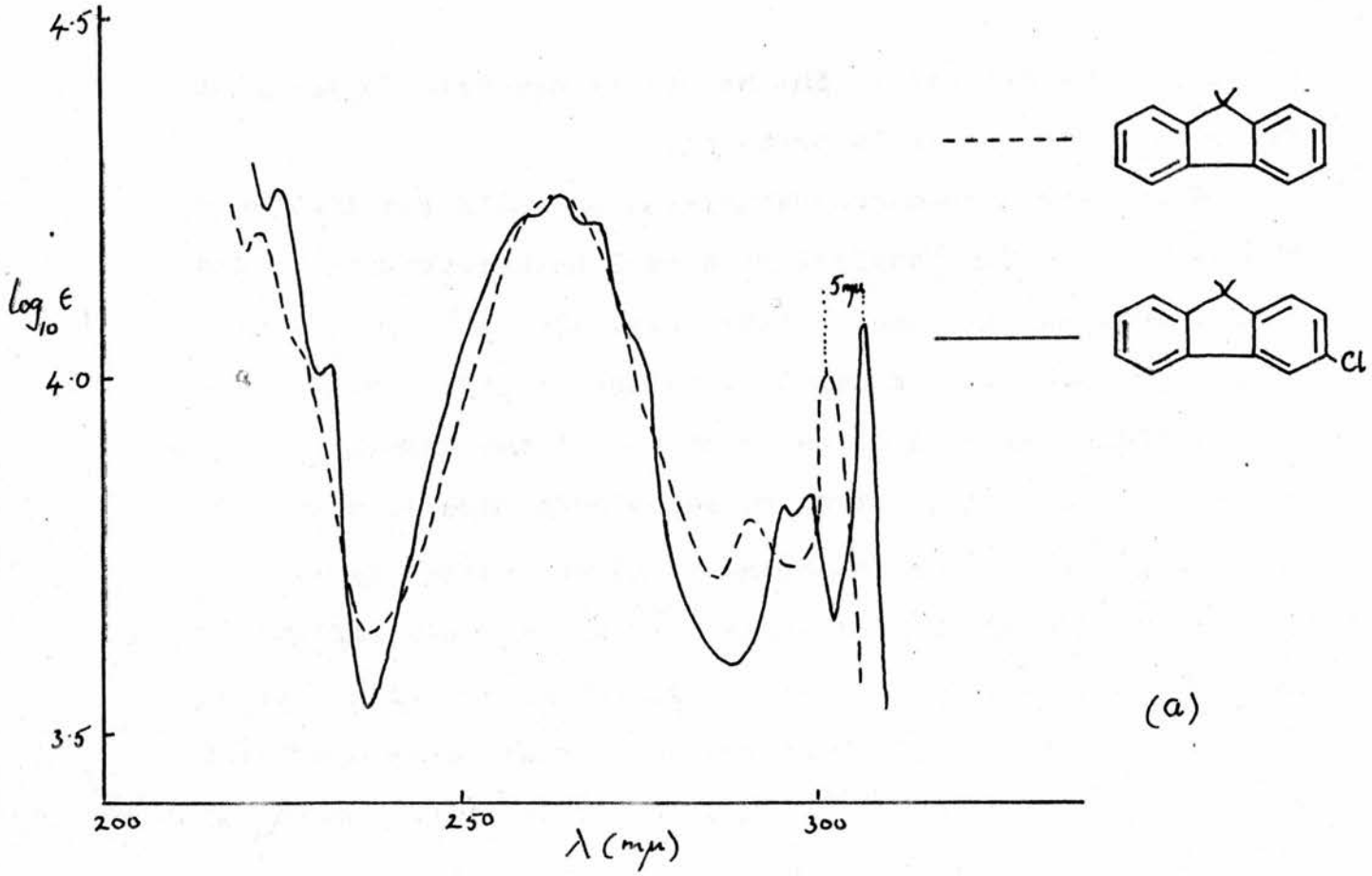


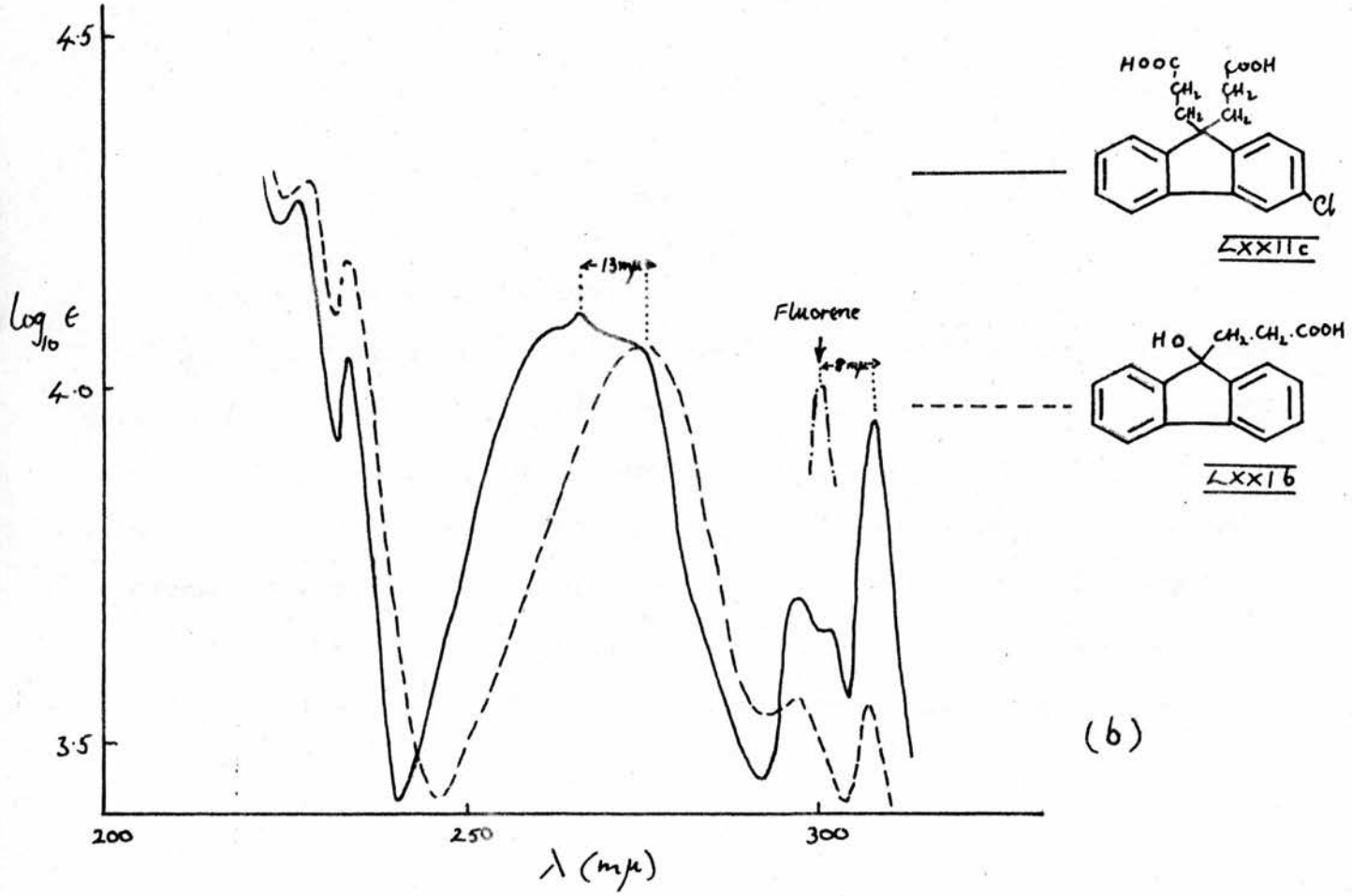
LXI LXVIII LXVII

Very little work has been carried out on the effect of nuclear substituents on the 9-position in fluorene, but the results of Eaborn and co-workers[125] indicate that substituents in the 2- and 3-positions in fluorene are roughly equivalent to o- and p-substituents in benzyl compounds, and can often greatly influence reactions at the 9-position. Since a knowledge of the reaction mechanism is required before a precise explanation of the influence of a group (particularly a halogen with its opposing -I and +T effects) can be given, it is difficult to say what is happening in this case. It is possible that the halogen increases the electron availability at the 9-carbon, rendering it more susceptible to electrophilic oxidative attack.

More success attended the carbonation of the lithium derivatives: Both 2-bromo- and 3-bromofluorenyllithium (formed by exchange with phenyllithium) gave 50% yields of the corresponding 9-carboxylic acids. Direct metalation with lithium in tetrahydrofuran was not considered in this case for fear of

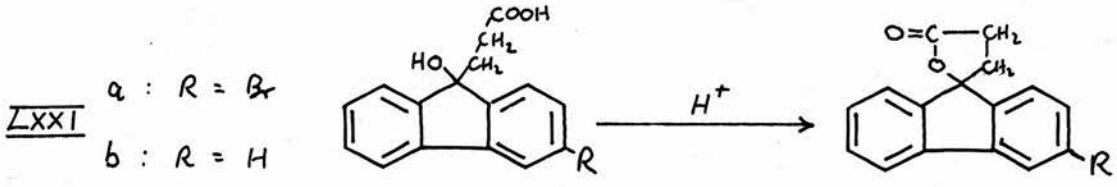
FIG. 4


4·5
4·0
3·5
log10 ε
5mμ
200
250
300
λ (mμ)
Cl
(a)


4·5
4·0
3·5
log10 ε
13mμ
Fluorene
8mμ
200
250
300
λ (mμ)
HOOC
COOH
CH2
Cl
LXXIIc
HO
CH2·CH2·COOH
LXXIb
(b)

attacking the halogen. The methyl esters were formed with dry hydrogen chloride in methanol.

When 3-bromo-9-carbomethoxyfluorene LXIX was treated in the usual way with acrylonitrile in 2-methoxyethanol;[41] and hydrolysed, an acid was obtained m.p. 178-180° which seemed to be too soluble in ethanol to be the required product LXX; (p.66) and it could not be cyclised with any of the common cyclising agents. Its U.V. spectrum showed a bathochromic shift of the 300 mμ peak in the fluorene spectrum, stated to be characteristic of fluoren-9-ols;[126] but the possibility of its being 3-bromo-9-hydroxy-9-carboxyethylfluorene LXXIa was ruled out, as it did not lactonise under the conditions specified by Campbell and Crombie[127] for the bromine-free compound LXXIb.



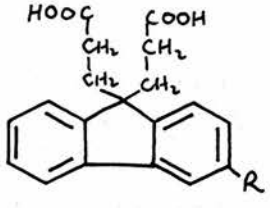
However, examination of the spectra of some substituted fluorenes indicated that a halogen atom in the fluorene nucleus causes an almost identical shift to that occasioned by a hydroxyl in the 9-position (Fig.4), i.e. from 300 mμ to about 310 mμ. Further, it was noticed that another peak in the fluorene spectrum, namely that at 262 mμ, undergoes a bathochromic shift to 271 mμ under the influence of a 9-hydroxyl, but is unaffected by a nuclear halogen. The unknown acid showed no such shift

and consequently probably does not possess a 9-hydroxyl. Its I.R. spectrum showed a band at ν_{max} = 1730 cm.$^{-1}$ as opposed to 1705 cm.$^{-1}$ for 9-carboxyethylfluorene (i.e. fluorene-β-9-propionic acid), and the acid hydroxyl band was much broader in the case of the former acid.

A similar acid was obtained from 3-chloro-9-carbomethoxyfluorene and, more significantly, from 3-chlorofluorene itself. In the latter case, the chloro-acid was obtained in a purer state, m.p. 189-190°.

Now when fluorene is reacted with two moles of acrylonitrile,[128] 9,9'-bis(2-carboxyethyl)fluorene LXXIIa is obtained m.p. 273-4°. It seemed probable that the unknown acids were the bromo- and chloro-analogues, LXXIIb and c.

LXXII a : R = H
b : R = Br
c : R = Cl

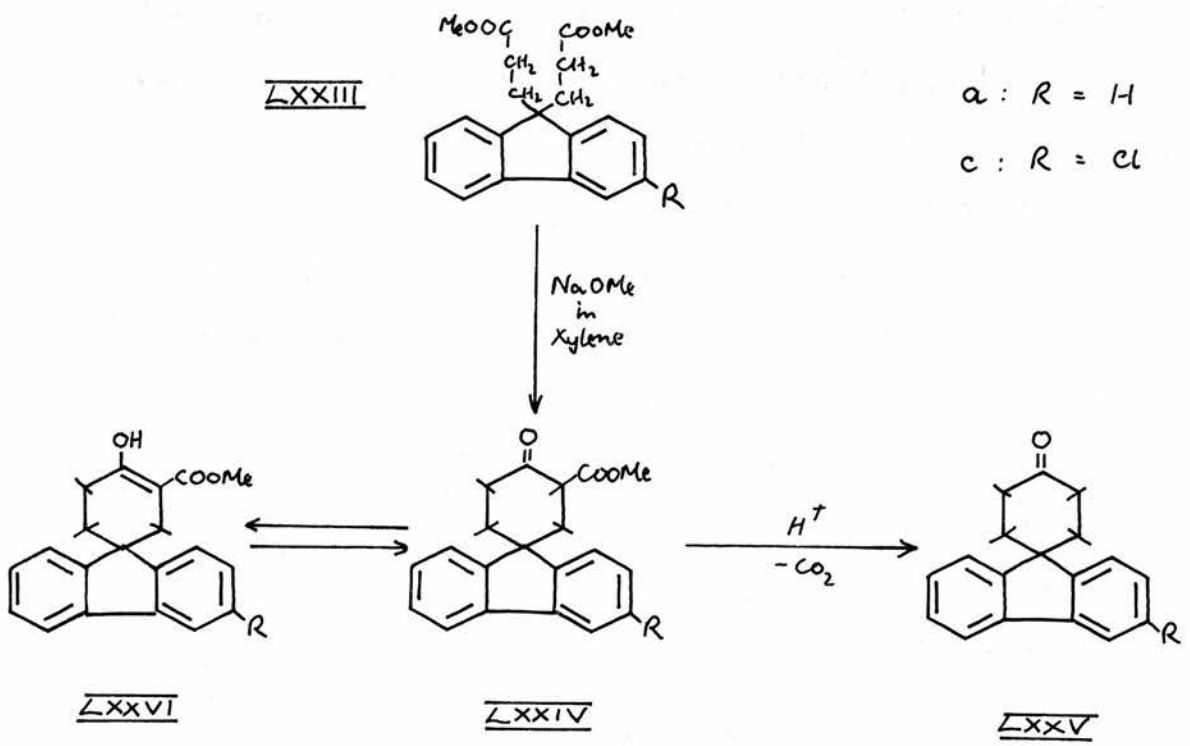


In fact, Campbell and Tucker[41] found that in some experiments with 9-carbomethoxyfluorene, the acid LXXIIa was formed instead of the required mono-acid. They suggested that, in these cases, the acrylonitrile failed to react initially with the ester, and after hydrolysis and decarboxylation during the work-up, two molecules of acrylonitrile were added. That this was so in the present case was shown by

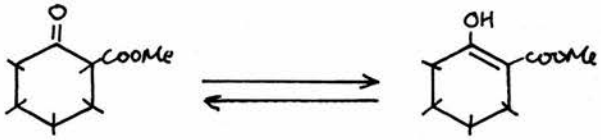
attempting to isolate the "intermediate," before hydrolysis: only unchanged ester was found.

Since the melting-points of LXXIIb and c were much lower than expected (compared with LXXIIa), and since their combustion analyses and neutralisation equivalents, though of the right order, were not quite satisfactory, some more experimental evidence was sought.

Stauffer and Fancher[129] cyclised the dimethyl ester of LXXIIa, LXXIIIa, by a Dieckmann condensation to give the keto-ester LXXIVa, which on hydrolysis spontaneously decarboxylated to the spiro-ketone LXXVa. When the same procedure was applied to the ester of the chloro-acid, LXXIIIc, the analogous products LXXIVc and LXXVc were obtained, as evidenced by their I.R. spectra.



An interesting point arising from the I.R. spectra is that the keto-esters LXXIV exist mainly in the enol forms LXXVI: ν_{max} = 1670 cm.$^{-1}$ (C:O) and 1625 cm.$^{-1}$ (C:C), whereas 2-carbomethoxycyclohexanone LXXVII shows peaks corresponding to both forms: ν_{max} = 1750, 1720, 1670 cm.$^{-1}$ (C:O) and 1625 cm.$^{-1}$ (C:C).

LXXVII 

The N.M.R. spectrum of the diester LXXIIIc showed a proton ratio of 7 aromatic : 8 methylene : 6 methyl, as expected. The methylene protons were in two bands, ratio 1:1, indicating the different chemical shifts of those next to the carboxyl group to those next to the fluorene nucleus; and the aromatic protons were in two bands, ratio 5:2, showing the effect of the chlorine atom on its neighbouring protons.

The spectrum of the mono-acid 9-carboxyethylfluorene, in contrast, gave a proton ratio of 8 aromatic : 4 methylene : 3 methyl : 1, the latter proton being that in the 9-position. It occurred as a triplet, due to splitting by the neighbouring methylene-group.

There seems to be no doubt, then, that the unknown acids are LXXIIb and c, though contaminated with some impurity: perhaps the mono-acid. Sieglitz[44] has recently encountered

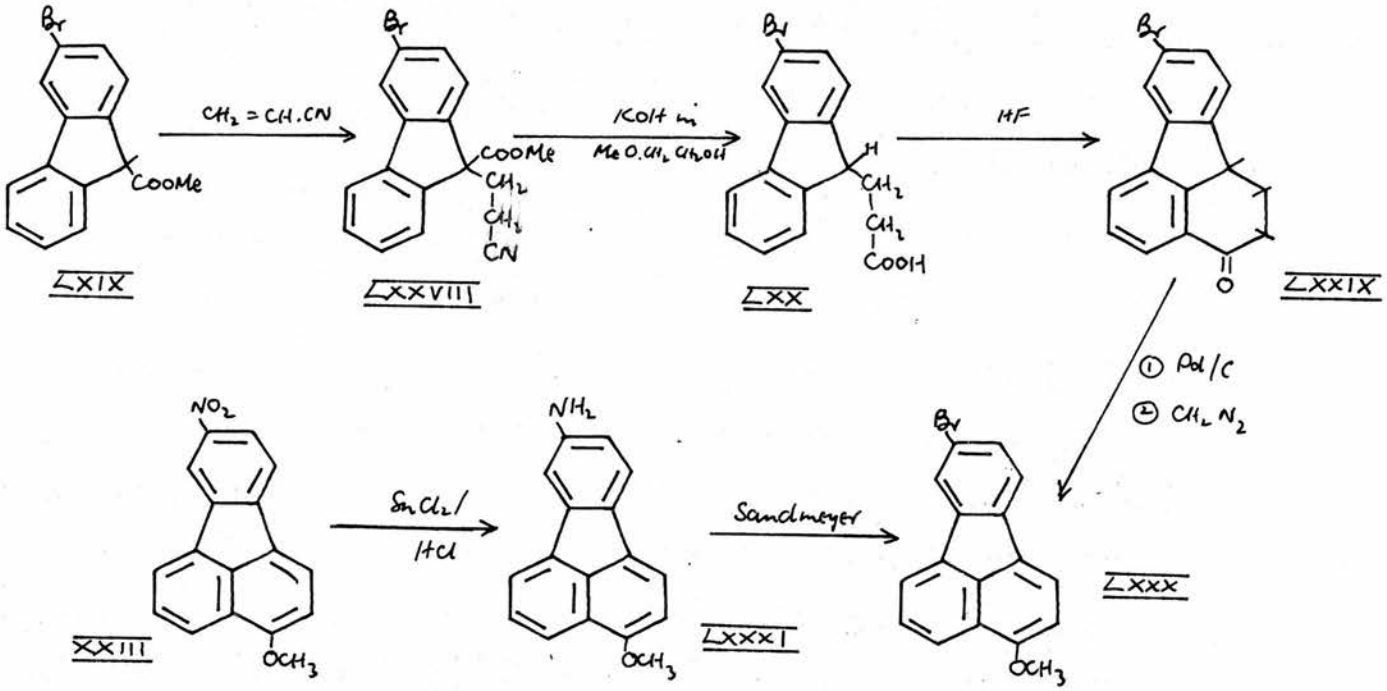
similar difficulties in the condensation of 2-chloro-9-carbomethoxyfluorene with acrylonitrile, although he managed to separate the mono- and di-acid by means of differential solubility in 2N sodium hydroxide. As this treatment failed to resolve LXXIIc into two components and to improve its melting point, the low melting point of this acid and its bromo-analogue remains unexplained.

In order to obtain the mono-acid LXX, that is to effect condensation before rather than after hydrolysis, the reaction conditions were changed from those of Campbell and Tucker.

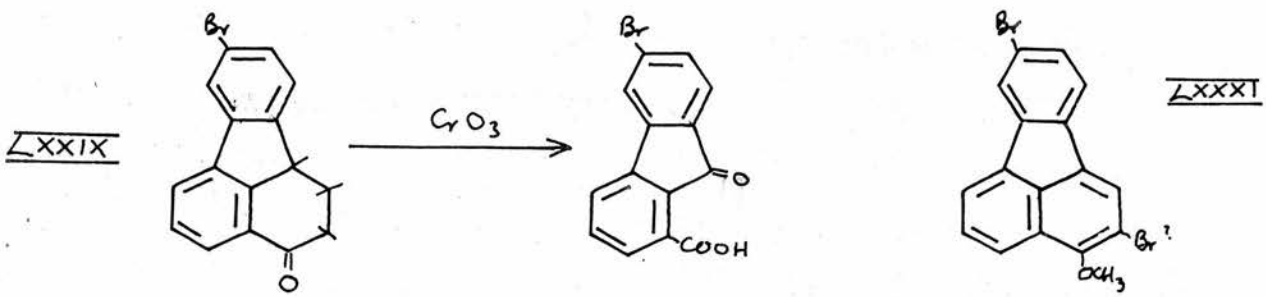
By warming 3-bromo-9-carbomethoxyfluorene LXIX and acrylonitrile for 3 hours with sodium methoxide in methanol, 3-bromo-9-carbomethoxy-9-(2'-cyanoethyl)fluorene LXXVIII was formed in 67% yield. Hydrolysis and decarboxylation with alkali in 2-methoxyethanol afforded the required mono-acid 3-bromo-9-(2'-carboxyethyl)fluorene LXX in 74% yield, and cyclisation in anhydrous hydrogen fluoride provided a rather poor yield (35%) of 8-bromo-1,2,3,10b-3-oxofluoranthene LXXIX. The ketone LXXIX was aromatised with palladium charcoal, unfortunately again in low yield, to the phenol, which was methylated with diazomethane to give 8-bromo-3-methoxyfluoranthene LXXX.

LXXX was also obtained when 3-methoxy-8-nitrofluoranthene XXIII, obtained previously, was reduced to the amine LXXXI, diazotised and treated with cuprous bromide (Sandmeyer reaction).

This confirms the orientation of XXIII given in Section I.



When LXXIX was oxidised with chromic acid, 6-bromofluorenone-1-carboxylic acid was formed m.p. 252-3°, identical with a specimen obtained as one of the products of oxidation of 3,8-dibromofluoranthene. (Introd.p.9).



Bromination of 3-methoxyfluoranthene in acetic acid yielded LXXXI as the only product, a surprising result since the nitration (under the same conditions) has been shown to give mainly the 2-nitro-isomer (Section I). Oxidation of LXXXI obtained in this way gave 6-bromofluorenone-1-carboxylic acid.

Summary

The results obtained in Section II, and those of other workers,[44,46] indicate that the direction of cyclisation of substituted β-9-fluorenylpropionic acids is dependent on the nature of the substituent group. As a general rule, it appears that a deactivating group, whether in position 2 or 3 of the fluorene nucleus, prevents cyclisation to the substituted ring, and the consequent cyclisation to the other ring provides a route to 3,9- and 3,8-disubstituted fluoranthenes respectively.

An activating group, on the other hand, directs cyclisation into the same ring, even when the position of attack is meta- to the substituent. This has provided a new synthesis of 2,4-disubstituted fluoranthenes, and should also (theoretically) be a means of synthesising 3,4-("peri") disubstituted fluoranthenes.

9-Fluorenylpropionic acids substituted in the 1-position of course have no choice but to cyclise to the unsubstituted ring, giving rise to 3,10-disubstituted fluoranthenes, although the route has so far only been applied to the synthesis of 7-monosubstituted fluoranthenes.[130]

When the possibility of the use of substituted acrylonitriles is taken into account,[40,43] it can be seen that (other things being equal) this method should be a general one for the synthesis of many fluoranthene derivatives. The key steps are the preparation of the fluorene-9-carboxylic acid, and the reaction of its ester with acrylonitrile; and the aromatisation

of the tetrahydro-oxofluoranthenes requires improvement. However, the simplest synthesis of 2,8-dibromo-3-methoxyfluoranthene is by bromination of 3-methoxyfluoranthene, and incidentally this provides an unambiguous route to 6-bromofluorenone-1-carboxylic acid.

EXPERIMENTAL

1. Analyses were carried out by Drs. Weiler and Strauss, Oxford and A. H. Baird Ltd., Edinburgh.

2. Melting-points were determined on a Kofler micromelting-point apparatus fitted with a polariser.

3. Alumina was of Type H, supplied by Peter Spence and Son, Widnes, and solvents were dried with anhydrous sodium sulphate unless otherwise stated.

4. Ultraviolet spectra were obtained on a Perkin-Elmer 137 UV spectrophotometer.

5. Infrared spectra were recorded on a Perkin-Elmer 137 "Infracord."

6. Nuclear Magnetic Resonance spectra were recorded on a Perkin-Elmer R10 (60 m/c) instrument.

7. Petroleum-Ether ("Petrol") was of b.p. 60-80° unless otherwise stated.

S E C T I O N I

Part 1.

2-Acetylfluorene

Bachmann and Sheehan, J.A.C.S. 62, 2688 (1940).

20 gm. Fluorene gave 14·6 gm. 2-acetylfluorene, m.p. 125-8° (59%).

Attempted nitration of 2-acetylfluorene

(a) Concentrated nitric acid (D 1·42 1·2 ml.) was added with stirring to a solution of 2-acetylfluorene (1·0 gm.) in glacial acetic acid (6 ml.) at 60-65°. The mixture was warmed to 80° and allowed to cool. No solid separated, and on pouring into water a dark yellow solid was obtained. Recrystallisation from acetic acid did not raise the melting point above 100-5°. (Lit. m.p. for 2-acetyl-7-nitrofluorene = 228°).

(b) 2-Acetylfluorene (1.0 gm.) was added in portions to 5 ml. concentrated sulphuric acid and 5 ml. nitric acid at room temperature. The product, obtained by pouring the reaction mixture into water, melted at 240-250° with decomposition.

2-Nitrofluorene

Organic Syntheses XIII, 74.

60 gm. Fluorene gave 58 gm. 2-nitrofluorene (77%). It was noted that heating to 65° was sufficient, and provided a purer product.

2-Acetyl-7-nitrofluorene

Oehlschlaeger and MacGregor, J.A.C.S., 71, 3224 (1949).

Since the product is insoluble in ether, purification of the crude material from the Friedel-Crafts reaction could be achieved by thorough extraction with ether, followed by crystallisation of the residue from glacial acetic acid.

48.5 gm. 2-Nitrofluorene yielded 26·0 gm. 2-acetyl-7-nitrofluorene (45%), m.p. 228°.

Reaction of 2-acetylfluorene and 2-acetyl-7-nitrofluorene with perbenzoic acid

cf. Friess, J.A.C.S., 71, 14 (1949).

Approximately 8% perbenzoic acid (300 ml.) in chloroform were made as in Organic Syntheses XIII, 86, employing dry benzoyl peroxide and the modifications described in Organic Reactions 7, 394. The solution was analysed as suggested and found to contain in fact 5·0% perbenzoic acid. 2-Acetylfluorene (5·0 gm.) was dissolved in the solution (100 ml.) and left in the dark for ten days.

2-Acetyl-7-nitrofluorene was found to be less soluble in chloroform, but soluble in tetrachlorethane. Therefore 5·0 gm. were dissolved in tetrachlorethane (100 ml.) and added to the perbenzoic acid solution (100 ml.). In both cases the reaction mixtures, initially dark red with a green fluorescence, gradually became yellow. Samples were tested at intervals with N/10 sodium thiosulphate, as follows:-

	2-Acetylfluorene (2 ml. samples)		2-acetyl-7-nitrofluorene (4 ml. samples)	
	N/10 Thio.titre	Total wt. of $PhCO_3H$	N/10 Thio.titre	Total wt.of $PhCO_3H$.
Initial	13.5 ml.	4.7 gm.	13.5 ml.	4.7 gm.
1 day	8.0 "	2.8 "	8.5 "	2.9 "
4 days	4.0 "	1.4 "	5.5 "	1.9 "
7 "	3.0 "	1.0 "	4.5 "	1.6 "
10 "	3.0 "	1.0 "	4.5 "	1.6 "
Uptake:		3.7 gm.		3.1 gm.
Theoretical uptake:		3.3 "		2.7 "

After 10 days the solvents were distilled off, leaving in each case a yellow solid. Chromatography on alumina resulted in hydrolysis on the column, and no further attempts at purification were made at this stage.

2-Methoxyfluorene

The crude product from the oxidation of 2-acetylfluorene (5.1 gm.) was refluxed with ethanol (100 ml.) and concentrated hydrochloric acid (100 ml.) for 2 hours. Undissolved material was filtered off, and on cooling the filtrate deposited a yellow solid. This was refluxed in sulphur-free xylene (200 ml.) with dimethyl sulphate (35 ml.) and potassium carbonate (50 gm.) for 1 hour, then filtered and reduced in volume to 50 ml.

Addition of petrol produced a precipitate which was recrystallised from petrol itself.

Yield = 2·3 gm. (49%).

m.p. = 106-8°.

Mixed m.p. with 2-methoxyfluorene (m.p. 106-8°) = 106-8°.

2-Methoxy-7-nitrofluorene

The product from the oxidation of 2-acetyl-7-nitrofluorene was treated exactly as above, except that, since the product was less pure, it was dissolved in benzene and chromatographed on alumina (200 gm.). Elution with benzene gave two bands, the first of which was bright yellow and on evaporation provided yellow needles which were crystallized from benzene.

Yield = 1·2 gm. (25%).

m.p. = 214-15°.

Mixed m.p. with 2-methoxy-7-nitrofluorene (m.p. 216-217°) = 216-217°.

Attempted reaction of 2-methoxy-7-nitrofluorene with maleic anhydride

cf. Bergmann and Orchin, J.A.C.S., 71, 1917 (1949).

(a) 2-Methoxy-7-nitrofluorene (1·2 gm.) and maleic anhydride (0·5 gm.) were heated together at 190° for 6 hours. Extensive charring occurred, and extraction with sodium carbonate followed by acidification failed to produce any acidic material.

(b) 2-Methoxy-7-nitrofluorene (0·6 gm.) and maleic anhydride

(0·25 gm.) were refluxed in nitrobenzene (10 ml.) for 4 hours. The mixture darkened, and no acid was obtained on extraction with sodium carbonate solution.

(c) 2-Methoxy-7-nitrofluorene (0·6 gm.) and maleic anhydride (0·25 gm.) were refluxed in pyridine (5 ml.) for 1 hour. Again darkening occurred, and no acid could be isolated.

2-Nitrofluorene, 2-acetyl-7-nitrofluorene, and 2-methoxy-7-nitrofluorene were all found to decompose and char when heated at their melting points, while fluorene and 2-acetylfluorene were stable.

Attempted reaction of 2-acetylfluorene with maleic anhydride

2-Acetylfluorene (1·2 gm.) and maleic anhydride (0·5 gm.) were heated at 190° for 6 hours. The cooled reaction mixture was extracted with sodium carbonate and the extract acidified. A slight reddish precipitate was obtained, which could not be purified.

2-Aminofluorene

2-Nitrofluorene was reduced by the method of Temple, Thesis (Edinburgh), p.52.

46 gm. 2-Nitrofluorene gave 35 gm. 2-aminofluorene (89%), m.p. 126-8°.

2-Acetamidofluorene

Stafford, Thesis, p.276.

34 gm. 2-Aminofluorene gave 37 gm. 2-acetamidofluorene

(88%), m.p. 191-2°.

Nitration of 2-acetamidofluorene

Diels, Ber. 35, 3286 (1902).

36 gm. 2-Acetamidofluorene gave 37 gm. crude product.

Hydrolysis of above product and separation of isomers

Koshits and Nikiforova, Chem. Abs., 35, 625 (1941).

Sawiki, Chastain and Bryant, J. Org. Chem., 21, 754 (1956).

2-Amino-7-nitrofluorene : Yield = 10·5 gm. m.p. 200-210°D.

2-Amino-3-nitrofluorene : Yield = 13·0 gm. m.p. 190-5°.

The latter compound was recrystallised from benzene.

Yield = 10·3 gm.

m.p. = 198-200°.

Deamination of 2-amino-3-nitrofluorene

(a) cf. Bardout, Chem. Abs., 26, 1275 (1932).

2-Amino-3-nitrofluorene (1·0 gm.) was dissolved in the minimum quantity of acetic acid and poured with stirring into concentrated hydrochloric acid. Bronze crystals were obtained on cooling, and these were filtered, washed with dilute hydrochloric acid, then suspended in concentrated hydrochloric acid (4 ml.) and water (12 ml.). Sodium nitrite (0·3 gm.) in water (2 ml.) was added slowly at 0°. After 1 hour, alcohol (30 ml.) and cuprous oxide (0·3 gm.) were added and the mixture warmed on the steam-bath. No noticeable nitrogen evolution occurred, and a red solid separated. The mixture was filtered hot, and on

cooling the filtrate afforded a small precipitate, which was recrystallized from aqueous alcohol, then from chloroform/petrol mixture.

Yield = 0·02 gm. (2%)

m.p. = 100-103°.

Lit. m.p. for 3-nitrofluorene = 105°.

(b) 2-Amino-3-nitrofluorene (1·0 gm.) was dissolved in concentrated sulphuric acid (14 ml.) and water (1 ml.). On addition of sodium nitrite (0·4 gm.) the solution became dark red. After 2 hours, a little copper sulphate was introduced, then 50% hypophosphorous acid added dropwise over 3 hours. Effervescence occurred, and the mixture was allowed to stand for 3 days at 0° before pouring into water (120 ml.). A sticky red solid was obtained, which was dissolved in benzene, dried and chromatographed on alumina (40 gm.). A thin red band was eluted with benzene, and on evaporation and recrystallization from chloroform/petrol mixture gave colourless needles.

Yield = 0·01 gm. (1%).

m.p. = 98-100°.

(c) cf. Cade and Pilbeam, Chem. and Ind., 1579 (1959).

2-Amino-3-nitrofluorene (1·0 gm.), was dissolved in tetrahydrofuran (25 ml.), but on addition of concentrated hydrochloric acid (6 ml.) and water (3 ml.), the hydrochloride separated. An additional 75 ml. T.H.F. were required to keep it in solution.

Sodium nitrite (0·4 gm.) in water (2 ml.) was added. After 1 hour, hypophosphorous acid was added, but no evolution of nitrogen occurred, even on warming. The red solid, obtained in the other experiments, was the only product.

3-Nitrofluorenone

(a) Arcus and Coombs, J.C.S. 3977 (1954):—

Biphenyl (100 gm.) was nitrated and the isomers separated by the method of Bell et al., J.C.S. 1242 (1926), giving 4-nitrobiphenyl (60 gm.) m.p. 114° and 2-nitrobiphenyl (43 gm.) m.p. 35-37°.

2-Aminobiphenyl

To 2-nitrobiphenyl (42 gm.) in alcohol (400 ml.), 100% hydrazine (30 gm.) was added, and the mixture warmed on the steam-bath. A small amount of Raney nickel was introduced and the suspension warmed for 1 hour, by which time the supernatant liquid was almost colourless. More Raney nickel was added and the mixture boiled to decompose excess hydrazine, then filtered. The filtrate was poured into water (1 litre), and the resulting white solid filtered and dried.

Yield = 36 gm. (quantitative)

m.p. = 43-46° (Lit. m.p. = 49°).

2-Amino-5-nitrobiphenyl

120 gm. 2-aminobiphenyl gave 77 gm. of crude 2-amino-5-nitrobiphenyl, by Arcus and Coombs' procedure. Batches of the

nitro-amine were purified by chromatography on alumina before proceeding to the next stage.

m.p. = 125°.

2-Cyano-5-nitrobiphenyl

2-Amino-5-nitrobiphenyl (8 gm.) was diazotized in concentrated hydrochloric acid, and urea added to destroy the excess nitrous acid. The solution was filtered and added at 10° to a freshly-made solution of sodium cuprocyanide containing sodium carbonate. The resulting brown precipitate was dissolved in benzene, dried and chromatographed on alumina (350 gm.). Elution with benzene gave a pink band which provided buff-coloured needles. Several coloured bands remained on the column.

Yield = 2·5 gm. (32%)

m.p. = 133-135°.

Two more recrystallizations from benzene raised the melting-point to 140-141°.

Bradsher and Jackson, J.A.C.S. 74, 4880 (1952), report 139·5-142° (Yield 24%).

Arcus and Coombs' product melted at 134-135° (Yield 72%).

2-Carboxy-5-nitrobiphenyl

2-Cyano-5-nitrobiphenyl (0·75 gm.) was refluxed for 3½ hours with concentrated sulphuric acid: acetic acid : water (1:1:1). The nitrile dissolved, and the solution deposited colourless plates on cooling. These were filtered (sintered glass),

washed with water, dried, and recrystallised from alcohol.

Yield = 0·52 gm. (64%)

m.p. = 180°.

In one experiment, the hydrolysis filtrate yielded, when poured into water, a substance which was insoluble in sodium carbonate. It was recrystallised from benzene as pinkish needles m.p. 184-186°.

$C_{13}H_{10}N_2O_3$ requires : C = 64·4% H = 4·2% N = 11·6%

Found : C = 64·3% H = 3·7% N = 11·8%.

i.e. This compound is the amide, presumably an intermediate in the hydrolysis.

3-Nitrofluorenone

2-Carboxy-5-nitrobiphenyl (1·5 gm.) was warmed for 10 minutes in concentrated sulphuric acid at 120°, cooled and poured on ice. The resulting yellow solid was crystallised from acetic acid, then from a large volume of alcohol.

Yield = 1·0 gm.

m.p. = 239-240° (sublimes at 150°).

(b) Ishikawa and Hayashi, Chem. Abs. 51, 16379 (1957); 52, 5349 (1958):-

2-Aminofluorenone

2-Nitrofluorenone (35 gm.) was obtained by sodium dichromate oxidation of 2-nitrofluorene (35 gm.), and reduced by the method of Gray, Hartley and Ibbotson, J.C.S. 2688 (1955):

Yield = 27 gm. (74%)

m.p. = 159-160°.

2-Acetamidofluorenone

2-Aminofluorenone (44 gm.) was refluxed for 1 hour with acetic acid (100 ml.) and acetic anhydride (100 ml.). On cooling, orange microneedles were obtained.

Yield = 46 gm.

m.p. = 227-228°.

3-Nitrofluorenone

2-Acetamidofluorenone (45 gm.) gave, by the procedure of Ishikawa and Hayashi, rather impure 3-nitrofluorenone.

Yield = 25 gm.

m.p. = 231-235°.

Two recrystallisations from xylene, and one from alcohol, raised the melting point to 239-240°, and reduced the yield to 18 gm.

Nitration of fluorenone

cf. Schultz, Annalen 203, 103.

Fluorenone (5 gm.) was added in portions to fuming nitric acid (D 1·51) at room temperature. When all solid had dissolved the solution was poured into ice-water, giving a yellow precipitate. This was refluxed with glacial acetic acid (50 ml.) and filtered. The residue was crystallized from a large volume of acetic acid.

Yield = 3.5 gm.

m.p. = 290°.

Lit. m.p. for 2,7-dinitrofluorenone = 290°.

The filtrate deposited yellow needles on cooling.

Yield = 1·1 gm.

m.p. = 219-220°.

When the reaction was performed at 0°, the ratio of isomers was changed: 1 gm. Fluorenone gave 0·35 gm. 2,7-dinitrofluorenone, and 0·65 gm. material m.p. 219-220°. Mixed m.p. of the latter compound with 2-nitrofluorenone m.p. 220°, = 170-175°.

$C_{13}H_7NO_3$ (mononitro-) requires: C = 69·3% H = 3·1% N = 6·2%

$C_{13}H_6N_2O_5$ (dinitro-) requires: C = 57·8% H = 2·2% N = 10·4%

Found : C = 58·3% H = 2·2% N = 10·1%.

A sample was dissolved in benzene and chromatographed on alumina. Elution with benzene gave one band, yielding yellow needles m.p. 241° alone, or when admixed with 2,5-dinitrofluorenone (obtained by sodium dichromate oxidation of 2,5-dinitrofluorene).

Attempted reduction of 3-nitrofluorenone

(a) Wolff-Kishner:- 3-Nitrofluorenone (0·2 gm.) was refluxed in diethylene glycol (2 ml.) with hydrazine hydrate (0·2 ml.). After 30 minutes the condenser was removed and the temperature allowed to reach 205°. The condenser was replaced and refluxing continued for 1 hour more. A pink solid was obtained on pouring

the reaction mixture into water. This was dissolved in benzene, dried and chromatographed on alumina (8 gm.). Nothing was eluted with benzene, and a pink band which was eluted with benzene containing 1% methanol produced only a red tar.

(b) Sodium borohydride:- 3-Nitrofluorenone (0·2 gm.) was suspended in methanol (5 ml.) and excess sodium borohydride added in portions (0·02 gm.). The ketone dissolved with effervescence, and on pouring into water a yellow precipitate was obtained, m.p. >270°.

3-Aminofluorenone

Ray and Barrick, J.A.C.S. 70, 1492 (1948).

1·0 gm. 3-nitrofluorenone gave 0·73 gm. 3-aminofluorenone, m.p. 157-158°.

3-Acetamidofluorenone

3-Aminofluorenone (0·70 gm.) was acetylated with acetic anhydride and the product recrystallised from alcohol.

Yield = 0·62 gm. (83%)

m.p. = 215-216°.

3-Aminofluorene

Weisburger, J.A.C.S. 77, 1914 (1955).

3-Acetamidofluorenone (0·5 gm.), potassium hydroxide (0·25 gm.), and hydrazine hydrate (0·6 ml.) were refluxed in diethylene glycol for 30 minutes. The condenser was removed and the temperature allowed to rise to 205°. The condenser was replaced

and refluxing continued for 45 minutes by which time the colour of the solution had changed from blood-red to faintly yellow, and effervescence had ceased. A white precipitate was obtained on the addition of water. This was filtered off and crystallised from alcohol, giving colourless needles.

Yield = 0·32 gm. (80%)

m.p. = 152-153°.

Lit. m.p. = 152-153°, "light tan plates."

Oxidations with peracetic acid

cf. Emmons, J.A.C.S. 79, 5528 (1957).

Mosby and Berry, Tetrahedron 5, 93 (1959).

An approximately 40% peracetic acid solution was prepared as in Organic Reactions I, 395: 90% Hydrogen peroxide (18·2 gm.) was added carefully at 20° to acetic acid (20 gm.) containing concentrated sulphuric acid (0·22 ml.).

Note: All operations were carried out behind a safety screen.

Reaction with 2-aminofluorene

cf. Weisburger, J.A.C.S. 77, 1914.

The peracetic acid solution (6 ml.) was added to 2-aminofluorene (0·3 gm.) in the minimum quantity of acetic acid. Effervescence occurred, and the colour changed to orange through green. When the initial reaction had subsided, acetic acid (5 ml.) was added and the solution refluxed for 5 minutes.

It was then filtered from some insoluble material (0·06 gm.) and poured into water, giving a pale yellow precipitate. This was dissolved in ether and the extract washed with concentrated hydrochloric acid to remove unreacted amine, and then with water. The ether layer was dried, and evaporated to give a solid which crystallised from alcohol as colourless needles.

Yield = 0·21 gm. (60%)

m.p. = 154-155°.

Mixed m.p. with 2-nitrofluorene = 155-156°.

Reaction with 3-aminofluorene

Peracetic acid solution (18 ml.) was added to 3-aminofluorene (0·90 gm.) in acetic acid, and worked up as above. Evaporation of the ether left a solid contaminated with red tar. 40/60 Petrol dissolved the solid, and the solution was decanted from the tar. On cooling, pale yellow clusters of needles were obtained.

Yield = 0·28 gm. (30%)

m.p. = 93-95°.

Recrystallisation from methanol raised the melting-point to 100-102°. Mixed m.p. with 3-nitrofluorenone obtained previously = 100-102°.

2-Nitrofluorene-9-carboxylic acid

The method of Craig, Thesis, p.140, was followed exactly: 2-Nitrofluorene (2·8 gm.) gave fluorenone (0·45 gm.) and 2-nitrofluorene-9-carboxylic acid (0·95 gm., 28%) m.p. 180-200°D.

Ester: The acid (0·6 gm.) was refluxed with methanol containing concentrated sulphuric acid, yielding methyl 2-nitrofluorene-9-carboxylate (0·55 gm.) m.p. 179-181°.

Attempted synthesis of 3-nitrofluorene-9-carboxylic acid

3-Nitrofluorene (0·05 gm.) and dimethyl oxalate (0·06 gm.) were added to a solution of potassium (0·02 gm.) in methanol (0·6 ml.). The solution became dark green, brown, then red. It was refluxed briefly, and the methanol distilled off, leaving a red solid only part of which dissolved in acetic acid. The residue separated from nitrobenzene as a red-brown powder.

Yield = 0·02 gm.

m.p. = >340°.

$C_{26}H_{14}N_2O_4$ requires : N = 6·7% , M.W. = 418

Found : N = 6·2% , M.W. = 425 (Rast).

This suggests that the red compound is 3,3'-dinitro-9,9'-bifluorenylidene.

The acetic acid filtrate was mixed with dilute sulphuric acid and refluxed for 1 hour. The cooled solution was treated with 30% hydrogen peroxide (1 ml.): A yellow solid separated which was crystallised from acetic acid.

Yield = 0·01 gm.

m.p. = 235°.

Mixed m.p. with 3-nitrofluorenone = 237-238°.

Reaction of phenyllithium with 2-nitrofluorene

Lithium (0·15 gm.) was suspended in anhydrous ether (6 ml.)

and bromobenzene (1·65 gm.) in ether (10 ml.) added. When most of the metal had reacted, the solution was filtered through a glass plug into a benzene solution of 2-nitrofluorene (2·0 gm.). The mixture darkened with evolution of heat, and after 10 minutes it was poured into a drikold/ether slurry, left overnight, water added and the layers separated. The aqueous layer afforded no acid on acidification, and the ether layer on evaporation left a black tar.

Reaction of lithium with fluorene in tetrahydrofuran.

Gilman and Gorsich, J. Org. Chem. 23, 550 (1958).

2 gm. Fluorene gave 1·5 gm. fluorene-9-carboxylic acid, m.p. 230-232° (from acetic acid).

Reaction of lithium with 2-nitrofluorene in tetrahydrofuran.

2-Nitrofluorene (1·0 gm.) in tetrahydrofuran (10 ml.) was added during 1½ hours to lithium (0·25 gm.) in tetrahydrofuran (2 ml.). The mixture was then refluxed for 30 minutes, cooled, and filtered on to a drikold/ether slurry. Again the ether layer yielded only a black tar, and the aqueous layer nothing.

Reaction of lithium with 2-aminofluorene in tetrahydrofuran

2-Aminofluorene (1·0 gm.) was treated as above. No acid was obtained from the aqueous layer, but the ether layer left an oil on evaporation which gave a solid when added to concentrated hydrochloric acid. The solid was soluble in water, and the solution on basification precipitated a white compound which

was crystallised from alcohol.

Yield = 0·71 gm.

m.p. = 124-126°.

Mixed m.p. with starting material = 127-128°.

1,2-Dimethylacenaphthene-1,2-diol

Criegee, Ann. 507, 176.

Acenaphthenequinone (15 gm.) gave cis-1,2-dimethyl-acenaphthene-1,2-diol (3·3 gm.) m.p. 188-189°, and impure trans-isomer (7·2 gm.) m.p. 155-158° which was used in the following syntheses.

7,8,9,10-Tetrahydrofluoranthene-8,9-dicarboxylic anhydride

Gow, Thesis, p.115.

The trans-diol (3·0 gm.) gave yellow prisms of the anhydride (1·7 gm.) m.p. 209-210°.

Fluoranthene-8,9-dicarboxylic anhydride

Gow, Thesis, p.117.

The above adduct (1·2 gm.) gave the dehydrogenated compound (0·8 gm.) m.p. 299-300°.

Attempted synthesis of fluoranthene-8,9-dicarboxylic imide

Fluoranthene-8,9-dicarboxylic anhydride (0·6 gm.) and urea (0·07 gm.) were intimately mixed and heated in a micro-sublimation apparatus at 280°. A yellow sublimate with the odour of iodoform was collected (0·2 gm.), and crystallised from glacial acetic acid. It gave yellow solutions with a green fluorescence

and was soluble in sodium hydroxide.

Yield = 0·17 gm.

m.p. = >300°.

$C_{18}H_9NO_2$ requires : C = 79·7% H = 3·4% N = 5·2%

Found : C = 37·5% H = 4·7% N = 19·4%.

This was obviously not the desired compound.

2-Nitroethanol

Gorski and Makarow, Ber., 67, 996 (1934).

Paraformaldehyde (1·0 gm.) and nitromethane (200 gm.) were heated to boiling-point, and potassium carbonate (0·1 gm.) added. Refluxing was continued for 15 minutes, when the solution was clear and free from the smell of formaldehyde. It was cooled, filtered and neutralised with 3-4 drops concentrated sulphuric acid, when a slight suspension appeared. It was removed by filtration and the filtrate distilled in vacuo: first with a water pump to remove nitromethane, then with an oil pump at 2 mm. to distil the nitroethanol at 75°.

Yield = 2·5 gm. (83%).

Attempted synthesis of 8-nitro-7,8,9,10-tetrahydrofluoranthene

Nitroethanol (2·0 gm.), phthalic anhydride (4·0 gm.), and trans-1,2-dimethylacenaphthene-1,2-diol (1·0 gm.) were refluxed in acetic anhydride (15 ml.) for 15 minutes. On cooling, yellow needles appeared which proved to be discoloured phthalic anhydride. The filtrate was poured on ice, yielding a brown

tar which solidified when triturated with sodium carbonate. It was ground to a powder, extracted with benzene, dried and chromatographed on alumina (50 gm.). A yellow band with a yellow fluorescence in the U.V. was eluted with benzene, but evaporation of the solvent left only a red amorphous solid which could not be purified, and melted over a wide range.

Attempted acetylation of 8-nitrofluoranthene

(a) 8-Nitrofluoranthene m.p. 158-160° (2·0 gm.) and anhydrous aluminium chloride (2·0 gm.) were dissolved in nitrobenzene (10 ml.), and acetyl chloride (1·0 ml.) added dropwise at 50-55°. The mixture was kept at this temperature for 4 hours, but only a fraction of the theoretical quantity of hydrogen chloride was evolved. The reaction complex was decomposed in the usual way and the product steam-distilled to remove nitrobenzene. The resulting solid was taken up in benzene, dried and chromatographed on alumina (100 gm.). Benzene eluted a yellow band which afforded starting material (1·4 gm.), and ether eluted an orange band which gave an impure solid (0·02 gm.). Several recrystallisations from acetic acid did not improve the melting point: m.p. 175-180°.

I.R. : ν_{max} = 1660 $cm.^{-1}$ (C:O)

(b) Aluminium chloride (3·6 gm.) was added in portions to a stirred solution of 8-nitrofluoranthene (2·5 gm.) and acetyl chloride (1·6 gm.) in carbon disulphide (30 ml.), and the mixture stirred for 24 hours at room temperature. Very little hydrogen

chloride was evolved, and only starting material was isolated from the product.

3-Hydroxyfluoranthene

Fluorene gave, by the method of Campbell and Tucker, J.C.S. 2624 (1949), and Craig, Thesis pp.68 and 135, 3-hydroxyfluoranthene, yellow needles from benzene.

Overall yield (5 stages) = 36%.

m.p. = 187-190°, resolidifying to long needles, m.p. >300°.

3-Toluenesulphonyloxyfluoranthene

p-Toluenesulphonyl chloride (2·0 gm.) in acetone (15 ml.) was added to a solution of 3-hydroxyfluoranthene (1·0 gm.) in 2N sodium hydroxide (10 ml.), and the mixture shaken vigorously for 15-20 minutes in a securely stoppered bottle, then poured into water (50 ml.). The product was filtered off, washed with water and crystallised from a benzene/petrol mixture as light yellow prisms.

Yield = 1·5 gm. (88%)

m.p. = 133-135°.

Another crystallisation raised the m.p. to 135-136°.

$C_{23}H_{16}SO_3$ requires : C = 74·2%, H = 4·3%, S = 8·6%.

Found : C = 73·7%, H = 4·4%, S = 8·5%.

3-Acetoxyfluoranthene

3-Hydroxyfluoranthene (3 gm.) was refluxed with acetic anhydride (5 ml.) containing a trace of concentrated sulphuric

acid. After 1 minute, water was added, and the resulting oil solidified by washing with sodium carbonate solution. The crude solid crystallized from alcohol as yellow prisms.

Yield = 2·2 gm. (61%)

m.p. = 116-117°. (Lit. m.p. = 116-117°).

Nitration of 3-toluenesulphonyloxyfluoranthene

3-Tosyloxyfluoranthene (7·0 gm.) was dissolved in acetic acid (75 ml.) and concentrated nitric acid D 1·42 (35 ml.) added dropwise. The solution was warmed to 70° for 1 minute, cooled, decanted from a little tarry material, and poured on ice. The crude nitro-compound was filtered and dried in air. Yield = 6·2 gm. This was dissolved in benzene and chromatographed on alumina (200 gm.). Benzene eluted a yellow band, leaving several coloured bands on the column. Evaporation of the solvent left a yellow solid which was crystallised from benzene/petrol mixture to give yellow needles of 8-nitro-3-tosyloxy-fluoranthene.

Yield = 2·3 gm.

m.p. = 180-183°.

Two further crystallisations from benzene/petrol raised the melting point to 189-190°.

$C_{23}H_{15}NO_5S$ requires : N = 3·4%, S = 7·7%.

Found : N = 3·3%, S = 6·8%.

The combined filtrates were evaporated to dryness (2·5 gm.) and rechromatographed on alumina (100 gm.). Elution with a

benzene/petrol mixture (1:1) gave essentially one band, the lower part of which was brighter in colour than the upper part. 100 ml. fractions were taken, concentrated to 5 ml., and allowed to crystallize. The first two fractions afforded another isomer as yellow needles.

Yield = 0·1 gm.

m.p. = 205-215°.

Two recrystallisations from acetic acid raised the melting point to 226-230°.

$C_{23}H_{15}NO_5S$ requires : N = 3·4%

Found : N = 2·8%.

The other fractions gave impure material consisting mainly of the first isomer (by I.R. comparison).

Mixed m.p. of the two isomers = 170-190°.

Nitration of 3-acetoxyfluoranthene

3-Acetoxyfluoranthene (1·0 gm.) in acetic acid (10 ml.) was nitrated with concentrated nitric acid D 1·42 (5 ml.) at 0° (higher temperatures caused decomposition). The solid which separated from the nitration mixture was filtered off, washed with water and dried (0·6 gm.). The crude material was dissolved in benzene and chromatographed on alumina (40 gm.). On elution with benzene, a pale yellow band was obtained which gave 8-nitro-3-acetoxyfluoranthene as light brown needles (from benzene).

Yield = 0·11 gm.

m.p. = 208-210°.

$C_{18}H_{11}NO_4$ requires : N = 4.6%

Found : N = 4.5%.

The coloured bands, which could only be eluted with alcohol, yielded a brown tarry solid which was mostly soluble in sodium hydroxide, but not in sodium bicarbonate.

Nitration of 3-hydroxyfluoranthene (attempted)

Addition of nitric acid to 3-hydroxyfluoranthene in acetic acid resulted in immediate darkening. No pure product could be isolated from the nitration mixture.

Fries rearrangement of 3-acetoxyfluoranthene

cf. Blatt, Chem. Rev., 27, 413 (1940).

(a) 3-Acetoxyfluoranthene (0·18 gm.) and aluminium chloride (0·12 gm.) were dissolved in carbon disulphide, stirred, then the solvent distilled off. The remaining mixture was heated to 120° on an oil bath, held at this temperature for 15 minutes, and cooled. Concentrated hydrochloric acid and ice were added, and the resulting yellow precipitate extracted with ether. The ether was washed with water, then shaken with 2N sodium hydroxide. The alkali layer was acidified giving a yellow solid which was filtered off and crystallised from benzene/petrol.

Yield = 0·10 gm.

m.p. = 175-180°.

Mixed m.p. with 3-hydroxyfluoranthene = 185-187°.
i.e. Hydrolysis had occurred instead of rearrangement.

(b) 3-Acetoxyfluoranthene (0·18 gm.) and aluminium chloride (0·12 gm.) were dissolved in tetrachlorethane (2 ml.). As the solution was heated near the boiling point of the solvent (146°), it began to effervesce, and the smell of acetic acid was noticed. The flask was immediately cooled, and left overnight at room temperature. The reaction mixture was worked up as in (a) but the product found to be less soluble in ether. The ether-soluble fraction proved to be essentially 3-hydroxyfluoranthene as before, and the ether-insoluble material was crystallised from acetic acid.

Yield = 3 mg.

m.p. = 185-190°.

Mixed m.p. with 3-hydroxyfluoranthene = 170-175°.

I.R. : ν_{max} = 1640 $cm.^{-1}$ (o-chelated C:O ?).

Hydrolysis of 3-acetoxy and 3-tosyloxy-8-nitrofluoranthenes

The nitro-ester (1·0 gm.) was warmed with potassium hydroxide (1·0 gm.) in ethanol (10 ml.), to give a deep purple solution. After cooling, this was poured on concentrated hydrochloric acid and ice, and the resulting yellow precipitate of 3-hydroxy-8-nitrofluoranthene filtered off and crystallised from acetic acid then ethanol.

Yield = 0·6 gm.

m.p. = 240° approximately.

Although fairly crystalline, the nitro-phenol was obviously not quite pure, but no further attempts at purification were made, the crude material being used for the next stage.

3-Methoxy-8-nitrofluoranthene

Crude 3-hydroxy-8-nitrofluoranthene (1·0 gm.) was dissolved in sulphur-free xylene (10 ml.), then dimethyl sulphate (1·0 ml.) and anhydrous potassium carbonate (1 gm.) added. The mixture was refluxed for 30 minutes during which time the colour lightened considerably, then it was filtered, shaken with 10% sodium hydroxide, and the layers separated. No unreacted phenol was recovered from the aqueous layer, and the xylene was washed with water, dried and concentrated to 2 ml. This was chromatographed on alumina (40 gm.), and a bright yellow band eluted with benzene, leaving a dark brown band at the top of the column. Evaporation of the benzene and xylene left a yellow oil which soon crystallised. It was recrystallised from benzene as yellow needles.

Yield = 0·25 gm. (25%)

m.p. = 205-208°.

A further recrystallisation from benzene raised the melting point to 208-209°. Mixed m.p. with 3-methoxy-9-nitrofluoranthene (m.p. 191-192°) = 180-185°.

$C_{17}H_{11}NO_3$ requires : C = 73·6% H = 4·0% N = 5·1%

Found : C = 73·7% H = 4·1% N = 7·0%.

3-Methoxy-2,8-dinitrofluoranthene

3-Methoxy-8-nitrofluoranthene (0·1 gm.) was dissolved in the minimum quantity of concentrated nitric acid (D 1·42) with slight warming, and left overnight. The yellow crystals which separated were filtered off, washed until acid-free, and dried. The crude material was crystallised twice from xylene as yellow needles subliming at 260°.

m.p. = 272-274°D.

Mixed m.p. with 3-methoxy-2,x-dinitrofluoranthene m.p. 278-283° obtained by Craig (Thesis p.138) = 276-278°.

Mixed m.p. with 3-methoxy-2,9-dinitrofluoranthene m.p. 278-283°D obtained by Nichol (Thesis p.52) = 235-260°.

Oxidations with potassium permanganate

Fluoranthene, 3-tosyloxy- and 3-methoxyfluoranthene were unaffected by permanganate.

Fluorenone-1-carboxylic acid

3-Hydroxyfluoranthene (0·5 gm.), potassium permanganate (1·0 gm.) and water (50 ml.) were made alkaline with sodium hydroxide and refluxed for 1 hour, after which the manganese dioxide was filtered off. The clear filtrate on acidification with sulphurous acid yielded a salmon-pink precipitate. This

was washed, dried, and crystallised from ethanol as orange needles.

Yield = 0·3 gm.

m.p. 189-191° (Lit. m.p. = 191-192°).

6-Nitrofluorenone-1-carboxylic acid

3-Hydroxy-8-nitrofluoranthene (1·0 gm.) was oxidised as above, and the product crystallised from acetic acid as light brown microneedles.

Yield = 0·3 gm.

m.p. = 275-276°D (Subliming at 250°).

$C_{14}H_7NO_5$ requires : C = 62·5%, H = 2·6%, N = 5·2%

Found : C = 61·6%, H = 2·7%, N = 5·3%.

Decarboxylation of fluorenone-1-carboxylic acid

(a) Copper in quinoline: The acid (5 mg.) was placed in a small tube in a heating block, and quinoline (3-4 drops) and a pinch of copper bronze added. No effervescence was observed, even when the mixture was refluxed, and only starting material was recovered.

(b) Copper in 4-methylquinoline: As above, but effervescence commenced at 200-210°, and after 10-15 minutes the reaction was complete. The solvent was diluted with ether, and extracted first with strong hydrochloric acid, then with 2N sodium hydroxide. The washed ether layer was evaporated to leave a yellow residue which was crystallised from ethanol as yellow needles.

Yield = 2 mg.

m.p. = 83-84°.

Lit. m.p. for fluorenone = 84°.

Decarboxylation of 6-nitrofluorenone-1-carboxylic acid

(a) Copper in 4-methylquinoline: The nitro-acid (5 mg.) was dissolved in 4-methylquinoline (5 drops) and heated with a pinch of copper bronze. Effervescence commenced at 180°, and after 15 minutes was complete. Ether was added, and the ether solution washed with acid and alkali as before. Evaporation left a yellowish solid which was sublimed at 160°.

m.p. = 235-237°.

Mixed m.p. with 3-nitrofluorenone m.p. 239° = 237-238°.

(" " " 2-nitrofluorenone m.p. 220° = 200-210°).

(b) Copper acetate (cf. Koelsch and Steinhauer, J. Org. Chem., 18, 1516 (1953)).

The nitro-acid (0·1 gm.) was mixed with an equal quantity of copper acetate and heated in a small sublimation apparatus. The yellow sublimate which was obtained was resublimed, then crystallised from ethanol.

Yield = 0·02 gm.

M.p., and mixed m.p. with 3-nitrofluorenone = 237-238°.

7-Nitrofluorenone-1-carboxylic acid

This was prepared by the nitration of fluorenone-1-carboxylic acid in mixed acid (Garascia, Fries and Ching, J. Org. Chem., 17, 226 (1952)). m.p. 245-6°.

7-Aminofluorenone-1-carboxylic acid

cf. Garascia and Overberg, J. Org. Chem., 19, 27 (1954).

7-Nitrofluorenone-1-carboxylic acid (17 gm.), stannous chloride (70 gm.), concentrated hydrochloric acid (75 ml.) and acetic acid (150 ml.) were warmed at 100° for 1 hour with stirring. The suspension was then cooled, the yellow amine hydrochloride filtered off and the free amine acid obtained by dissolving the salt in sodium hydroxide and acidifying carefully with hydrochloric acid. It was crystallised from ethanol as dark red (almost black) needles.

Yield = 13·5 gm.

m.p. = 190° (The substance was placed on the block at this temperature; otherwise decomposition set in before melting).

7-Acetamidofluorenone-1-carboxylic acid

The amino-acid (10 gm.) was heated with acetic anhydride (500 ml.) for 2 hours at 100°, and the resulting clear red solution poured into water to give a red-brown precipitate which was crystallised from ethanol as red needles.

Yield = 8·5 gm.

m.p. = 275° (Placed on the block at this temperature).

Attempted nitration of 7-acetamidofluorenone-1-carboxylic acid

(a) The acid (5·0 gm.) was added in portions to concentrated sulphuric acid (25 ml.) and concentrated nitric acid D 1·42 (25 ml.), and the solution warmed at 40° for 1 hour. It was

then poured on ice and the resulting scarlet solid filtered off and dried. It was practically insoluble in water, ethanol, acetic acid and chlorobenzene, but soluble in pyridine and sodium hydroxide. When heated in a flame, it deflagrated violently with a puff of black smoke.

Attempted deamination of above product

The red compound (1 gm.) was dissolved in concentrated sulphuric acid (5 ml.), and sodium nitrite (0·3 gm.) in sulphuric acid (2 ml.) added dropwise with stirring. After 5 hours, the solution was poured on ice, and hypophosphorous acid (10 ml.) added. However, the product appeared to be essentially starting material.

The nitration was also attempted in acetic acid and acetic anhydride, but the acetamido-acid was insoluble in these solvents and no pure product could be isolated from the reactions in suspension.

Part 2

Synthesis of 3-methylfluoranthene

(a) The method of Stubbs and Tucker, J.C.S. 3290 (1950), was followed exactly, except at the following stages:

4-9'-fluorenylbutan-2-ol.

2-9'-Fluorenylethyl methyl ketone (2·5 gm.) was dissolved in anhydrous ether and added dropwise to lithium aluminium hydride (0.5 gm. - 5x excess) in ether (25 ml.) at such a rate as to maintain refluxing. After the addition the mixture was refluxed for a further 15 minutes, then excess reagent destroyed with ethyl acetate. The sludge was filtered off, washed thoroughly with ether, and the washings combined with the main filtrate. This was then evaporated to leave an oil which crystallised from petrol as needles.

Yield = 2·0 gm. (78%)

m.p. = 45-49° (Lit. 45-49°).

3-Methylfluoranthene

1,2,3,10b-Tetrahydro-3-methylfluoranthene (1.0 gm.) was refluxed with tetrachloro-orthoquinone (2·5 gm.) in benzene (10 ml.) for 1 hour, cooled, filtered and chromatographed on alumina (40 gm.) directly. Benzene eluted a greenish band (bright blue in U.V. light), from which pale green blades of 3-methylfluoranthene were obtained. They were recrystallised from ethanol.

Yield = 0·6 gm. (61%)

m.p. = 65-66° (Lit. m.p. = 66°).

(b) von Braun and Manz, Ber., 70, 1609 (1937).

3-Methyl-1,10b-dihydrofluoranthene

1,2,3,10b-Tetrahydro-3-oxofluoranthene (24 gm.), made by the method of Craig (Thesis p.68), was added in portions to a Grignard reagent from magnesium (4·4 gm.) and methyl iodide (25·5 gm.) in dry ether (60 ml.). The volume of ether was increased to 120 ml. during the addition. After 15 minutes additional refluxing, the complex was decomposed with concentrated hydrochloric acid and ice to give a granular yellow precipitate of 3-methyl-3-hydroxy-1,2,3,10b-tetrahydrofluoranthene. Most of this was dehydrated by boiling with 90% formic acid for 2 hours, but about 30% remained undissolved, and required refluxing with a mixture of concentrated hydrochloric acid and acetic acid for its dehydration. (Perhaps this latter portion consisted of a different geometrical isomer). The acid solutions when diluted with water gave 3-methyl-1,10b-dihydrofluoranthene, which was crystallised from methanol as pale green plates.

Yield = 12·5 gm. (53%)

m.p. = 127-128° (Lit. 127-128°).

3-Methylfluoranthene

The above dihydro-compound was dehydrogenated in the same

way as was the tetrahydro-compound in Method (a).

Yield = 8.0 gm. (65%)

m.p. = 65-66°.

Nitration of 3-methylfluoranthene

3-Methylfluoranthene (2.0 gm.) was dissolved in acetic acid (40 ml.), and concentrated nitric acid D 1·42 (20 ml.) added dropwise with stirring. After 1 hour at 40°, the reaction mixture was poured on ice and the resulting crude nitro-product filtered off, dried and dissolved in benzene. The dried benzene solution was chromatographed on alumina (80 gm.). Benzene eluted a yellow band which yielded a yellow oil. This was dissolved in benzene and petrol added at the boiling-point until the solution was just cloudy. On cooling, yellow needles were obtained (0·93 gm.) m.p. 178-180° (A). The filtrate was concentrated and rechromatographed on alumina (20 gm.). This time benzene : petrol (1:1) was used as eluant giving two bands: The upper band provided 0·23 gm. of compound A, and the lower band was eluted in portions. The first fractions gave a small yield of another isomer B m.p. 180-183° (square plates from benzene), and the later fractions afforded another isomer C in a rather impure state m.p. 165-175° (needles from benzene). Several crystallisations and rechromatography failed to improve the melting point of C, but mixed melting-points and I.R. spectra showed that A, B and C were certainly different isomers.

Compound A: Total yield = 1·16 gm. (48%)

m.p. = 178-180°

$C_{17}H_{11}NO_2$ requires : C = 78·1%, H = 4·2%, N = 5·4%

Found : C = 78·2%, H = 4·3%, N = 5·4%.

Compound B: Yield = 10 mg.

m.p. = 180-183°

Found: C = 77·1%, H = 4·4%, N = 4·4%.

Compound C: Yield (impure) = 20 mg.

m.p. = 165-175°

Found: C = 76·4%, H = 4·3%, N = 4·6%.

The analyses of B and C indicate that they are mononitro-isomers, though a certain amount of impurity (perhaps starting material) is present.

Nitration of Compounds A and B

The nitromethylfluoranthene was warmed with concentrated nitric acid D 1·42 for 5 minutes, then left overnight. The resulting yellow solid was filtered off, washed with water and dried. It crystallised from acetic acid as yellow microneedles which sublimed below the melting-point to give longer needles.

m.p. = 275-280°D.

Sublimate: m.p. = 278-280°D.

$C_{17}H_{10}N_2O_4$ requires: C = 66·7%, H = 3·3%, N = 9·2%

Found: C = 66·0%, H = 3·0%, N = 7·0%.

Dinitration of 3-methylfluoranthene

3-Methylfluoranthene was added in portions to concentrated nitric acid with vigorous stirring and slight warming. Much of the hydrocarbon congealed to a plastic mass which was shown to consist mainly of the mononitro-compound A, and was curiously resistant to the acid; but the supernatant liquid on cooling deposited a small amount of material melting, after crystallisation from acetic acid, at 275-280°D.

Mixed m.p. with above material = 278-280°.

Oxidation of A with potassium permanganate (attempted)

Compound A was suspended in water, excess potassium permanganate added, and the mixture refluxed for 4 hours, but no colour change took place and starting material was recovered quantitatively.

The reaction was repeated, with the addition of acetone to keep A in solution, but again no oxidation occurred.

3-Methylfluoranthene itself was similarly unaffected by permanganate.

Oxidation of 3-Methylfluoranthene with sodium dichromate

cf. Craig, Thesis p.125.

3-Methylfluoranthene gave a 40% yield of fluorenone-1-carboxylic acid m.p. 188-191°.

Oxidation of Compound A with sodium dichromate

x-Nitro-3-methylfluoranthene A (0·3 gm.) was refluxed for 4 hours with sodium dichromate (3·0 gm.) in acetic acid (10 ml.), then poured into dilute sulphuric acid. The product was washed thoroughly with water and crystallised from acetic acid as orange microneedles.

m.p. 275-276° (subliming at 250°).

A mixed m.p. with 6-nitrofluorenone-1-carboxylic acid obtained previously from the oxidation of 3-hydroxy-8-nitrofluoranthene was undepressed. Hence A is 3-methyl-8-nitrofluoranthene.

S E C T I O N II

Part 1

2-(4-Toluyl)benzoic acid

This was prepared as in Vogel, "Practical Organic Chemistry" (3rd Edition), p.740. M.p. (crude) = 136-138°.

2-(4-Toluyl)benzamide

The above acid was refluxed with excess thionyl chloride for 1 hour, then the excess thionyl chloride was distilled off and the last traces removed by co-distillation with benzene, leaving a brown oil. The crude oil was dissolved in benzene and added slowly to ethanol saturated with ammonia, while ammonia gas was bubbled through the solution. The precipitated amide was filtered off, extracted with warm water to remove the ammonium salt, and crystallised from benzene as colourless needles.

Yield = 44% from the crude acid.

m.p. = 172-173° (Lit. 175-6°).

The water washings, when acidified, gave 20% of the original acid, m.p. 140-142°.

2-(4-Toluyl)aniline

Kippenberg, Ber., 30, 1132 (1897).

The above amide (3·0 gm.) was made into a paste with 2N sodium hydroxide and added in portions to a solution of

sodium hypobromite (prepared from 0·8 ml. bromine) at 0°. The mixture was allowed to warm to room temperature and stirring was continued for 1 hour. On being heated at 100° the clear solution deposited a dark oil from which, by several crystallisations from ethanol, a low yield of the amine was obtained. However, when the reaction was repeated with a sodium hypobromite solution which had been left for 10 days, a yellow oil resulted which crystallised on standing overnight. Recrystallisation from ethanol gave yellow needles.

Yield = 1·7 gm. (64%)

m.p. = 92-93° (Lit. m.p. = 96°).

3-Methylfluorenone

Kippenberg, loc.cit.; Dickinson and Eaborn, J.C.S., 2339 (1959).

The amine (1·5 gm.) gave 3-methylfluorenone (0·9 gm.), m.p. 66-67°.

3-Methylfluorene

3-Methylfluorenone (1 gm.) was reduced to 3-methylfluorene by the Wolff-Kishner reaction (without alkali) described elsewhere.

Yield = 0·65 gm.

m.p. = 86-87°.

3-Methylfluorene-9-carboxylic acid

3-Methylfluorene (0·2 gm.) was metalated directly with

lithium in tetrahydrofuran by the method used for fluorene (p. 86), and carbonated, to give 3-methylfluorene-9-carboxylic acid, crystallised from benzene-petrol as colourless needles.

Yield = 0·12 gm.

m.p. = 205-210°D.

Benzoylformic acid

Org. Synth. VIII, 72; Acree, Am. Chem. J., 50, 391 (1913).

The crude acid (85 gm.) was recrystallised from carbon disulphide to give 67 gm. pure acid.

Reaction of benzoylformic acid and toluene

Vorlander and Pritzche, Ber., 46, 1795 (1913).

Benzoylformic acid (15 gm.) was dissolved in toluene (100 ml.) and anhydrous aluminium chloride added portionwise at 70-80°. When evolution of hydrogen chloride ceased, the dark reaction mixture was poured into concentrated hydrochloric acid and ice. The excess toluene was steam-distilled off to leave a plastic mass, which was dissolved in 2N sodium hydroxide, boiled with charcoal, filtered and acidified. The semi-solid product was dried and crystallised from benzene-petrol (10 gm.). Evaporation of the solvent left 6 gm. of a brown, fluorescent oil. The acid was recrystallised from benzene-petrol.

Yield = 8·5 gm.

m.p. = 205-210°D (Lit. 210°D).

3-Methyl-9-carbomethoxyfluorene

The above acid (8·0 gm.) was esterified with methanol saturated with dry hydrogen chloride.

Yield = 6·5 gm.

m.p. = 81·0-81·5°.

$C_{16}H_{14}O_2$ requires : C = 80.6% H = 5·9%

Found : C = 80·5% H = 5·8%.

3-Methyl-9-(2'-carboxyethyl)fluorene

To 3-methyl-9-carbomethoxyfluorene (4·5 gm.) in 2-methoxyethanol (25 ml.) was added potassium hydroxide (0.27 gm.) and acrylonitrile (1·26 gm.), and the mixture warmed for 15 minutes on the water-bath. Then 10N potassium hydroxide (40 ml.) and 2-methoxyethanol (25 ml.) were added and the mixture refluxed for 30 minutes. Addition of water caused no precipitation, but acidification gave an oil which solidified on standing. The solid was filtered off, dried and crystallised from benzene petrol as colourless prisms.

Yield = 3·1 gm. (65%)

m.p. = 145-146°.

A further crystallisation from benzene-petrol raised the melting-point to 151-152°.

$C_{17}H_{16}O_2$ requires : C = 80·9% H = 6·4%

Found : C = 80·6% H = 6·4%.

I.R.: ν_{max} = 1705 $cm.^{-1}$ (C:O).

5-Methyl-1,2,3,10b-tetrahydro-3-oxofluoranthene

(a) 3-Methyl-9-carboxyethylfluorene (0·9 gm.) was dissolved in anhydrous hydrogen fluoride (30 ml.) in a loosely-stoppered polythene bottle, and the solution allowed to evaporate to dryness (about 48 hours). The residue was extracted with ether (75 ml.), and the ether solution washed successively with water, sodium carbonate and water again. It was then dried and evaporated to leave colourless needles (0·75 gm.) which were crystallised from methanol.

Yield = 0·57 gm.

m.p. = 162-163° (sublimes in "sword-blades").

$C_{17}H_{14}O$ requires : C = 87.2%, H = 6·0%

Found : C = 87·2%, H = 5·9%.

I.R. ν_{max} = 1670 $cm.^{-1}$

(b) Phosphorus pentoxide (30 gm.) was dissolved in phosphoric acid (25 ml.), cooled to 100° and 3-methyl-9-carboxyethylfluorene (1 gm.) added in portions. The mixture was warmed at 100° for 1 hour, then at 150° for 15 minutes, cooled and poured on ice. The resulting milky solution was extracted with four 25 ml. portions of benzene, and the combined extracts washed with sodium carbonate and water. The sodium carbonate washings yielded unchanged acid (0·2 gm.), and the benzene solution was dried and evaporated to leave a brown oil. This was dissolved in methanol, boiled with charcoal and filtered. On cooling, the filtrate deposited colourless needles.

Yield = 0·31 gm.

m.p. = 158-160°.

Mixed m.p. with product from (a) = 162-163°.

I.R. spectra identical.

(c) To 3-methyl-9-carboxyethylfluorene (0·25 gm.) in benzene (1 ml.) was added phosphorus pentachloride (0.25 gm.) and the mixture was warmed on the water-bath for 15 minutes. Stannic chloride (0·25 ml.) was added, and the purple solution warmed for 10 minutes, then left for 30 minutes at room temperature before pouring on a mixture of ice and concentrated hydrochloric acid. Ether was added, the layers separated, and the organic layer washed with water and sodium carbonate. The carbonate washings gave no unchanged acid, and the dried benzene/ether layer provided a solid which was crystallised from methanol.

Yield = 0·12 gm.

m.p. = 158-160°.

A mixed m.p. with the products from (a) and (b) was undepressed.

2-Methylfluoranthene

5-Methyl-1,2,3,10b-tetrahydro-3-oxofluoranthene (0·2 gm.) potassium hydroxide (0·05 gm.) and hydrazine hydrate (0·17 ml.) were refluxed in diethylene glycol for 15 minutes. The condenser was removed, until the temperature reached 205°, then replaced and refluxing continued for 1 hour. The cooled reaction mixture was poured on ice and hydrochloric acid, and the resulting oil extracted with ether. Evaporation of the

dried ether solution left 5-methyl-1,2,3,10b-tetrahydrofluoranthene (0·16 gm.) as a yellow oil, and this was used unpurified for the next stage: It was dissolved in benzene (2 ml.) and refluxed with tetrachloro-o-quinone (0·4 gm.) for 30 minutes, cooled and filtered from the precipitated quinol. The filtrate was chromatographed on alumina (8 gm.), and a colourless band with a bright blue fluorescence in U.V. light was eluted with petrol. This gave, on evaporation, colourless needles m.p. 74-77°. Recrystallisation from methanol raised the melting-point to 78-79°.

Lit. m.p. for 2-methylfluoranthene = 79-81°.

" " " 8-methylfluoranthene = 91-92°.

Mixed m.p. of product with 8-methylfluoranthene = 55-56°.

The picrate was prepared by heating equal quantities of the hydrocarbon and picric acid in ethanol.

Yellow needles, m.p. = 164-165°.

Lit. m.p. for 2-methylfluoranthene picrate = 163-165°

" " " 8-methylfluoranthene picrate = 156-157°.

4-Hydroxy-2-methylfluoranthene

5-Methyl-1,2,3,10b-tetrahydro-3-oxofluoranthene (0·17 gm.) and 30% palladium charcoal (0·02 gm.) were refluxed in 1-methylnaphthalene for 20 hours under nitrogen. The mixture was cooled, diluted with ether and filtered. Extraction of the filtrate with sodium hydroxide and acidification gave the crude phenol which was crystallised from benzene as yellow prisms.

Yield = 0·08 gm. (48%)

m.p. = 181-182°, resolidifying to needles m.p. >350°.

$C_{17}H_{12}O$ requires : C = 87·9%, H = 5·2%

Found : C = 90·4%, H = 5·1%.

4-Methoxy-2-methylfluoranthene

Diazomethane in ether was added to a solution of 4-hydroxy-2-methylfluoranthene (0·04 gm.) in ether until evolution of nitrogen ceased. The ether was removed leaving a yellow solid which was dissolved in benzene and chromatographed on alumina (2 gm.). A pale yellow band with a bright blue fluorescence in U.V. light was eluted with benzene, and yielded a yellow solid, crystallised from benzene-petrol as pale yellow sword-blades.

Yield = 0·02 gm.

m.p. = 138-139°.

$C_{18}H_{14}O$ requires : C = 87·8%, H = 5·7%

Found : C = 86·8%, H = 6·0%.

2,4-Dimethylfluoranthene

5-Methyl-1,2,3,10b-tetrahydro-3-oxofluoranthene (0·2 gm.) was added portionwise to a Grignard reagent prepared from magnesium (0·04 gm.) and methyl iodide (0·11 gm.) in ether (0·5 ml.). The resulting yellow complex was decomposed with concentrated hydrochloric acid to give a yellow solid, and this was boiled with formic acid (5 ml.) for 2 hours. The cooled reaction mixture deposited a white solid which was filtered off,

dried and crystallised from methanol as diamond shaped plates of 1,10b-dihydro-3,5-dimethylfluoranthene m.p. 79-80°. This was dissolved in benzene (1·5 ml.), and refluxed with tetrachloro-o-quinone (0·15 gm.) for 30 minutes. The cooled reaction mixture was filtered and chromatographed on alumina (8 gm.). Elution with benzene gave a pale yellow band with bright blue fluorescence in U.V. light which yielded an oil. This crystallised from ethanol as pale greenish sword-blades.

Overall Yield = 0·02 gm.

m.p. = 94-95°.

$C_{18}H_{14}$ requires : C = 93·9%, H = 6·1%

Found : C = 93·8%, H = 6·2%.

The picrate crystallised from ethanol as orange needles, m.p. 175-177° (softening at 169°).

$C_{24}H_{17}N_3O_7$ requires: C = 62·7%, H = 3·7%, N = 9·2%

Found : C = 62·2%, H = 3·8%, N = 7·8%.

Part 2

Synthesis of 3-bromofluorenone

Method (a):

2-(4-Bromobenzoyl)benzoic acid

Prepared by the method of Ullman and Sone, Ann., 380, 337 in 88% yield, m.p. 167-168°.

I.R.: ν_{max} = 1725, 1680 $cm.^{-1}$ (C:O) "Normal."

2-(4-Bromobenzoyl)benzoyl chloride

The acid (58 gm.) was refluxed with thionyl chloride until evolution of hydrogen chloride ceased, and the excess thionyl chloride removed by co-distillation with benzene to leave a colourless oil.

I.R. : ν_{max} = 1795 $cm.^{-1}$ (C=O) "Pseudo."

Methyl 2-(4-bromobenzoyl)benzoate

The chloride was warmed with methanol and cooled to give the ester, m.p. 112-113°.

I.R.: ν_{max} = 1730, 1680 $cm.^{-1}$ "Normal."

2-(4-Bromobenzoyl)benzamide

Excess concentrated ammonia solution was added in a slow stream to the chloride (60 gm.) dissolved in benzene (500 ml.), with vigorous stirring. After 30 minutes 2-(4-bromobenzoyl)-benzamide separated and was crystallised from ethanol as needles.

Yield = 52·2 gm. (90%)

m.p. = 213-214°.

A sample was crystallised three times from xylene:

m.p. = 218°.

$C_{14}H_{10}O_2NBr$ requires : C = 55·2%, H = 3·3%, N = 4·6%

Found : C = 55·5%, H = 3·2%, N = 4·1%.

I.R.: ν_{max} = 1720 $cm.^{-1}$ (C:O), 3500 $cm.^{-1}$ (OH), 3,300 $cm.^{-1}$ (NH).

The amide is therefore in the "pseudo"-form, i.e. 1-oxo-3-(4'-bromophenyl)-3-hydroxy-isoindolin.

When the reaction was carried out in the absence of solvent, the product was soluble in hot water, and melted at 184-185°D (colourless, feathery needles from ethanol). Acidification of its water solution gave the original acid m.p. 168-170°, showing that this compound is the ammonium salt.

2-(4-Bromobenzoyl)aniline

The amide (17·0 gm.), by the method of Miller and Bachman, J.A.C.S., 57, 2443 (1935) except that only 1·2 moles of bromine were used in making up the hypobromite solution, gave the aniline as yellow needles from ethanol. Some acid (4·0 gm.) was recovered from the alkali.

Yield = 9·5 gm. (81%, based on amide used).

m.p. = 107-108°.

3-Bromofluorenone

The aniline (10 gm.) was suspended in concentrated hydrochloric

acid (30 ml.) and water (150 ml.), cooled to 10°, and diazotised by the dropwise addition of sodium nitrite (2·6 gm.) in water (6 ml.). Solid separated which when crystallised from ethanol yielded 1·4 gm. of the bromoanthranil described below. The filtered diazonium solution was warmed on the water-bath and kept at 100° until evolution of nitrogen ceased. The yellow precipitate obtained on cooling was crystallised from ethanol to give 3-bromofluorenone.

Yield = 4·5 gm. (50%)

m.p. = 160-162°.

The ethanolic filtrate when reduced to 50 ml. deposited crude 4-bromo-2'-hydroxybenzophenone (2·0 gm.), m.p. 93-96°. Extraction of the crude phenol with 2N sodium hydroxide left 3-bromofluorenone (0·2 gm.), and acidification of the alkaline solution gave 1·3 gm. of the bromohydroxybenzophenone. m.p. 97-98° (Plates from ethanol).

$C_{13}H_9BrO_2$ requires: C = 56·3%, H = 3·3%, Br = 28·9%

Found : C = 56·2%, H = 3·3%, Br = 29·4%.

3-(4-Bromophenyl)anthranil

The benzamide (40 g.) described above was treated with sodium hypobromite as described by Miller and Bachman (loc.cit.), and the reddish precipitate thus obtained was dissolved in benzene and chromatographed on alumina (500 gm.). A red band was eluted with benzene to give the anthranil as pale yellow needles (from ethanol, then benzene).

Yield = 23 gm.

m.p. = 155° (subliming at 145°).

$C_{13}H_8BrNO$ requires: C = 56·9%, H = 2·9%, N = 5·1%, Br = 29·2%

Mol. Wt. = 274.

Found: : C = 56·9%, H = 2·5%, N = 5·3%, Br = 28·8%

Mol. Wt. = 254.

I.R.: ν_{max} = 1645 cm. (C:C or C:N).

U.V.: λ_{max} = 255*, 263, 350 mμ

log ε = 4·27, 4·34, 4·31. * = inflection

The anthranil in ethanol was added to an ethanolic solution of mercuric chloride and boiled for 1 minute. The cooled solution deposited the mercuric chloride adduct in pale yellow silky needles m.p. 222-223°D (from ethanol).

When the adduct was boiled briefly with charcoal in acetone and filtered, the filtrate yielded the anthranil quantitatively. This provides a convenient means of purification.

5(?)-Bromo-3-(4-bromophenyl)anthranil

During the crystallisation of the monobromo-anthranil from benzene, another, less soluble compound was isolated. m.p. 220-222°.

$C_{13}H_7Br_2NO$ requires: C = 44·5%, H = 1·8%, N = 4·0%, Br = 45·0%

Found : C = 44·2%, H = 2·3%, N = 4·0%, Br = 45·3%.

U.V.: λ_{max} = 257*, 264, 358 mμ

log ε = 4·36, 4·42, 4·16 * inflection.

It formed a mercuric chloride adduct m.p. 224-225°D

(Depressed when admixed with the adduct from the monobromo-anthranil).

3-Bromoacridone

3-(4-Bromophenyl)anthranil (0·1 gm.) was dissolved in concentrated sulphuric acid (10 ml.), cooled, and a few crystals of sodium nitrite were added with stirring. After 1 hour the mixture was poured into water, yielding 3-bromo-acridone, yellow needles from acetic acid.

Yield = 0·08 gm.

m.p. = >350° (subliming at 200°)

$C_{13}H_8BrNO$ requires : N = 5·1%, Br = 29·2%

Found : N = 5·2%, Br = 29·1%.

I.R.: ν_{max} = 1640, 1610, 1580, 1525 $cm.^{-1}$

cf. Acridone ν_{max} = 1632, 1596, 1570, 1530 $cm.^{-1}$

2(?),6-Dibromoacridone

The dibromoanthranil gave, by the above method, 2(?),6-dibromoacridone (≡ 3,7(?)-dibromo-acridone) as yellow needles, m.p. >350°, subliming at 280°.

Reduction of 3-(4-bromophenyl)anthranil to 2-(4-bromobenzoyl) aniline

The anthranil (0·2 gm.), zinc dust (2 gm.), calcium chloride (0·1 gm.), water (15 ml.) and ethanol (10 ml.) were refluxed for 2 hours with the addition of water (10 ml.) and ethanol (5 ml.) after 1 hour. The yellow solution was filtered, poured into

water, and the yellow precipitate extracted with benzene. Evaporation of the dried benzene layer left a yellow oil, which was dissolved in ethanol and cooled. Long needles of the anthranil separated first (0·05 gm.), then the concentrated solution deposited yellow needles of the amine. Extraction of the zinc with benzene gave 0.03 gm. of the anthranil.

Yield = 0·08 gm. (67%, based on anthranil used).

m.p. = 108-109°.

Method (b)

2-Amino-3-bromofluorenone

Fletcher, J.A.C.S., 78, 4812 (1956); Dickinson and Eaborn, J.C.S., 2337 (1959).

2-Aminofluorenone (60 gm.) gave 62 gm. of 3-bromo-2-amino-fluorenone m.p. 215-216°.

2-Acetamido-3-bromofluorenone

The acetyl-derivative was obtained by acetylation of the amine with acetic anhydride, and also by bromination of 2-acetamidofluorenone. Yellow blades from acetic acid.

m.p. = 248-250°

$C_{15}H_{10}O_2BrN$ requires: N = 4·4%, Br = 25·4%

Found : N = 4·5%, Br = 26·8%.

3-Bromofluorenone

The above bromoaminofluorenone (20 gm.) was warmed in 6N

sulphuric acid, the resulting suspension of the sulphate was cooled to 10°. Sodium nitrite (8 gm.) was added and the mixture vigorously stirred, but even at room temperature the reaction was incomplete. When warmed to 70°, however, solution was complete except for some tarry solid which was filtered off. The orange filtrate was cooled and excess hypophosphorous acid added, giving a voluminous yellow precipitate of crude 3-bromofluorenone. It was dried, dissolved in benzene and passed through a short column of alumina to remove phenolic matter. The concentrated benzene solution gave yellow irregular plates.

Yield = 13·9 gm. (73%)

m.p. = 160-162°.

When the reaction was carried out in 6N hydrochloric acid, the product contained a large amount of 3-chlorofluorenone.

2-Acetamido-3-chlorofluorenone

Prepared by chlorination of 2-acetamidofluorenone (Bell and Gibson, J.C.S., 113 (1938)). M.p. 260°.

2-Amino-3-chlorofluorenone

Hydrolysis of the acetamido-compound with ethanolic hydrochloric acid gave the amine quantitatively. The melting point was 207-208° (red needles from ethanol). Bell and Gibson (loc.cit.) give 189°.

$C_{13}H_8ONCl$ requires : N = 6·1%, Cl = 15·4%

Found : N = 5·9%, Cl = 15·1%.

3-Chlorofluorenone

The above chloroamine was deaminated in the same way as the corresponding bromo-compound, although either hydrochloric acid or sulphuric acid could be used in this case. 3-Chlorofluorenone was obtained as yellow blades from ethanol, m.p. 158-160° (Lit. 159°).

Reduction of 3-bromofluorenone to 3-bromofluorenol

(a) Clemmensen: c.f. Miller and Bachman, J.A.C.S., 57, 2448 (1935).

3-Bromofluorenone (1 gm.) in ethanol (30 ml.) was added over a period of 3 hours to refluxing hydrochloric acid (10 ml.), water (5 ml.) and amalgamated zinc (25 gm.), and the mixture boiled for a further 3 hours. The zinc was separated, washed twice with ethanol (5 ml.) and the washings added to the main solution. Addition of water gave 3-bromofluorenol.

Yield = 0·7 gm.

m.p. and mixed m.p. = 171-172°.

$C_{13}H_9BrO$ requires: C = 59·7%, H = 3·5%, Br = 30·6%

Found : C = 59·7%, H = 3·5%, Br = 30·6%.

Increasing the reaction time to 22 hours gave essentially the same results.

(b) Zinc and ammonia: Orchin and Woolfolk, J.A.C.S., 67, 124 (1945)

3-Bromofluorenone (0·5 gm.), zinc dust (2 gm.), ethanol (20 ml.) and concentrated ammonia solution (3 ml.) were refluxed for 3 hours. The mixture was filtered, poured into water, and the

resulting white precipitate dried. Crystallisation from benzene-petrol gave colourless needles.

Yield = 0·27 gm. (56%)

m.p. = 168-170°.

Unchanged starting material (0·02 gm.) was recovered from the filtrate.

(c) Sodium borohydride: Fletcher, J.Org.Chem., 23, 799 (1958).

3-Bromofluorenone (3·6 gm.) was suspended in methanol (200 ml.) and sodium borohydride (0·27 gm.) added portionwise with vigorous stirring. After 30 minutes, the clear (almost colourless) solution was poured into water (200 ml.) giving a bulky white precipitate. This was filtered, dried, and crystallised from benzene-petrol.

Yield = 3·5 gm. (97%)

m.p. = 171-172°.

It should be noted that the melting point for 3-bromofluorenol given by Miller and Bachman (loc.cit.) 142-145°, is erroneous.

Reduction of 3-bromofluorenol to 3-bromofluorene

3-Bromofluorenol (10 gm.), red phosphorus (10 gm.) and iodine (10 gm.) in acetic acid (250 ml.) and water (25 ml.) were boiled vigorously for 1 hour. The cooled mixture was filtered and poured into aqueous sodium thiosulphate to give a solid which was chromatographed in benzene on alumina (400 gm.). Development with petrol yielded 3-bromofluorene as colourless

plates.

Yield = 6.9 gm. (70%)

m.p. = 87-88°.

If the phosphorus was not thoroughly dispersed by vigorous boiling, the yield was greatly decreased, and unchanged 3-bromofluorenol resulted along with another product, probably 3-bromo-9-iodofluorene, m.p. 135-137°D.

$C_{13}H_8BrI$ requires : Br = 21·6%, I = 34·2%

Found : Br = 23·2%, I = 33·4%.

When refluxing was continued beyond 1 hour, yet another product was obtained, as pale yellow prisms m.p. 115-117°. A mixed melting point with fluorene m.p. 113° was depressed.

Reduction of 3-bromofluorenone to 3-bromofluorene

(a) 3-Bromofluorenone (0·1 gm.), sodium hydroxide (0·03 gm.), 85% hydrazine hydrate (0·1 ml.), and diethylene glycol (0·6 ml.) were refluxed for 30 minutes. Fluorene, m.p. 116°, gathered in the condenser. The condenser was removed and the temperature of the mixture allowed to reach 205°. Refluxing was continued for 30 minutes, then the solution poured into water and the resulting precipitate extracted with benzene and chromatographed on alumina. Development with benzene gave first a little fluorene and then a pale yellow band which yielded 3-bromofluorene as colourless plates.

Yield = 0·02 gm.

m.p. = 84-86°.

2-Bromofluorenone, by the same method gave a 70% yield of 2-bromofluorene m.p. 110-111°, along with some less soluble material m.p. 270°, probably 2,2'-dibromobifluorenyl (Lit. m.p. = 272°).

(b) Under the same conditions, but without any alkali, 3-bromofluorenone gave 3-bromofluorene m.p. 87-88°, in 60% yield.

Reduction of fluorenones by method (b)

Fluorenone gave a 99% yield of fluorene, while 2-bromo-, 3-chloro- and 3-methylfluorenones gave 90% yields of the corresponding fluorenes.

2-Acetylfluorenone (0·5 gm.) under the same conditions but with twice the usual quantity of hydrazine yielded a mixture which was decomposed by potassium hydroxide in boiling diethylene glycol to give 2-ethylfluorene m.p. 80° (0·36 gm.) which when chromatographed in petrol on alumina melted at 98° (Sawiki, J.A.C.S., 76, 2269 (1954) reports 99·5-100·5°). The mixture was also decomposed by sodium dichromate in acetic acid in the cold to give 2-ethylfluorene and a little 2-ethyl-fluorenone.

Methyl fluorenone-4-carboxylate (1 gm.) gave 0·75 gm. of a product with an indefinite m.p. about 160°, probably a hydrazone-hydrazide, which dissolved in sodium hydroxide with effervescence to produce a nitrogen-containing acid m.p. 250-252°. This reacted vigorously with sodium dichromate in the cold, and dilution with water gave fluorene-4-carboxylic acid (0·32 gm.),

m.p. and mixed m.p. with an authentic sample = 186-187°. The decomposition was better effected by boiling with potassium hydroxide in diethylene glycol.

Benzophenone yielded only the hydrazone as colourless needles m.p. 95-97° (Lit. 98°) which with sodium dichromate and acetic acid gave a mixture of diphenylmethane and benzophenone. Method (a) in this case gave an excellent yield of diphenylmethane.

3-Cyanofluorene

c.f. Friedman, J. Org. Chem., 26, 2522 (1961).

3-Bromofluorene (0·5 gm.), freshly prepared cuprous cyanide (0·3 gm.) and dimethylformamide (0·5 ml.) were refluxed for 4 hours. The reaction mixture was poured into a solution of ferric chloride (0·8 gm.) in concentrated hydrochloric acid (0·2 ml.) and water (1·2 ml.), kept at 60-70° for 20 minutes and filtered. The precipitate was dissolved in benzene and washed successively with dilute hydrochloric acid, water and sodium hydroxide; then the benzene was evaporated to leave 0·35 gm. crude oil. This was crystallised from benzene-petrol as colourless prisms.

Yield = 0·20 gm. (50%)

m.p. = 93-94°.

A further crystallisation from petrol raised the melting-point to 94-95°.

$C_{14}H_9N$ requires : N = 7·3%

Found : N = 6·9%.

I.R.: ν_{max} = 2,200 $cm.^{-1}$ (CN).

Fluorene-3-carboxylic acid

The above nitrile (0·1 gm.) was hydrolysed with acetic acid: water: concentrated sulphuric acid mixture (3 ml.) and poured into water to give fluorene-3-carboxylic acid, crystallised from acetic acid.

Yield = 0·06 gm.

m.p. = 228° (Lit. 230°).

Attempted condensation of 3-bromofluorene with dimethyl oxalate

c.f. Dickinson and Eaborn, J.C.S., 2337 (1957).

3-Bromofluorene (1·0 gm.) and dimethyl oxalate (2 gm.) were added to a solution of potassium (0·5 gm.) in methanol (25 ml.). After 15 minutes, the methanol was distilled off slowly (30 minutes), the pressure reduced, and other liquids taken off during 15 minutes. The remaining sticky orange solid was dissolved in acetic acid (15 ml.) to give a light yellow solution. Concentrated sulphuric acid (3 ml.) and water (15 ml.) were added, and the mixture boiled for 30 minutes, then cooled. Hydrogen peroxide (30%, 10 ml.) was added, and the solution stirred overnight. Addition of water gave a yellow precipitate which was dissolved in ether and the ether extracted with sodium carbonate solution. Acidification gave a small precipitate of 3-bromo-9-carboxyfluorene m.p. 222-224°D (from aqueous acetic acid). The ether layer gave a yellow solid, crystallised from alcohol m.p. 160-162° (Lit. m.p. for 3-bromofluorenone = 162°).

By the same method, 2-bromofluorene gave a 30% yield of 2-bromo-9-carboxyfluorene m.p. 226°D, as reported by Dickinson and Eaborn (loc.cit.).

3-Bromo-9-carboxyfluorene

Lithium (0·15 gm.), cut into small pieces, was dropped into anhydrous ether (6 ml.) in a nitrogen atmosphere. Bromobenzene (1·65 gm.) in ether (10 ml.) was added slowly, and the reaction started by warming. After 1 hour, most of the lithium had dissolved, and the reaction was completed by refluxing for 30 minutes. The mixture was filtered through a glass plug into an ethereal solution of 3-bromofluorene (2·0 gm.) to give a brown solution with evolution of heat. This was added carefully to a slurry of ether and solid carbon dioxide, then left overnight to evaporate. The remaining solid was shaken with ether and water, and the layers separated. The ethereal layer was evaporated to leave a red oil containing biphenyl, and the aqueous layer on acidification yielded 3-bromo-9-carboxyfluorene, as colourless needles from aqueous alcohol.

Yield = 1·1 gm. (46%)

m.p. = 224-226°D.

A sample was recrystallised from aqueous acetic acid, then sublimed. M.p. = 234-235°D.

$C_{14}H_9O_2Br$ requires: C = 58·1%, H = 3·1%, Br = 27·7%

Found : C = 58·0%, H = 3·8%, Br = 27·1%.

3-Bromo-9-carbomethoxyfluorene

The acid (2 gm.) was warmed with methanol saturated with hydrogen chloride to give the ester as long, colourless needles (from methanol).

Yield = 1·8 gm. (89%)

m.p. = 105·5-106°.

$C_{15}H_{11}O_2Br$ requires : C = 59·4%, H = 3·6%, Br = 26·4%

Found : C = 58·6%, H = 3·9%, Br = 23·2%, 25·6%.

3-Chloro-9-carboxyfluorene

Prepared in the same way as the bromo-analogue, m.p. 225-228°D. Sublimation raised the melting-point to 228-230°D.

3-Chloro-9-carbomethoxyfluorene

Esterification of the above acid with methanol gave long, colourless needles.

Yield = 90%

m.p. = 112-113°.

$C_{15}H_{11}O_2Cl$ requires : Cl = 13·7%

Cl = 13·2%.

Reaction of 3-bromo- and 3-chloro-9-carbomethoxyfluorenes with acrylonitrile, followed by hydrolysis

c.f. Campbell and Tucker, J.C.S., 2623 (1949).

The ester (0·5 gm.), then acrylonitrile (0·11 ml. = 0·09 gm.) were added to potassium hydroxide (0·03 gm.) in 2-methoxyethanol

(3 ml.). After 15 minutes at 100°, potassium hydroxide (10N, 5 ml.) and 2-methoxyethanol (3 ml.) were added, and the mixture refluxed for 30 minutes. Dilution of the cooled solution with water discharged the green colour, but produced no precipitate; and acidification yielded a white solid which was dissolved in benzene. Addition of petrol precipitated a white powder. Yield = 0·41 gm. In both cases the product melted at 178-180°, after crystallisation from benzene-petrol (colourless plates). A mixed melting-point showed a distinct depression.

$C_{19}H_{17}O_4Br$ requires: C = 58·6%, H = 4·4%, Br = 20·6%

Found : C = 60·1%, H = 4·7%, Br = 19·0%.

$C_{19}H_{17}O_4Cl$ requires: C = 66·2%, H = 5·0%, Cl = 10·3%

Found : C = 68·3%, H = 5·4%, Cl = 13·1%.

I.R. (Both acids): ν_{max} = 1730 $cm.^{-1}$ (C=O).

The analyses indicate that condensation with two molecules of acrylonitrile has occurred to give 3-bromo- and 3-chloro-9,9-bis(2'-carboxyethyl)fluorenes, although the products are impure. In a second experiment, the solution after 15 minutes at 100° was diluted with water, and extracted with ether. Evaporation of the dried ether layer left unchanged starting material, showing that no condensation had occurred before this stage.

Reaction of 3-chlorofluorene with acrylonitrile

By the above procedure, 3-chlorofluorene gave the same acid as that obtained from 3-chloro-9-carbomethoxyfluorene, and since more material was available in this case, the acid was

crystallised several times from toluene. M.p. = 189-190°, colourless plates.

I.R.: ν_{max} = 1730 $cm.^{-1}$

U.V.: λ_{max} = 227, 234, 267, 297, 308 mμ

log ϵ = 4·26, 4·05, 4·10, 3·70, 3·95.

M.W. from neutralisation equivalent = 388

Required M.W. = 345

Reaction of fluorene with acrylonitrile

c.f. Bruson, J.A.C.S., 64, 2457 (1942).

By the same procedure, fluorene gave an acid, m.p. = 274-276°. Lit. m.p. for 9,9-bis(2'-carboxyethyl)fluorene is 273-274°.

I.R.: ν_{max} = 1730 $cm.^{-1}$ (C:O)

Methyl 4-oxo-spiro[cyclohexane-1,9'-fluorene]-3-carboxylate

Stauffer and Fancher, J. Org. Chem., 25, 935 (1960).

The above acid was converted into its dimethyl ester, m.p. 83-84° (plates) and the latter (0·25 gm.) was cyclised by a Dieckmann condensation to the keto-ester.

Yield = 0·15 gm.

m.p. = 119-121°.

I.R.: ν_{max} = 1670 $cm.^{-1}$ (C:O) and 1625 $cm.^{-1}$ (C:C).

4-Oxo-spiro[cyclohexane-1,9'-fluorene]

Hydrolysis of the keto-ester (0·1 gm.) with acetic acid (0·5 ml.) and concentrated hydrochloric acid (0·25 ml.) gave

the spiro-ketone as colourless plates from ethanol.

Yield = 0·06 gm.

m.p. = 190-200° (crude).

Another crystallisation from ethanol reduced the yield to 0.03 gm., and raised the m.p. to 206-208° (Lit. 209-210°).

I.R.: ν_{max} = 1705 $cm.^{-1}$ (C:O).

Esterification of the chloro-acid m.p. 189-190°

The acid was refluxed briefly with methanol containing a trace of concentrated sulphuric acid, and cooled, to give the methyl ester, m.p. 65-66° (from methanol).

I.R.: ν_{max} = 1735 $cm.^{-1}$ (C:O).

N.M.R.: Aromatic H, 2·35, 2·70 τ; Methyl H, 6·60 τ;
Methylene H, 7·60, 8·5 τ (Relative to T.M.S.).
Integral ratios: 5,2; 6; 4,4.

c.f. 9-(2'-Carbomethoxyethyl)fluorene:-
Aromatic H, 2·70 τ; Methyl H, 6·50 τ;
Methylene H, 7.70, 8.10 τ; Fluorene-9H, 6·00 τ.
Integral ratios: 8; 3; 2,2; 1.

The ester was cyclised as for the chlorine-free compound to give an oil which crystallised on trituration with methanol.

M.p. = 88-90°.

I.R.: ν_{max} = 1670 $cm.^{-1}$ (C:O) and 1625 $cm.^{-1}$ (C:C).

Hydrolysis of the above compound also resulted in decarboxylation, giving a ketone, crystallised from ethanol, m.p. 180-183° (crude).

I.R.: ν_{max} = 1705 $cm.^{-1}$ (C:O).

A further crystallisation from ethanol raised the melting point to 195°.

3-Bromo-9-carbomethoxy-9-(2'-cyanoethyl)fluorene

3-Bromo-9-carbomethoxyfluorene (1·5 gm.) was dissolved in a solution of sodium (0·06 gm.) in dry methanol (5 ml.), then acrylonitrile (0·33 ml.) added and the mixture kept at 60° for 2 hours. The methanol was distilled off, the residue shaken with ether and water, and the layers separated. The ether layer was washed with water, dried, and evaporated to leave a clear oil which solidified when scratched. It crystallised from methanol as colourless needles.

Yield = 1·2 gm. (67%)

m.p. = 115-117°.

Recrystallisation from methanol raised the melting-point to 117.5-118.5°.

$C_{18}H_{14}O_2NBr$ requires: C = 60·6%, H = 3·9%, N = 3·9%, Br = 22·5%.

Found : C = 60·9%, H = 3·9%, N = 3·6%, Br = 21·8%.

I.R.: ν_{max} = 2,250 $cm.^{-1}$ (C:N), 1725 $cm.^{-1}$ (C:O).

3-Bromo-9-(2'-carboxyethyl)fluorene

The above cyano-ester (1·05 gm.), potassium hydroxide (10N, 7 ml.) and 2-methoxyethanol (11 ml.) were refluxed for 30 minutes. Dilution with water discharged the green colour, and acidification gave a yellowish solid. Washing with petrol (b.p. 40-60°) removed the yellow impurity, and the residue was crystallised

from aqueous methanol.

Yield = 0·7 gm. (74%)

m.p. = 160-161°.

A further crystallisation from aqueous methanol raised the melting point to 161-161·5°.

$C_{16}H_{13}O_2Br$ requires: C = 60·6%, H = 4·1%, Br = 25·2%

Found : C = 60·7%, H = 4·3%, Br = 24·6%.

I.R.: γ_{max} = 1705 $cm.^{-1}$ (C=O).

8-Bromo-1,2,3,10b-tetrahydro-3-oxofluoranthene

The above acid (0·6 gm.) was left in anhydrous hydrogen fluoride (30 ml.) for 24 hours in a stoppered polythene bottle, then allowed to evaporate to dryness. The residue was dissolved in ether, and washed successively with water, sodium carbonate and water again. The sodium carbonate washings gave an acidic oil on acidification (0·25 gm.) I.R.: γ_{max}= 1700, 1730 $cm.^{-1}$, and the ether layer on evaporation left a white solid which crystallised from methanol as colourless sword-blades.

Yield = 0·21 gm. (34%)

m.p. = 173-174°.

$C_{16}H_{11}OBr$ requires: C = 64·1%, H = 3·7%, Br = 26·8%

Found : C = 64.3%, H = 4·0%, -

I.R.: γ_{max} = 1685 $cm.^{-1}$ (C:O).

6-Bromofluorenone-1-carboxylic acid

The above ketone (0·05 gm.) was refluxed in acetic acid (1 ml.) with chromic anhydride (0·05 gm.) for 1 hour, and the

mixture poured into water. The resulting orange precipitate was filtered, and crystallised from acetic acid.

m.p. = 248-250° (sublimes).

Mixed m.p. with an authentic specimen m.p. 253·5°, = 251-253°.

8-Bromo-3-hydroxyfluoranthene

The ketone (0·14 gm.) and 30% palladium charcoal (0·02 gm.) were refluxed in 1-methylnaphthalene for 24 hours in a current of nitrogen. The mixture was then cooled, diluted with ether and filtered. Extraction of the filtrate with 2N sodium hydroxide followed by acidification yielded a yellow precipitate which crystallised from benzene-petrol as yellow needles.

Yield = 3 mg.

m.p. = 185-190°, resolidifying to needles m.p. >350°.

8-Bromo-3-methoxyfluoranthene

The above bromo-phenol (2 mg.) was treated with diazomethane in ether until nitrogen evolution ceased. The ether was distilled off and the residue dissolved in benzene and chromatographed on a miniature column of alumina. Petrol eluted a pale yellow, fluorescent band which yielded a trace of material m.p. 140-145°. Several micro-sublimations raised the m.p. to 145-146° (rosettes).

8-Amino-3-methoxyfluoranthene

8-Nitro-3-methoxyfluoranthene (0·25 g.) and stannous chloride (1 gm.) were refluxed in acetic acid (4 ml.) and

hydrochloric acid (2 ml.) for 1 hour. The solution was filtered hot, cooled in ice, and the amine hydrochloride which separated was filtered off and washed with water. The free amine was obtained by stirring the salt in 2N sodium hydroxide, and crystallised from ethanol as orange-yellow plates.

Yield = 0·1 gm.

m.p. = 185-190°.

A further crystallisation from ethanol, then one from benzene-petrol raised the melting-point to 200-202°.

$C_{17}H_{13}ON$ requires: N = 5·7%

Found : N = 5.7%

Sandmeyer reaction on 8-amino-3-methoxyfluoranthene

The amine m.p. 185-190° (50 mg.) was dissolved in the minimum quantity of acetic acid, and concentrated hydrobromic acid (0·2 ml., 40%) added. The amine dissolved, and the hydrobromic acid salt separated a few minutes later. The suspension was cooled to 0° and diazotised with sodium nitrite (20 mg.) in water (0.5 ml.). After 45 minutes, a little urea was added and the mixture filtered quickly, then added dropwise to a solution of freshly-prepared cuprous bromide (25 mg.) in hydrobromic acid (1 ml.) and water (1 ml.) at 40°. The resulting solid was extracted with hot benzene and washed successively with sodium hydroxide, sodium bisulphite solution, and concentrated sulphuric acid. Finally, the benzene layer was washed with water, dried and evaporated to leave a trace

of yellow solid which sublimed in a micro-sublimation apparatus to give yellow needles.

M.p. and mixed m.p. with 8-bromo-3-methoxyfluoranthene obtained above = 145-146°.

Bromination of 3-methoxyfluoranthene

Bromine (0·07 gm.) in acetic acid (3 ml.) was added to 3-methoxyfluoranthene (0·2 gm.) in acetic acid (5 ml.) at 60°. The yellow needles which separated on cooling were recrystallised from acetic acid, then benzene/petrol.

Yield = 0·18 gm. (67%)

m.p. = 166-167°.

Mixed melting-points with samples of monobromo- obtained by the other two routes were depressed.

$C_{17}H_{11}OBr$ requires : C = 65·5%, H = 3·55%, Br = 25·8%
$C_{17}H_{10}OBr_2$ " : C = 52·4%, H = 2·6%, Br = 41·0%
Found : C = 52·4 %, H = 2·7 %, Br = 41·0 %.

Oxidation of 3,8-di-bromo-3-methoxyfluoranthene with chromic acid.

This was carried out in the usual way. Crystallisation of the crude product from acetic acid (charcoal) removed some red impurity and gave yellow needles which were further purified by sublimation, m.p. 256-257° (Lit. 253·5°).

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ACKNOWLEDGEMENTS

The author would like to take this opportunity to express his indebtedness to Dr. Neil Campbell, O.B.E. for his friendly encouragement and advice, in matters both chemical and non-chemical, during the course of this research.

Thanks are also due to the Department of Scientific and Industrial Research for a maintenance grant and to the University of Edinburgh for the provision of laboratory facilities.