PART A

STUDIES OF 1-SUBSTITUTED FLUORANTHENES

PART B

SYNTHESIS OF SOME 3,6-DISUBSTITUTED FLUORENONES

By

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ABSTRACT

PART A

1-Nitro-, 1-acetamido- and 1-bromofluoranthene unlike the corresponding 2- and 3-substituted fluoranthenes all dibrominate in positions 4 and 9. The theoretical implication of this has been discussed. With excess bromine and heat on 1-nitrofluoranthene, six bromines entered the structure and the nitro group was completely lost. 1-Acetamido- and 1-bromofluoranthene tribrominate in positions 4,8 and 9. Side chain bromination of 1-acetamidofluoranthene was accomplished using pyridine hydrobromide perbromide. Both 1-bromo- and 1-hydroxyfluoranthene have been synthesized from the amine through diazonium reactions. 3-Acetamidofluoranthene was found to brominate in position 2 in carbon tetrachloride just as it did in acetic acid and in carbon tetrachloride: acetic acid 1:2.

1-Nitro- and 1-acetamidofluoranthene have been nitrated to give dinitro derivatives. A mono nitro derivative was also obtained in the case of the acetamido compound. The orientations of these compounds have not been rigidly established. New amino and acetamido compounds have been derived from these. During the course of this work, twenty-one new compounds have been synthesized.

PART B

Following the scheme of Charlesworth and Mathiaparanam (1) for the synthesis of 3,6-disubstituted unsymmetrical fluorenones, the synthesis of 3-chloro-6-nitrofluorenone and 3-fluoro-6-nitrofluorenone have been accomplished. In the process, twelve intermediate compounds have been synthesized. 4-Iodo-2-methyl-4'-benzophenone and 5-acetamido-2-(p-nitrobenzoyl)-benzoic acid have also been synthesized but the above scheme did not achieve the synthesis of 3-iodo-6-nitrofluorenone. Alternate schemes have been proposed. During the course of this work, 16 new compounds have been synthesized.

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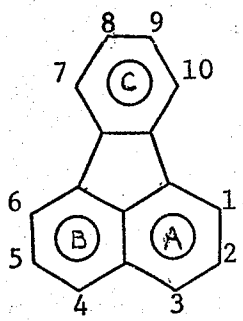
PART A

STUDIES OF 1-SUBSTITUTED FLUORANTHENES

INTRODUCTION

The directive properties of substituents in the fluoranthene nucleus have provided exciting though formidable research over the past twenty years. Even as late as 1964 R.D. Brown (1) in a discussion of non-alternant hydrocarbons concluded that fluoranthene deserves closer study, both theoretically and experimentally. Much work has been done on the further substitution of 3-substituted fluoranthenes. In this laboratory over the past five years, similar studies have been done on 2- as well as 3-substituted fluoranthenes.



In 1955 Campbell and Keir (2) found that 3-carboxy, 3-carbomethoxy, 3-cyano and 3-nitrofluoranthene were all brominated in position 9, and that direct sulfonation of fluoranthene gave 3,9-fluoranthenedisulfonic acid. These reations coupled with the fact that bromination of 3-bromofluoranthene gave 3,8-dibromofluoranthene caused them to draw an analogy to disubstitution in monosubstituted diphenyl, and postulate that a meta-directing group in ring A of fluoranthene would direct a second substituent

to position 9, and that an ortho-para directing group in the same ring would direct a second substitutent to position 8. This was shown to be an oversimplification since Kloetzel et al. (3) in 1956 found that 3-acetamidofluoranthene was nitrated in position 2 rather than in position 8. They suggested, that in this case, substitution occurred in the same ring because the acetamido group is a highly activating substituent. Charlesworth and Blackburn (4) further substantiated this by demonstrating that 3-acetamido and 3-aminofluoranthene were brominated in position 2.

Charlesworth and Dolenko(I9) showed that 2-nitrofluoranthene undergoes bromination in position 9, whereas 2-acetamidofluoranthene brominates in position 3. Recently Charlesworth and Lithown(30) showed that nitration of 3-nitro and 3-acetamidofluoranthene occurred in the 9 and 2 positions respectively.

From the foregoing it can be seen that nitration goes the same way as bromination whether the initial substituents were in the 3 or 2-positions. Furthermore a mono substituted fluoranthene has never been found to substitute into ring B of the fluoranthene nucleus.

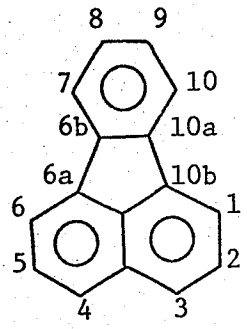
Up to this point further substitution of the final position in ring A (i.e. 1-substituted fluoranthenes) had never been reported. Wilshire (personal communication) attempted nitration of 1-nitrofluoranthene, but was unable to isolate any useful products. It seemed therefore particularly desirable to brominate (and possibly nitrate) 1-nitro-, 1-acetamido- and 1-bromofluoranthene. These substituents were chosen because of their interesting directive properties. The nitro group is highly deactivating and meta directing, whereas near the opposite end of the activity scale the acetamido group is highly activating and ortho-para

directing. The bromo group occupies a unique position in that it is slightly deactivating but ortho-para directing.

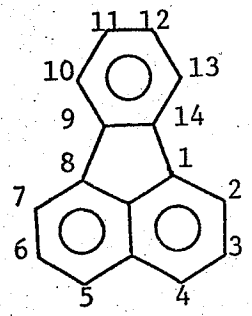
As can be observed from earlier paragraphs (also Table II page 40) much work had been done on further bromination of 2- and 3-nitro, 2- and 3-acetamido and 2- and 3-bromofluoranthenes. Somewhat less has been reported on nitration of the corresponding compounds. The products from the reactions of the 1-substituted fluoranthenes would be isolated, their orientations established and the results compared with analogous reactions of the substituents in the 2 and 3 positions. One might expect similar behavior in further substitution regardless of whether the initial substituents were in positions 1,2 or 3. Experimentation, however, proved otherwise.

LITERATURE SURVEY*

The structure of fluoranthene, a colorless crystalline hydrocarbon of molecular formula $C_{16}H_{10}$ and melting at 109.5 - 110.5° is depicted below. The numbering system in formula 1a is now used almost



1a



1b

exclusively throughout the world. The numbering system in 1b is in accordance with the Richter system of notation and until quite recently was used by most European chemists. The notation in 1a will be used throughout this thesis. It is both interesting and informative to note that the following hydrocarbon molecules can be discerned in the fluoranthene structure: benzene, naphthalene, fluorene, indan, acenaphthene, diphenyl and cyclopentane.

Fluoranthene was discovered independently by Fittig and Gebhard (6) and by Goldschmiedt (7) in 1877. Goldschmiedt obtained fluoranthene by fractional distillation and crystallization of a mixture of hydrocarbons

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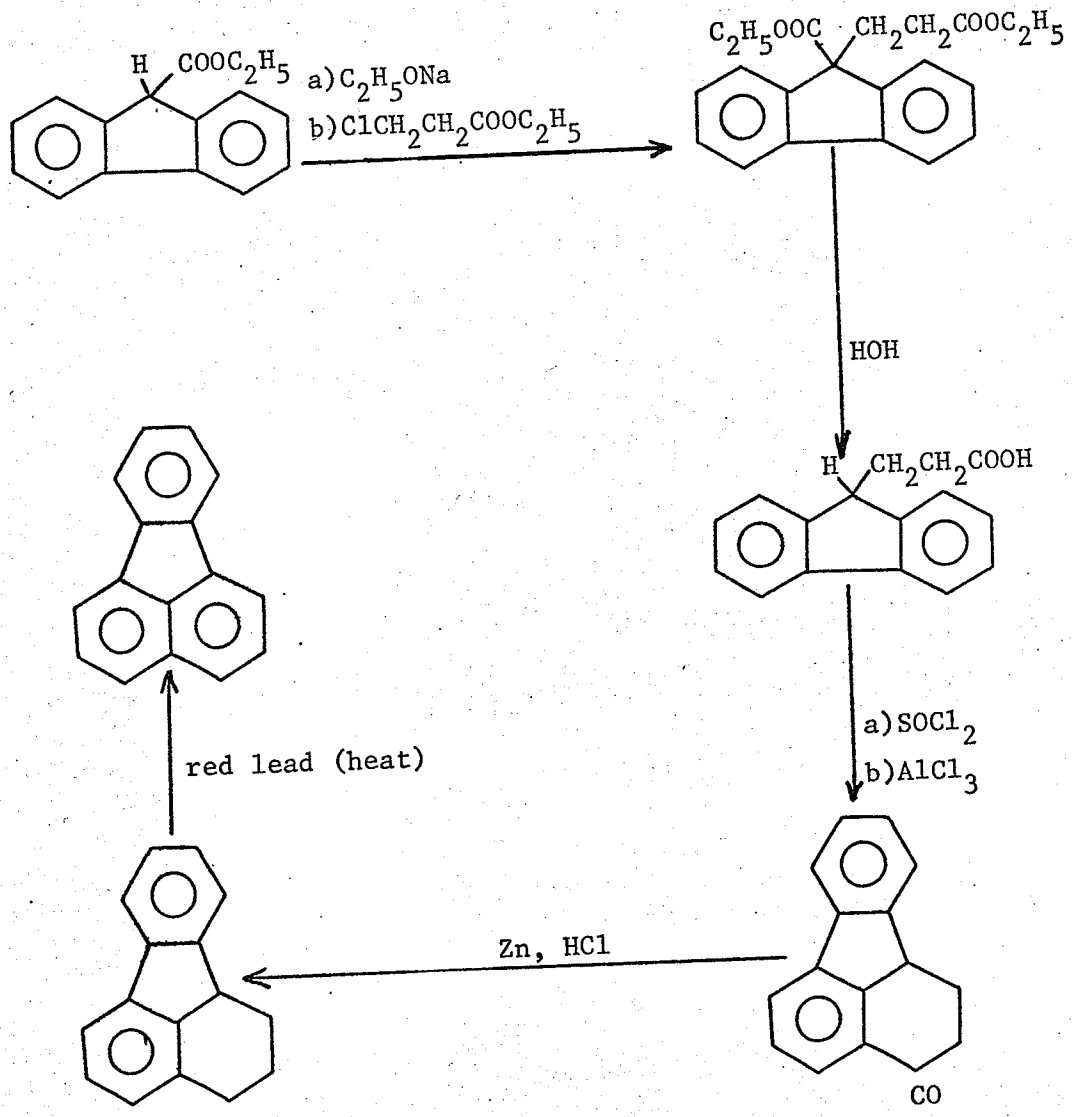
* An excellent review of fluoranthene chemistry up to 1951 is contained in reference (5).

known as idrialene which had previously been obtained by extraction of the mercury ores of Idria by Dumas (8) and Laurent (9). Fittig and Gebhard isolated fluoranthene from the high boiling fraction of coal tar. Little interest was shown in the compound until 1929 when von Braun and Anton (10) proved the structure of fluoranthene by synthesis from ethyl-9-fluorenecarboxylate and β-chloroethylpropionate. This is illustrated below.

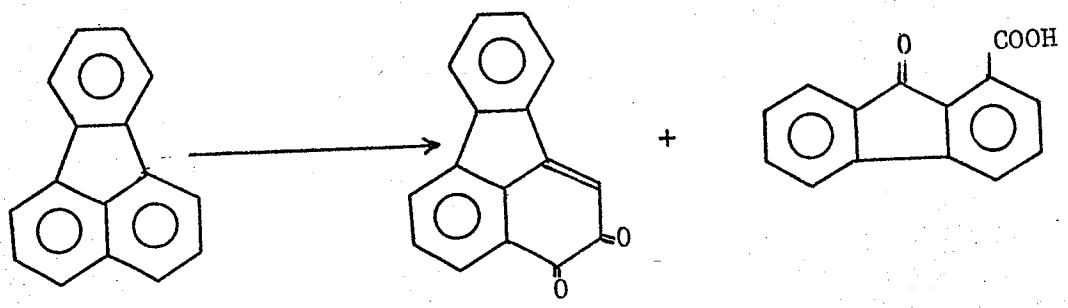


Addition Compounds of Fluoranthene (11, 12, 13)

Fluoranthene closely resembles naphthalene and pyrene in its propensity for forming molecular complexes with nitro compounds. These complexes, often used for characterization, include the picrate, m.p. 185 - 186°; the 1,3,5-trinitrobenzene complex, m.p. 205-206°; the 1,3-dinitrobenzene complex, m.p. 77°; the 2,4-dinitrotoluene complex, m.p. 75.5° and several others.

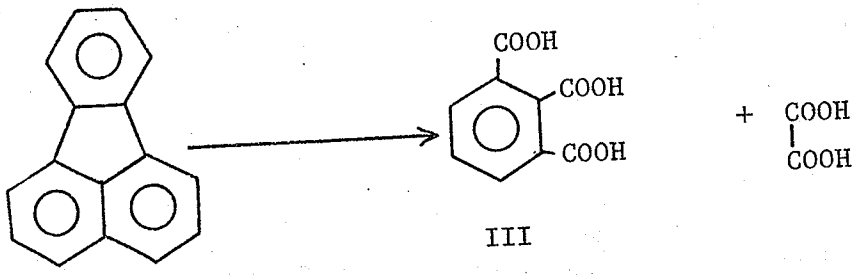
Oxidation of Fluoranthene (5)

The products of oxidation of fluoranthene vary greatly with the oxidizing conditions. Oxidation with potassium chromate in dilute sulfuric acid and chromic anhydride or potassium chromate in acetic acid yields 2,3-fluoranthenequinone (I) and 1-fluorenonecarboxylic acid (II) as the principal products. II is also produced in good yield with chromic

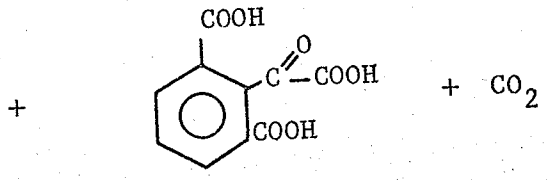


I II

anhydride in acetic acid or with aqueous permanganate as was found by this author. Prolonged treatment with alkaline permanganate yields hemimellitic acid (III), oxalic acid, carbon dioxide, with some 2,6-dicarboxyphenyl-glyoxylic acid (IV).

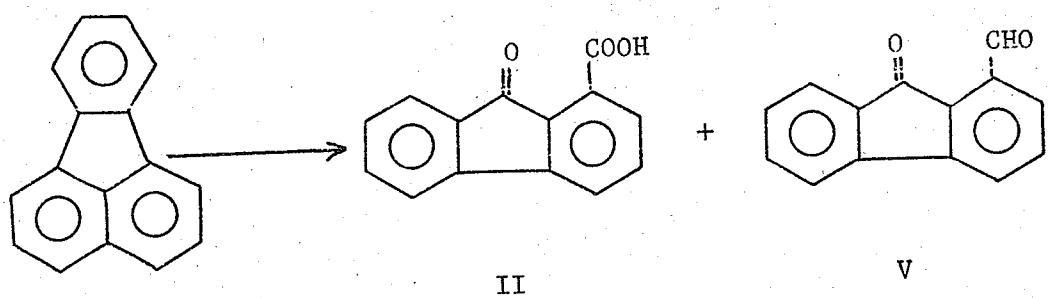


III



IV

Ozonolysis in glacial acetic acid gives a mixture of 1-fluorenonecarboxylic acid (II) and 1-fluorenonealdehyde (V).

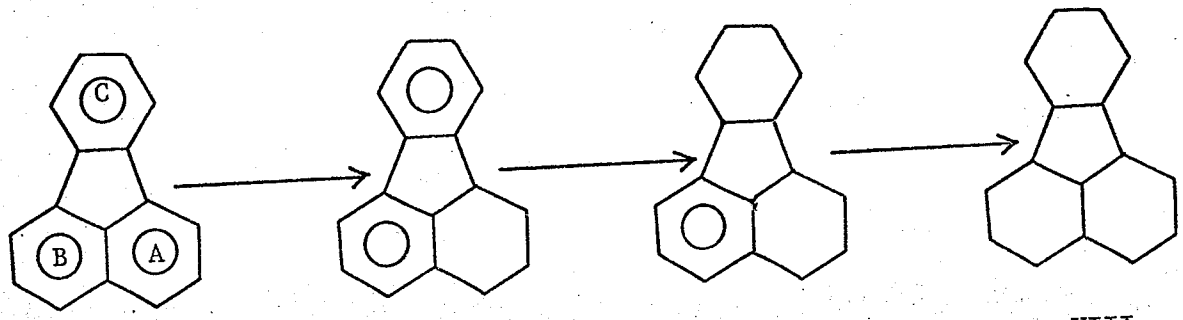


II V

Reduction of Fluoranthene

Goldschmiedt (13) in 1880 prepared hydrogenated derivatives of fluoranthene but was unable to characterize the products obtained. In a detailed investigation completed in 1930, von Braun and Manz (14) reported that reduction of the hydrocarbon with sodium amalgam and alcohol, or with phosphorus and hydriodic acid below 180°, gave almost a quantitative yield of 1,2,3,10b-tetrahydrofluoranthene (VI). Above 200°, they obtained an inseparable mixture of products. Catalytic hydrogenation of fluoranthene under pressure using 20% palladium-charcoal as catalyst, gave VI as the

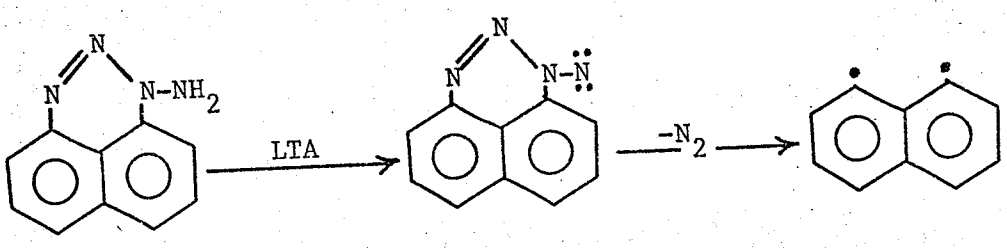
initial product (71). Further hydrogenation produced 1,2,3,6b,7,8,9, 10,10a,10b-decahydrofluoranthene (VII) and perhydrofluoranthene (VIII).



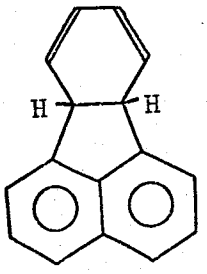
VI VII VIII

The addition of hydrogen to the fluoranthene nucleus therefore occurs in such a way that ring A is hydrogenated first, then ring C and finally ring B. Perhydrofluoranthene (VIII) is dehydrogenated at 450° with chrome-alumina catalyst to give fluoranthene as the principal product together with some partially hydrogenated fluoranthenes (probably VII and VI).

Recently (54) a novel method has been reported for the synthesis of 6b,10a-dihydrofluoranthene which cannot be obtained by hydrogenation of fluoranthene. Oxidation of 1-aminonaphthotriazine with lead tetra-acetate (LTA) is believed to form a nitrene, fragmentation of which could form 1,8-dehydronaphthalene.

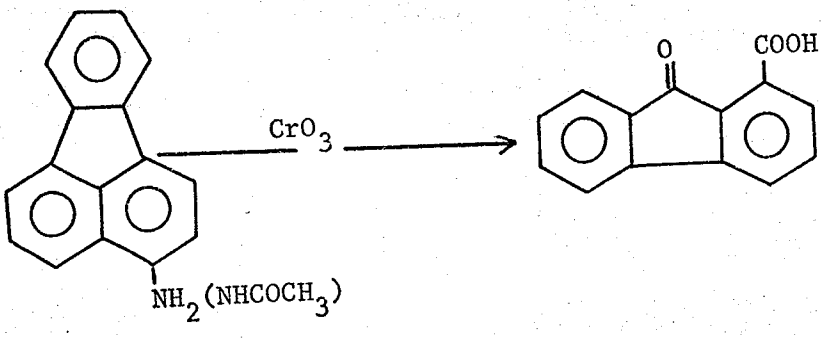


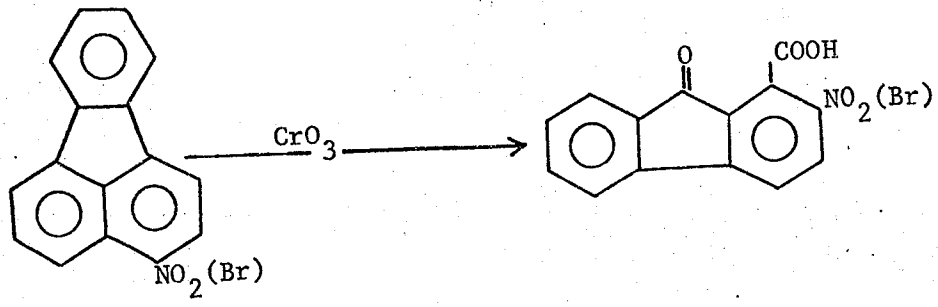
When the reaction is done in benzene besides the formation of perylene and fluoranthene, 6b,10a-dihydrofluoranthene is also found. When this reaction was done in p-xylene 7,10-dimethylfluoranthene was obtained.



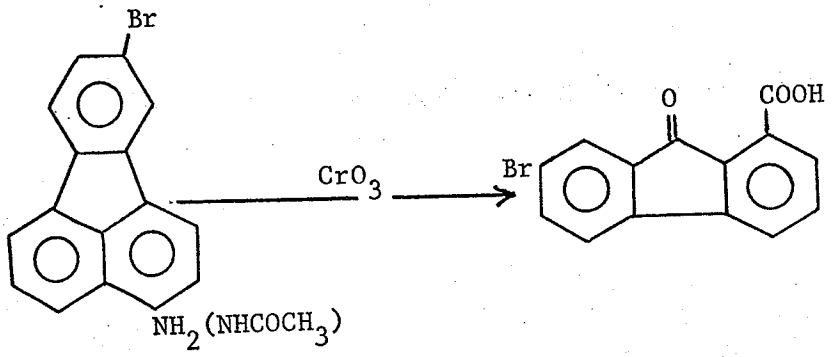
Oxidation of Substituted Fluoranthenes

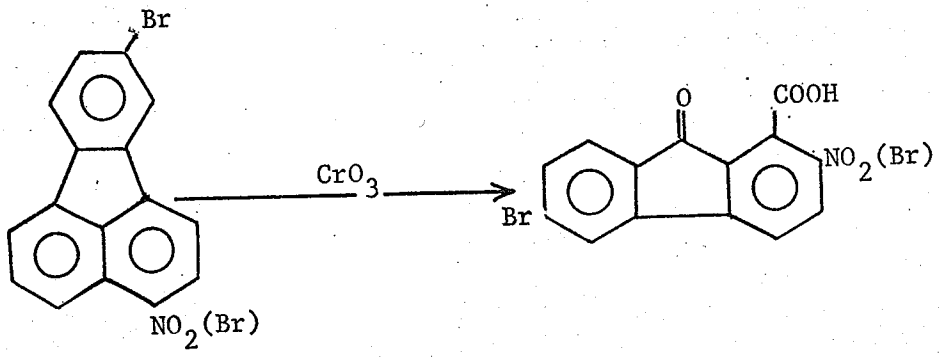
Oxidation of substituted fluoranthenes with dichromate or chromic acid solutions, invariably gives substituted or unsubstituted fluorenone carboxylic acids depending on the ring broken. Thus the naphthalene rather than the benzene part of the structure is broken. Electron rich rings are easily oxidised. An electron donating or activating substituent therefore, will facilitate ring breaking whereas an electron withdrawing or deactivating substituent will hinder ring breaking (5)(19)(29).



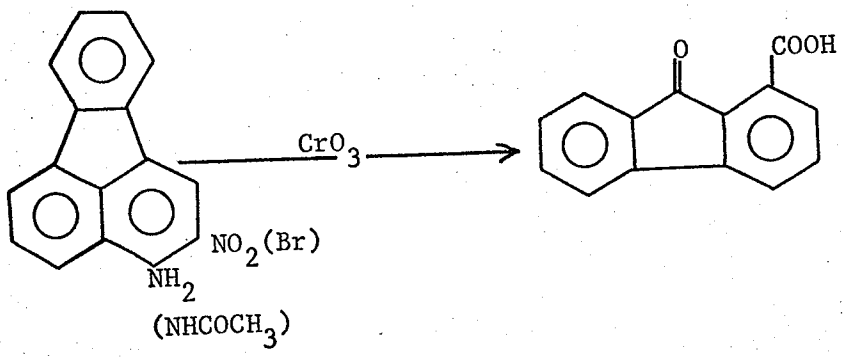


With polysubstituted fluoranthenes, the same behavior is observed (5)(24)(33).





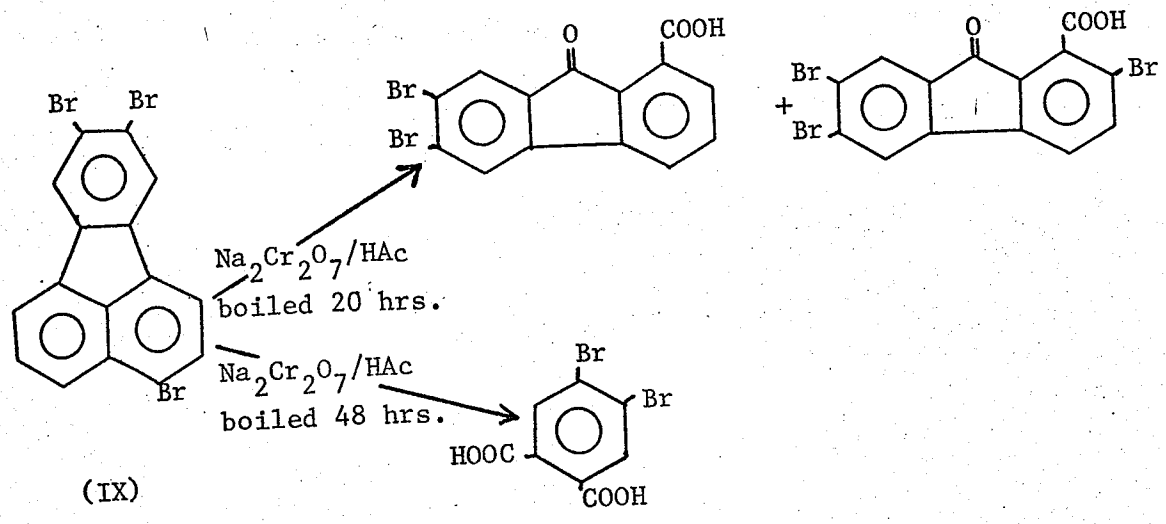
When two substituents are in one ring of the naphthalene part of the molecule oxidation occurs as follows (4)(5).



Thus it seems that the activating substituent overcomes the effect of the deactivating substitutent in chromic acid oxidations.

Although the above generally holds true apparently with a slightly

deactivating group as bromine more than one oxidation product can be obtained. Campbell et al. (25) obtained the following products on the oxidation of 3,8,9-tribromofluoranthene (IX) using different oxidation times.



Monosubstituents in Fluoranthene

1) Halogens

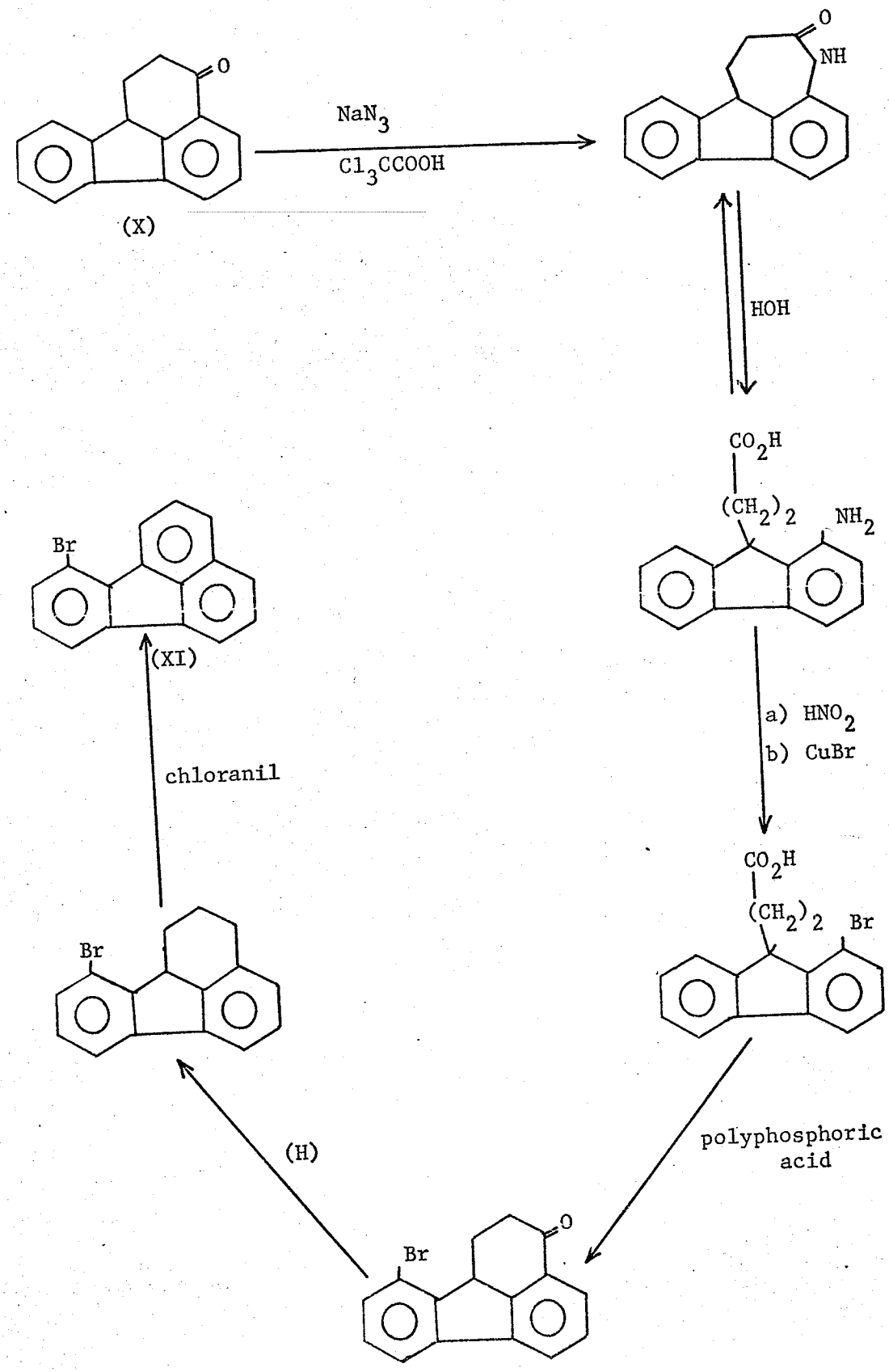
The only mono bromo fluoranthenes obtainable by direct substitution of fluoranthene are the 3- and 8-isomers. The 2- and 7-isomers have been obtained by indirect methods and the 1-isomer has never appeared in the literature. Bromination of fluoranthene in carbon disulfide results in the formation of two isomers. 3-Bromofluoranthene is the main product and some 8-bromofluoranthene is also formed (5). 3-Bromofluoranthene is also readily prepared by the dehydrogenation of 4-bromo-1,2,3,10b-tetrahydrofluoranthene with chloranil in boiling xylene (15). 2-Bromofluoranthene was prepared by Charlesworth and Blackburn (4) both by deamination of 2-bromo-3-aminofluoranthene and by a Sandmeyer reaction on 2-aminofluoranthene. 7-Bromofluoranthene (XI) and 7-chlorofluoranthene were

ingeniously synthesised by Campbell and Crombie (16) from 1,2,3,10b-tetrahydro-3-oxofluoranthene (X) by a method which could be used for the synthesis of other 7-substituted fluoranthenes. Their work is illustrated on the following page.

3-Chlorofluoranthene was prepared by direct substitution by passing chlorine through a solution of the hydrocarbon in propylene oxide at room temperature (17). Attempts at iodination and fluorination resulted in the formation of complex mixtures of polysubstituted products of unknown origin (5). However, in 1961 Fletcher (72) succeeded in converting 3-aminofluoranthene to the 3-fluoro derivative using tetrahydrofuran in a Schiemann reaction. 3-Iodofluoranthene (18), 2-chloro-, 2-iodo- and 2-fluorofluoranthene (19) have been prepared from the corresponding amines by the usual methods.

2) Nitro Groups

The nitration of fluoranthene has long been known to give predominantly 3-nitrofluoranthene (20). von Braun and Manz (21) proved the presence of 8-nitrofluoranthene in the crude nitration product but this isomer was isolated and characterized by Kloetzel et al. (3). 1-Nitrofluoranthene is best prepared by nitration of 1,2,3,10b-tetrahydrofluoranthene according to the method of Campbell and Wilshire (33). This will be discussed in greater detail on page 34. Streitwieser and Fahey (22) obtained four of the five possible mononitrofluoranthenes by nitration in either acetic acid or acetic anhydride. Their results showed that acetic acid is the solvent of choice when only the nitration product at the most reactive position is desired, whereas acetic anhydride is the solvent to use if one desires to isolate products of reaction at less reactive positions. A summary of their results is presented in the


O
NaN3
Cl3CCOOH
(X)
O
NH
HOH
CO2H
(CH2)2
NH2
a) HNO2
b) CuBr
CO2H
(CH2)2
Br
polyphosphoric acid
O
Br
(H)
Br
chloranil
(XI)
Br

following table.

Table I

NITRATION PRODUCTS OF FLUORANTHENE

Position	Per Cent		Partial rate factors relative to a 1-naphthalene position	
	Acetic anhydride, 0°	Acetic acid, 50°	Acetic anhydride, 0°	Acetic Acid, 50°
1	11.1 ± 3.3	2.3 ± 1.5	0.7	0.3
3	43.5 ± 5.8	69.6 ± 2.7	2.9	8.1
7	18.4 ± 3.9	5.0 ± 1.9	1.2	0.6
8	27.0 ± 5.8	23.1 ± 2.7	1.8	2.7

2-Nitrofluoranthene has never been obtained by direct substitution of the parent hydrocarbon but Kloetzel et al. (3) obtained it by nitration of 3-acetamidofluoranthene followed by hydrolysis and deamination.

3) Other Mono Substituents

Direct sulfonation of fluoranthene by chlorosulfonic acid in an inert solvent yields 3-fluoranthenesulfonic acid (5). von Braun and Anton (10) showed that a small amount of the 8-substituted isomer was also found. Treatment of fluoranthene in a Friedel-Crafts reaction with benzoyl chloride in the presence of aluminum chloride gives a mixture of 3-benzoyl and 8-benzoylfluoranthene in approximately equal quantities. Acetyl bromide in the presence of aluminum chloride in carbon disulfide acts on fluoranthene to produce a mixture of 3-acetyl-, 8-acetyl- and 3,9-diacetylfluoranthene (5).

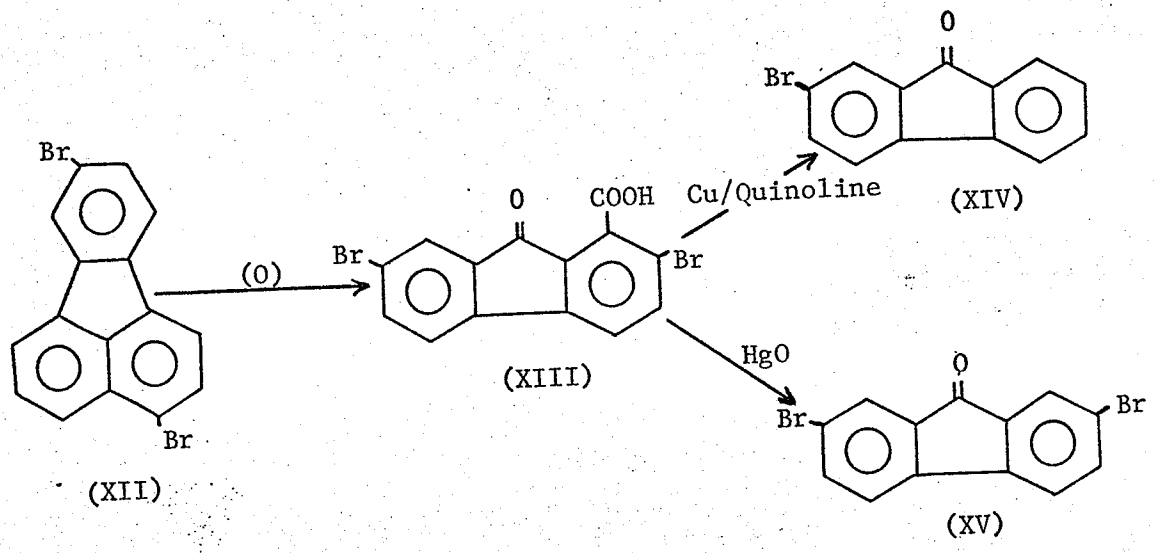
Recently Shenbor (47) synthesized 3-hydroxyfluoranthene by treating fluoranthene with $Pb(OAc)_4$ in acetic acid. The 3-acetoxy-fluoranthene obtained was treated with base to give the hydroxy compound.

The 3-hydroxy compound had also been prepared from the 3-sulfonic acid by alkali fusion. The 3-methoxy derivative has been synthesized from the hydroxy compound by treatment with dimethyl sulfate and potassium carbonate (31)(65).

Disubstituents in Fluoranthene

1) Bromination

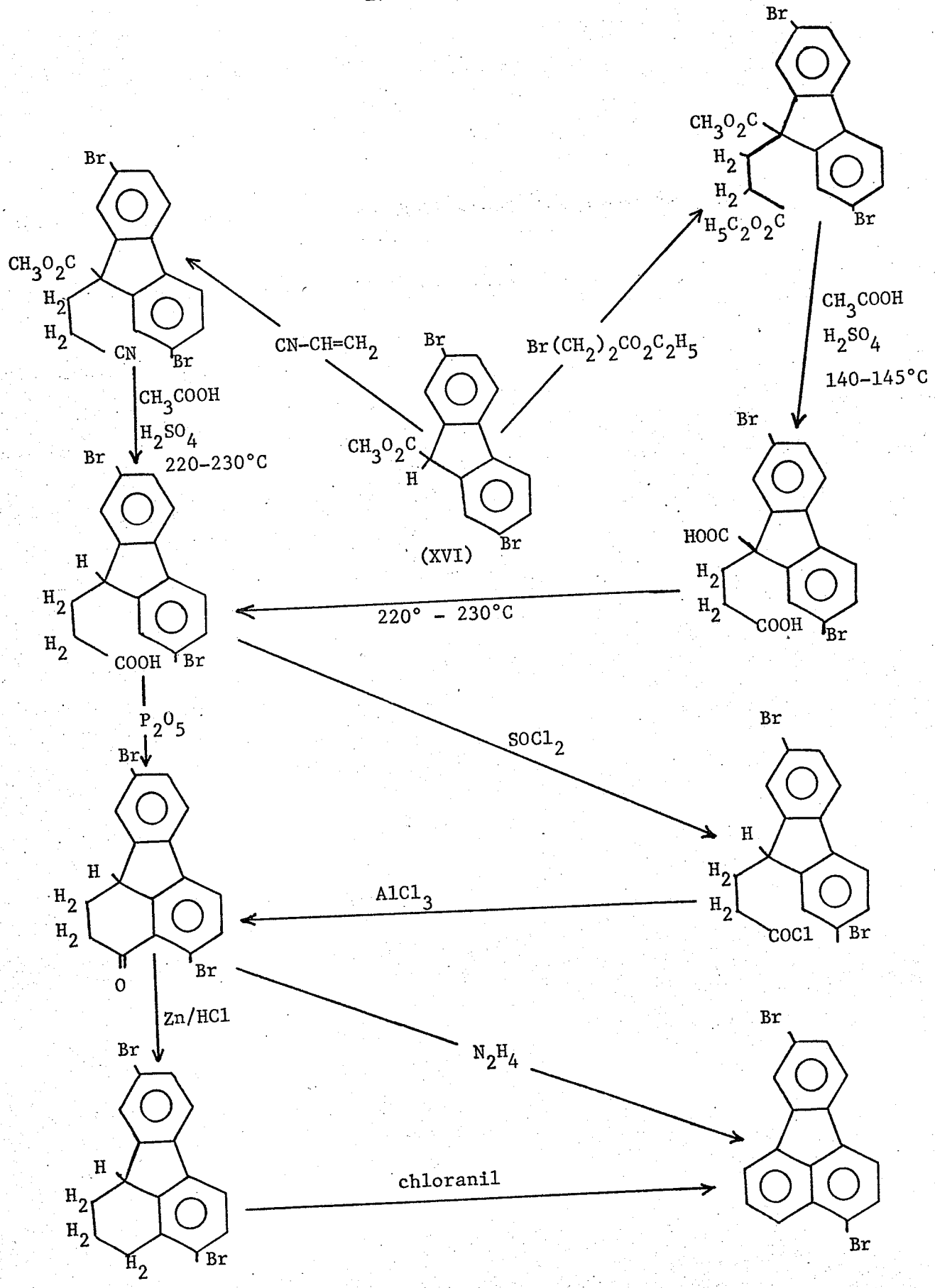
An appreciable amount of work has been done on the bromination of mono substituted fluoranthenes. Nothing has been reported, however, on other halogenation of mono substituted fluoranthenes. The first disubstituted fluoranthene compound whose orientation was determined was 3,8-dibromofluoranthene (XII) in 1950. This compound, most conveniently prepared by direct bromination of fluoranthene in nitrobenzene, has had its structure ascertained by two independent methods. Campbell et al. (24) oxidised the dibromo compound with chromic acid to give dibromofluorenone-1-carboxylic acid (XIII) which gave different results upon decarboxylation, depending upon the catalyst. Using copper and quinoline, they obtained 2-bromofluorenone (XIV), whereas when they used mercuric oxide at 180°, 2,7-dibromofluorenone (XV) resulted.

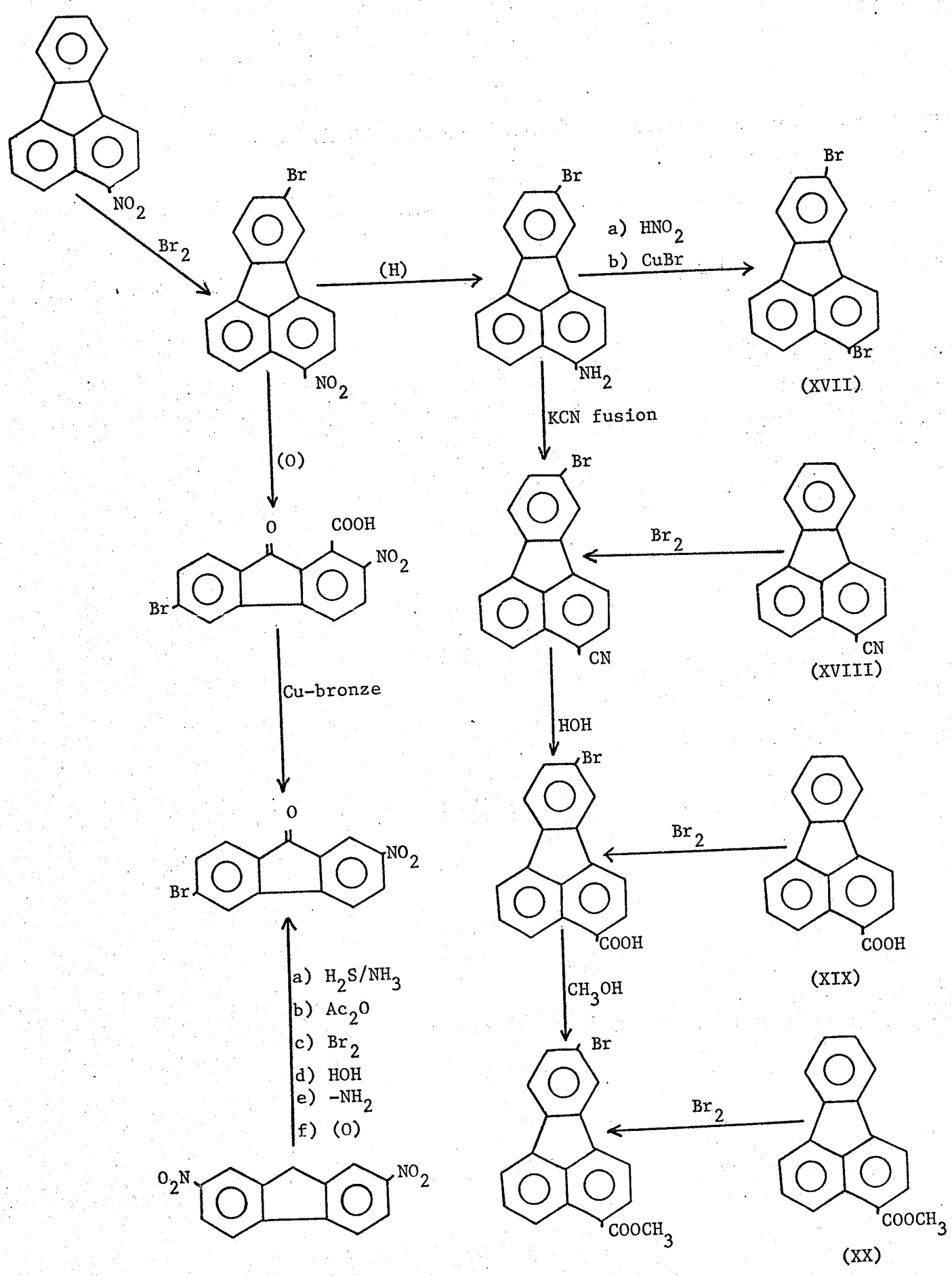


The structure of 3,8-dibromofluoranthene was independently determined by Holbro and Tagmann (26) who synthesized it from 2,7-dibromo-9-fluorenemethylcarboxylate (XVI) as shown on the following page. 3,8-Dibromofluoranthene besides being obtained by the direct bromination of fluoranthene itself (15), can also be obtained by further bromination of 3-bromofluoranthene (2). Recently Kaminska and Mazonski (27) have investigated the bromination of fluoranthene with dioxane-dibromide with respect to the effect of temperature, solvent and molar ratio of the substrates. They isolated specific percentages of the 3-bromo-, 3,8-dibromo- and 3,8,9-tribromo- derivatives depending on the molar ratio of the substrates.

In 1955, Campbell and Keir (2) prepared 3,9-dibromofluoranthene (XVII) from 3-nitrofluoranthene which was brominated, reduced, diazotized and treated in a Sandmeyer reaction. At the same time they showed that 3-cyano- (XVIII), 3-carboxy- (XIX) and 3-carbomethoxyfluoranthene (XX) like 3-nitrofluoranthene all brominated in position 9. Their work is summarized on page 18.

Charlesworth and Blackburn (4) showed that 3-aminofluoranthene in acetic acid and 3-acetamidofluoranthene in pyridine both brominated in position 2. The product which they obtained from hydrolysis of the acetamidobromofluoranthene was identical to that produced from the bromination of 3-aminofluoranthene. Thus, the bromine atom must enter the same position in both cases. Oxidation of 3-amino-2-bromofluoranthene gave 1-fluorenonecarboxylic acid proving that both substituents were in the same ring. Deamination of the bromo-amine produced 2-bromofluoranthene, identical with an authentic sample prepared from 2-nitrofluoranthene by reduction, diazotization and treatment with cuprous

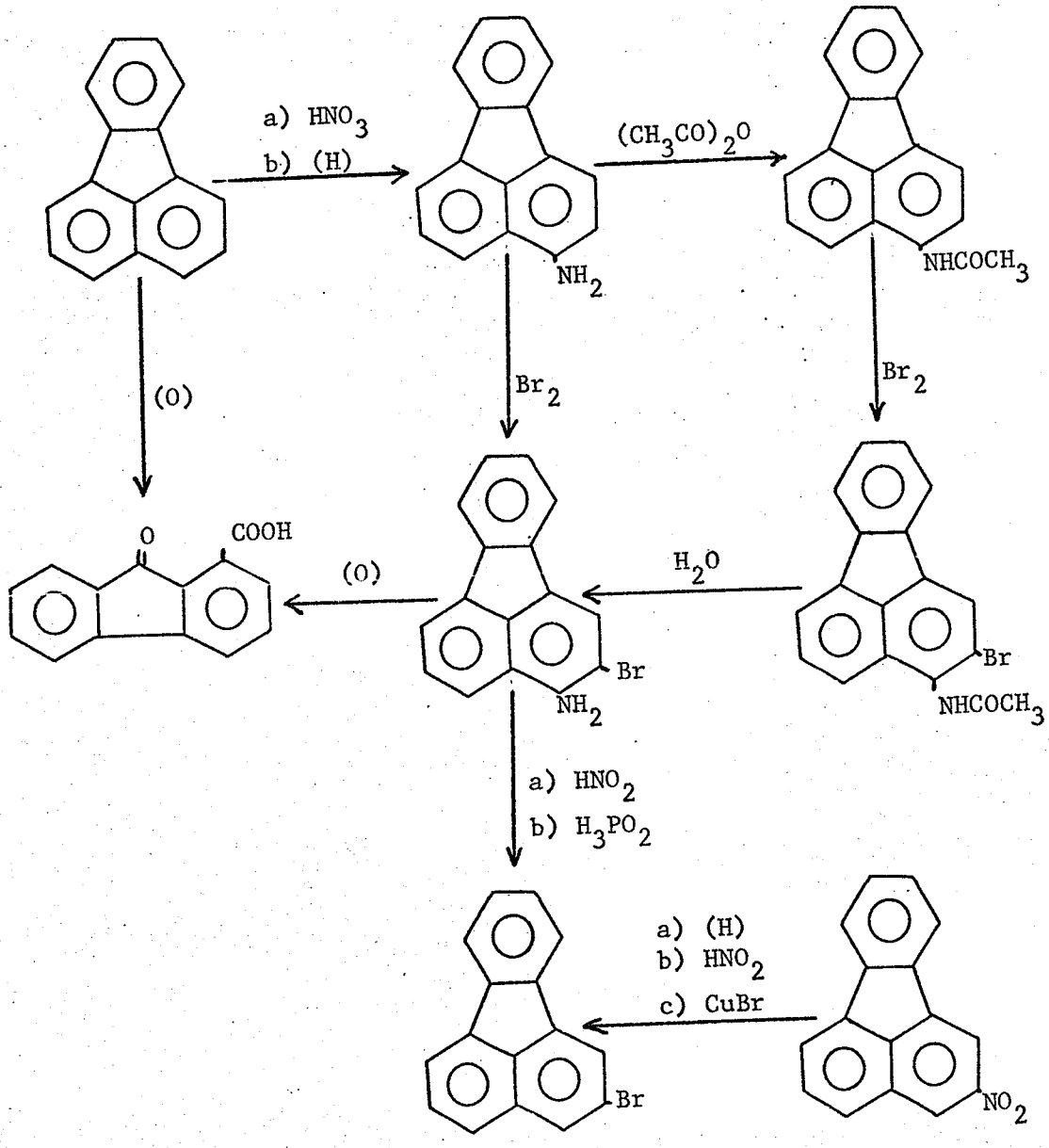

Br
CH3O2C
H2
H2
CN
Br
CN-CH=CH2
Br
CH3O2C
H
Br
(XVI)
Br(CH2)2CO2C2H5
Br
CH3O2C
H2
H2
H5C2O2C
Br
CH3COOH
H2SO4
220-230°C
CH3COOH
H2SO4
140-145°C
Br
H
H2
H2
COOH
Br
220° - 230°C
Br
HOOC
H2
H2
COOH
Br
P2O5
SOCl2
Br
H
H2
H2
O
Br
AlCl3
Br
H
H2
H2
COCl
Br
Zn/HCl
N2H4
Br
H
H2
H2
H2
Br
chloranil
Br
Br

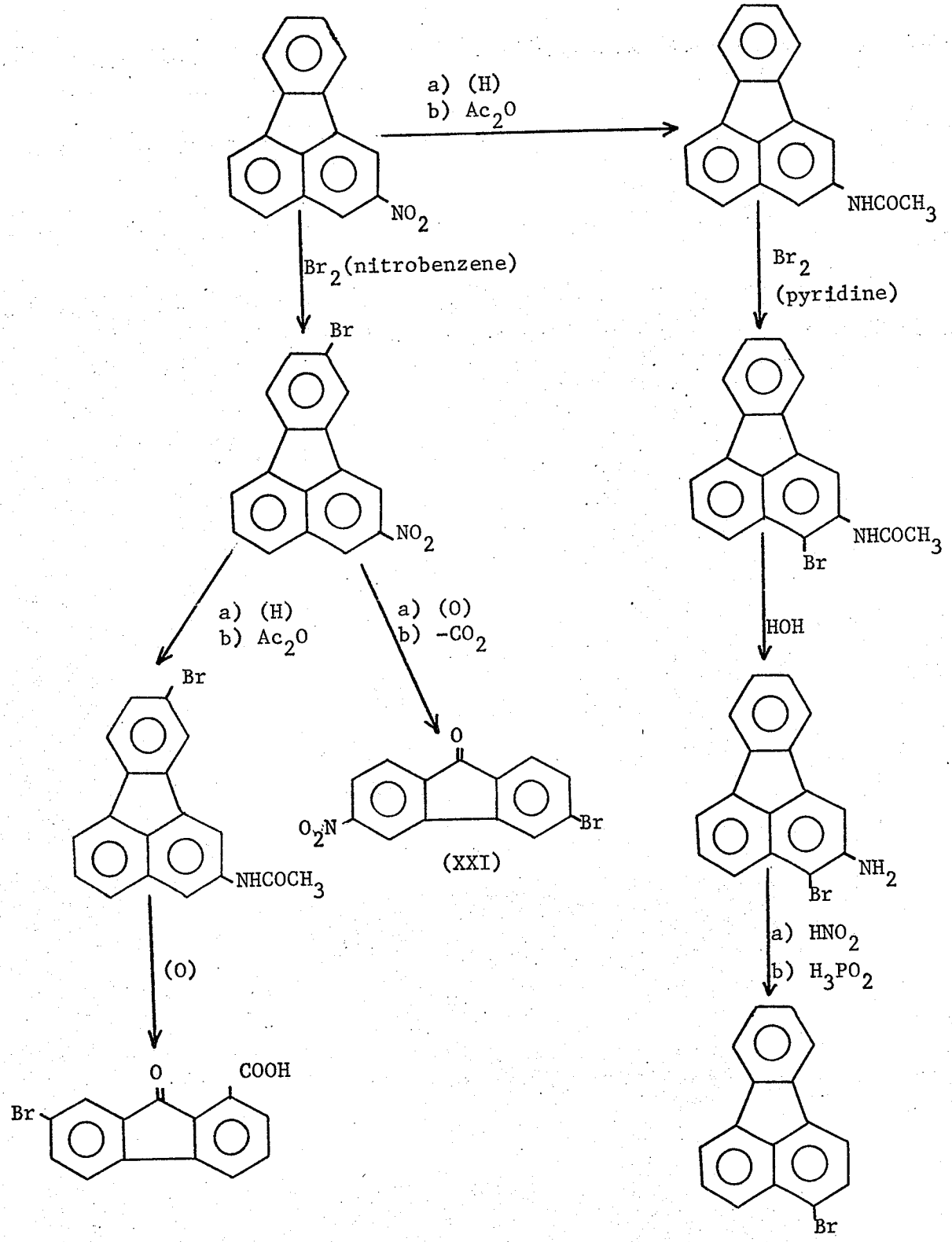

NO2
Br2
Br
NO2
(H)
Br
NH2
a) HNO2
b) CuBr
Br
Br
(XVII)
KCN fusion
(O)
O
COOH
NO2
Br
Br
CN
Br2
CN
(XVIII)
Cu-bronze
HOH
O
NO2
Br
Br
COOH
Br2
COOH
(XIX)
a) H2S/NH3
b) Ac2O
c) Br2
d) HOH
e) -NH2
f) (O)
CH3OH
O2N
NO2
Br
COOCH3
Br2
COOCH3
(XX)

bromide in a Sandmeyer reaction. This work is summarized on page 20.

Charlesworth and Blackburn (4) and Charlesworth and Lithown (30) also found that the position of bromination of 3-acetamidofluoranthene depends on the solvent used. In pyridine bromination occurs in position 2,whereas in acetic acid bromination occurs in position 8. Moreover Kaminska and Mazonski (27) found that 3-acetamidofluoranthene brominated in position 8 in acetic acid and carbon tetrachloride (2:1).

In 1965, Charlesworth and Dolenko (19) studied the influence of strongly activating and deactivating substituents in position 2 of the fluoranthene molecule. They showed that in pyridine 2-acetamido-fluoranthene brominated in position 3 and that 2-nitrofluoranthene brominated in position 9. The orientation of the substituents was established in the following way. Hydrolysis of the acetamido-bromo compound gave a bromo-amine, which on deamination gave the well known 3-bromofluoranthene, thus proving that bromination of 2-acetamidofluor-anthene occurred in position 3. The 2-nitrobromofluoranthene was also oxidised and decarboxylated to give a bromonitrofluorenone. The structure of this compound was later proved to be 3-bromo-6-nitrofluorenone (XXI) by Charlesworth and Mathiaparanam (28) who developed a very efficient synthesis for unsymmetrical 3,6-disubstituted fluorenones. This is discussed in part B of this thesis, where some similar synthetical work in this field is reported. The product obtained from the 2-nitrobromo-fluoranthene after reduction, acetylation and oxidation was 7-bromo-fluorenone-1-carboxylic acid, as this was identical with an authentic sample of this material. This work is summarized on page 21. Up to this point no bromination of 1,7,or 8 mono-substituted fluoranthenes had been done.

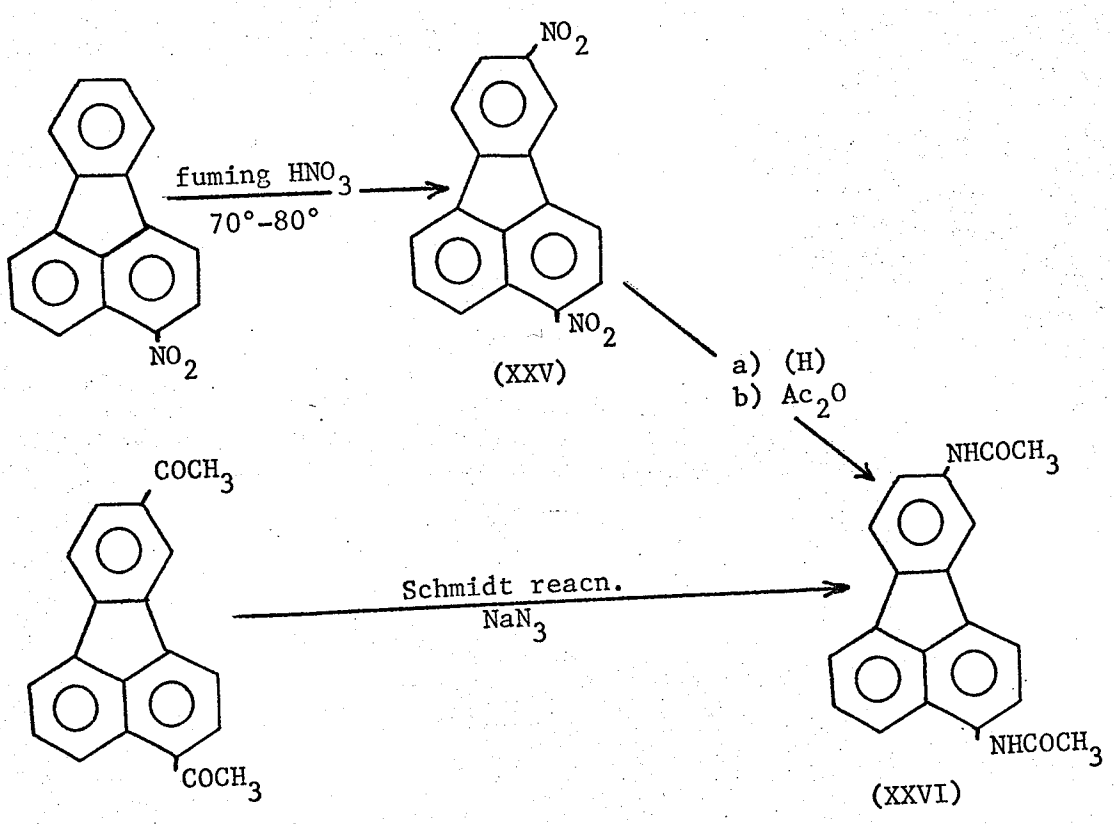

a) HNO3
b) (H)
(CH3CO)2O
NH2
NHCOCH3
(O)
Br2
Br2
O
COOH
(O)
H2O
Br
NH2
Br
NHCOCH3
a) HNO2
b) H3PO2
a) (H)
b) HNO2
c) CuBr
Br
NO2

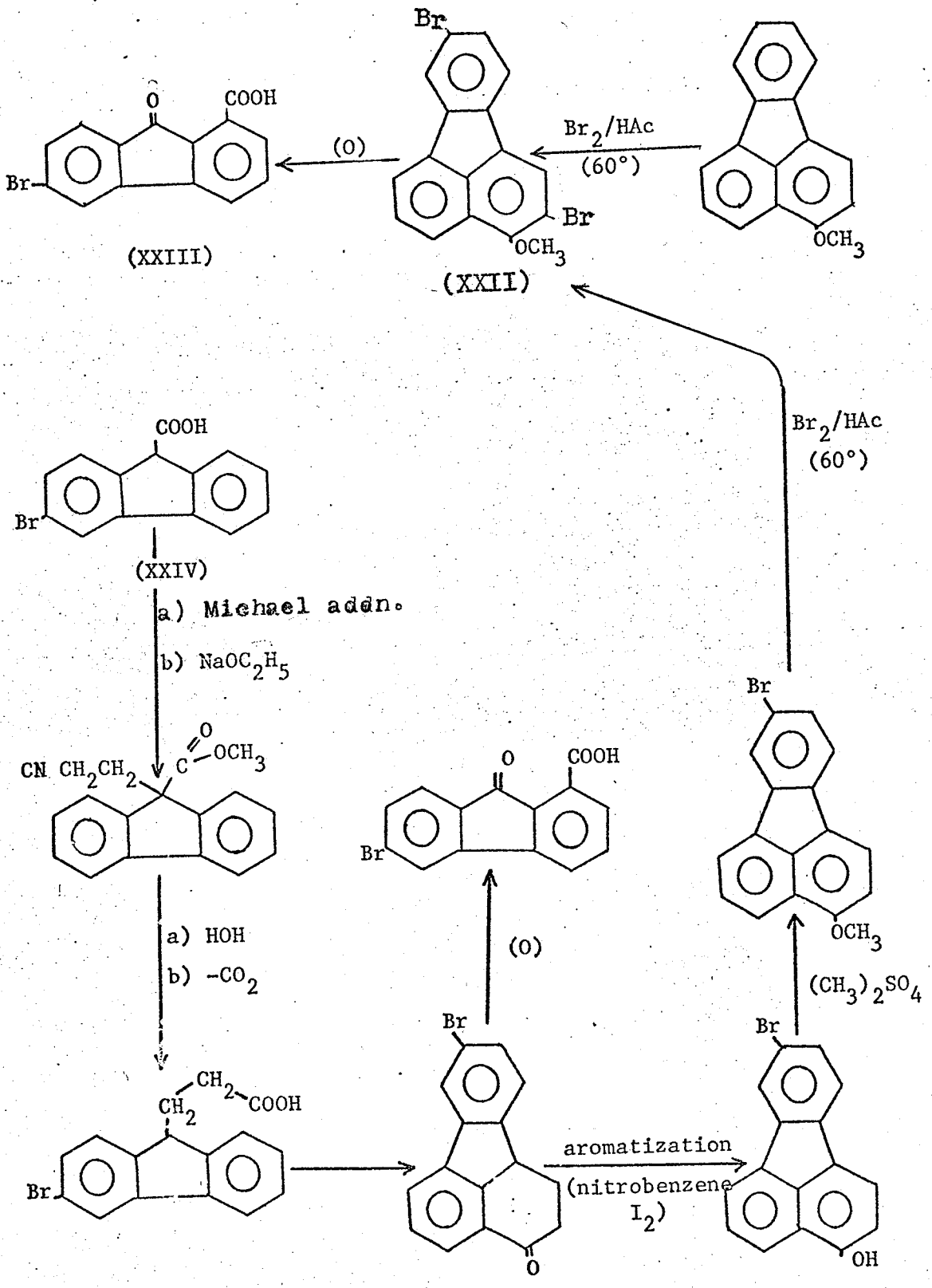

a) (H)
b) Ac_2O
NO_2
Br_2(nitrobenzene)
Br
NO_2
a) (H)
b) Ac_2O
a) (O)
b) $-CO_2$
Br
$NHCOCH_3$
O
O_2N
Br
(XXI)
(O)
O
COOH
Br
$NHCOCH_3$
Br_2
(pyridine)
Br
$NHCOCH_3$
HOH
NH_2
Br
a) HNO_2
b) H_3PO_2
Br

Quite recently Campbell et al. (65) found that bromination of 3-methoxyfluoranthene yields 2,8-dibromo-3-methoxyfluoranthene (XXII), the structure of which follows from its oxidation to 6-bromofluorenone-1-carboxylic acid (XXIII), and also by the synthesis from 3-bromofluorene-9-carboxylic acid (XXIV). Their work is illustrated on page 23. Thus dibromination of 3-methoxyfluoranthene occur in the same positions as dinitration (31). These authors also showed that 2-nitro-3-methoxy-fluoranthene brominates in position 8 and developed a short method for deamination of fluoranthene amines.

2) Nitration

Charlesworth and Lithown (30) reacted 3-nitrofluoranthene with fuming nitric acid to obtain 3,9-dinitrofluoranthene (XXV). This was verified by conversion to 3,9-diacetamidofluoranthene (XXVI) which proved to be the same product as that prepared from 3,9-diacetylfluoranthene by a Schmidt reaction with sodium azide as described by Campbell et al. (29). Their work is summarized below.

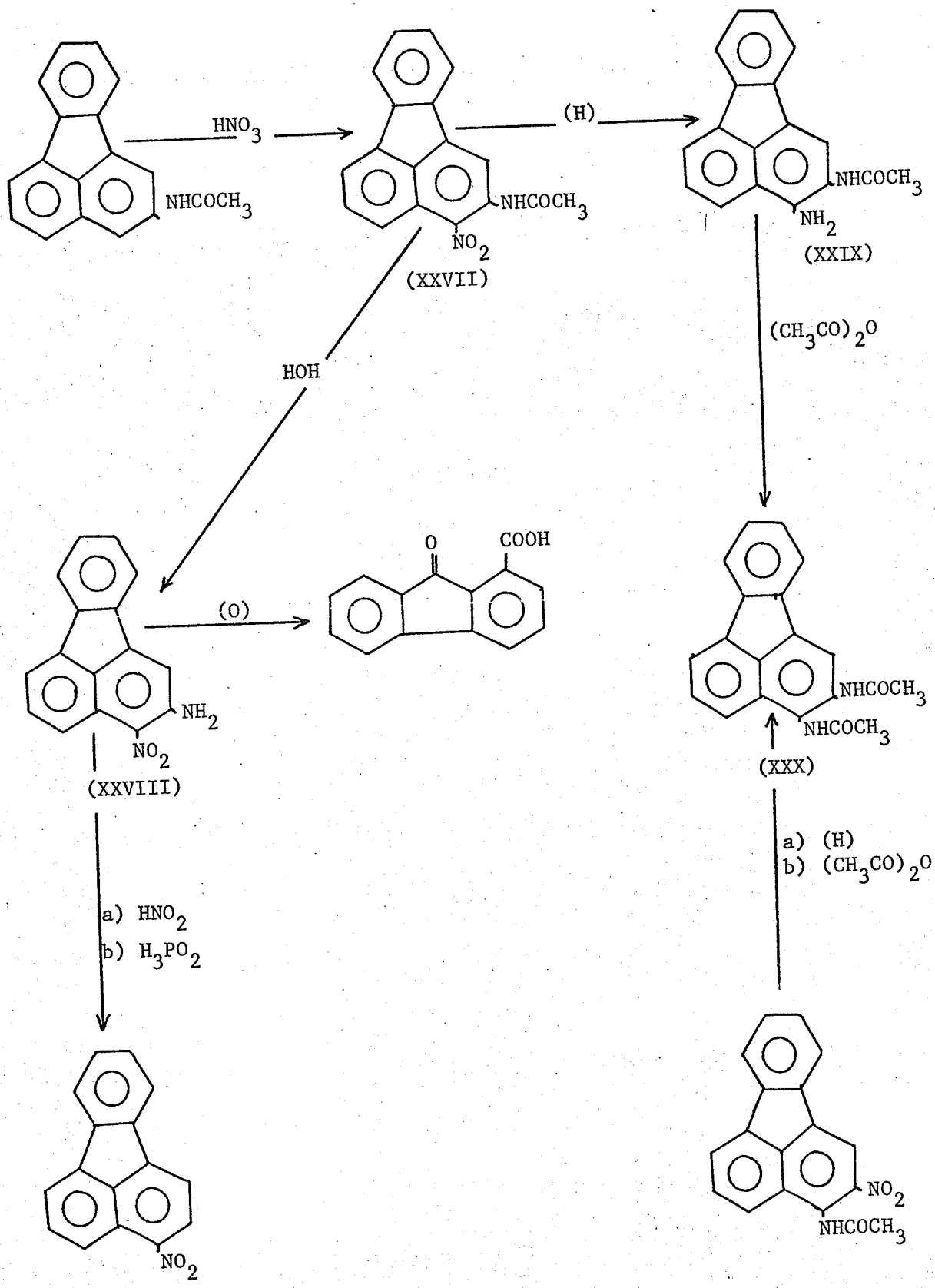



Br
O
COOH
Br
(O)
Br2/HAc
(60°)
Br
OCH3
OCH3
(XXIII)
(XXII)
Br2/HAc
(60°)
COOH
Br
(XXIV)
a) Michael addn.
b) NaOC2H5
CN CH2CH2
C
O
OCH3
Br
O
COOH
Br
Br
OCH3
a) HOH
b) -CO2
(O)
(CH3)2SO4
CH2
CH2
COOH
Br
Br
Br
aromatization
(nitrobenzene
I2)
O
OH

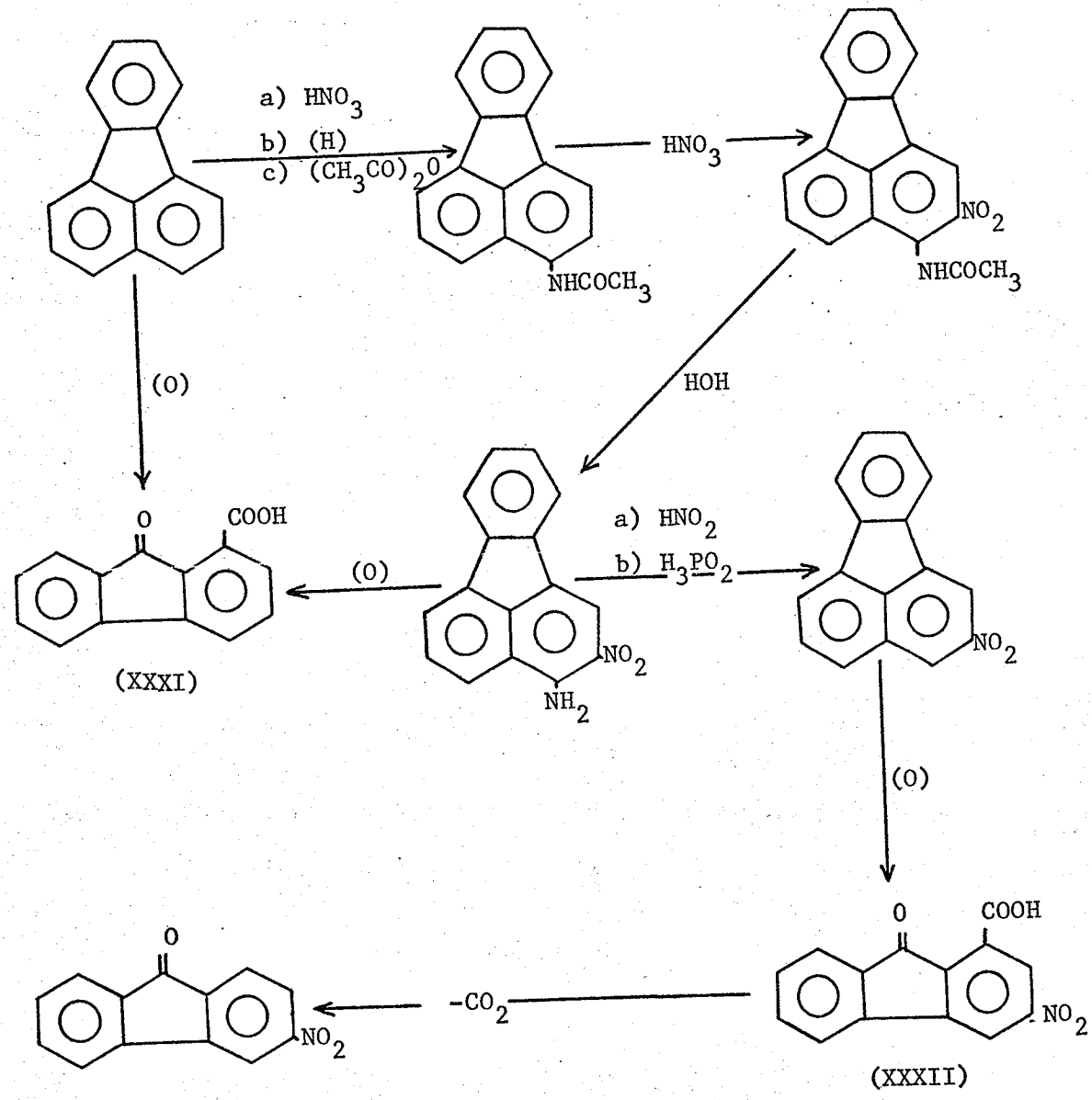
A similar attempt at further nitration of 2-nitrofluoranthene produced a very small amount of a dinitrofluoranthene. Since 3-nitro and 2-nitrofluoranthene both brominate in position 9, and 3-nitrofluoranthene nitrates in position 9, it is expected that 2-nitrofluoranthene will nitrate in the same position as it brominated i.e. position 9. Mass spectral evidence also suggests this but the orientation as 2,9-dinitrofluoranthene remains to be rigorously proved.

The above authors also studied the influence of nitration on a strongly activating group. They found that 2-acetamidofluoranthene nitrates in position 3. This was proved in the following way. Hydrolysis of the 2-acetamidonitro compound (XXVII) gave the 2-amino compound (XXVIII). Deamination by diazotization and treatment with hypophosphorous acid gave the well known 3-nitrofluoranthene indicating that the nitro group had entered position 3. Oxidation of 2-amino-3-nitrofluoranthene gave 1-fluorenonecarboxylic acid, which is further proof that the nitro group had entered the A ring. Catalytic reduction of 2-acetamido-3-nitrofluoranthene gave the rather crude 2-acetamido-3-aminofluoranthene (XXIX). Acetylation gave 2,3-diacetamidofluoranthene (XXX) identical with that prepared by Kloetzel et al. (3) from 3-acetamido-2-nitrofluoranthene. This work is summarized on page 25.

In 1956, Kloetzel et al. (3) showed that 3-acetamidofluoranthene was nitrated in position 2 rather than the expected position 8. They proved the orientation of the acetamido-nitrofluoranthene as follows. Oxidation of the nitro-amine yielded 1-fluorenonecarboxylic acid (XXXI), thus proving that both substituents were in the same ring. Hydrolysis of the acetamido-nitrofluoranthene, deamination and finally oxidation of the resultant nitrofluoranthene gave 3-nitrofluorenone-1-


HNO3
NHCOCH3
NHCOCH3
NO2
(XXVII)
(H)
NHCOCH3
NH2
(XXIX)
(CH3CO)2O
HOH
(O)
O
COOH
NH2
NO2
(XXVIII)
NHCOCH3
NHCOCH3
(XXX)
a) HNO2
b) H3PO2
a) (H)
b) (CH3CO)2O
NO2
NO2
NHCOCH3

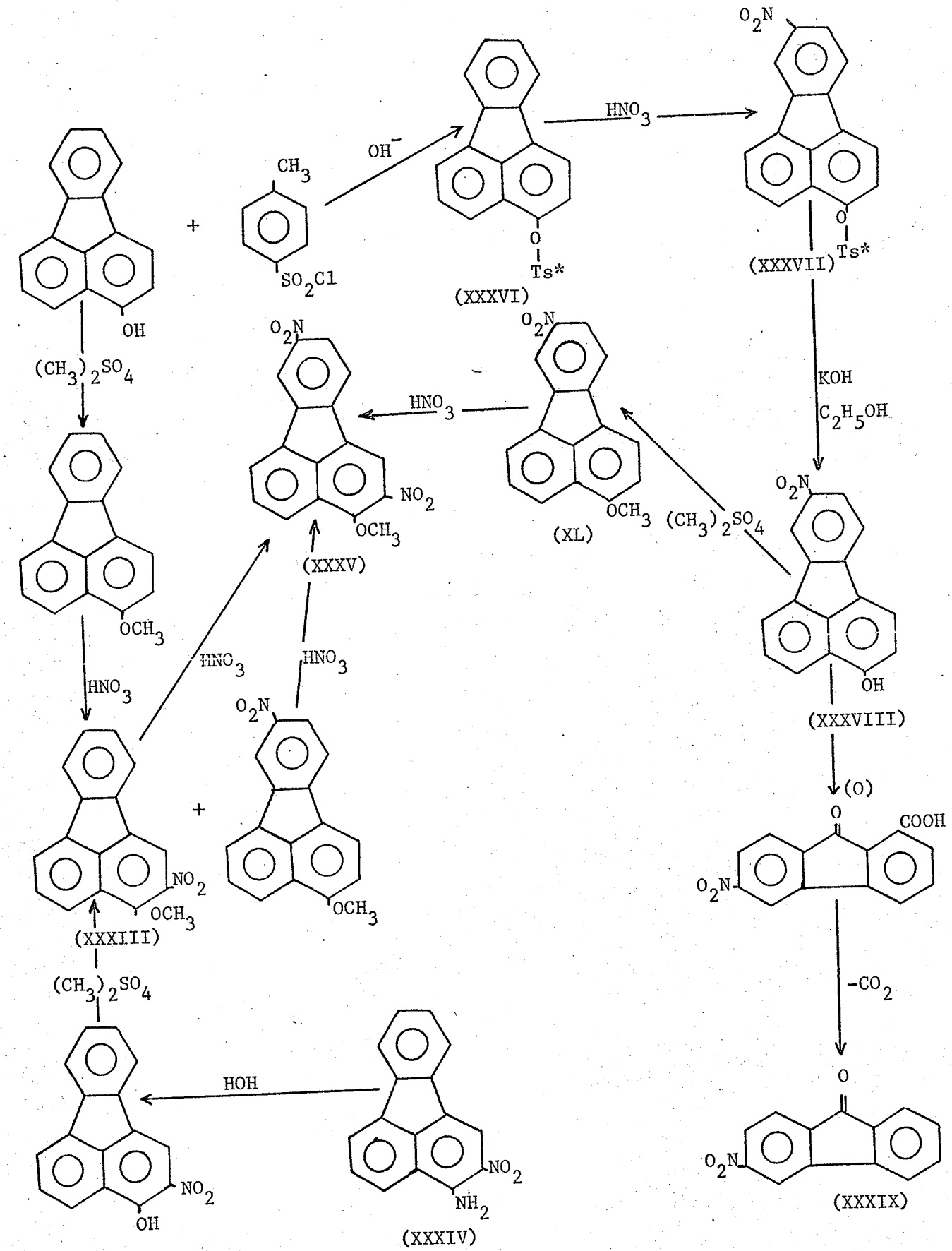
carboxylic acid (XXXII) proving that the nitro group was in position 2. This work is summarized below.



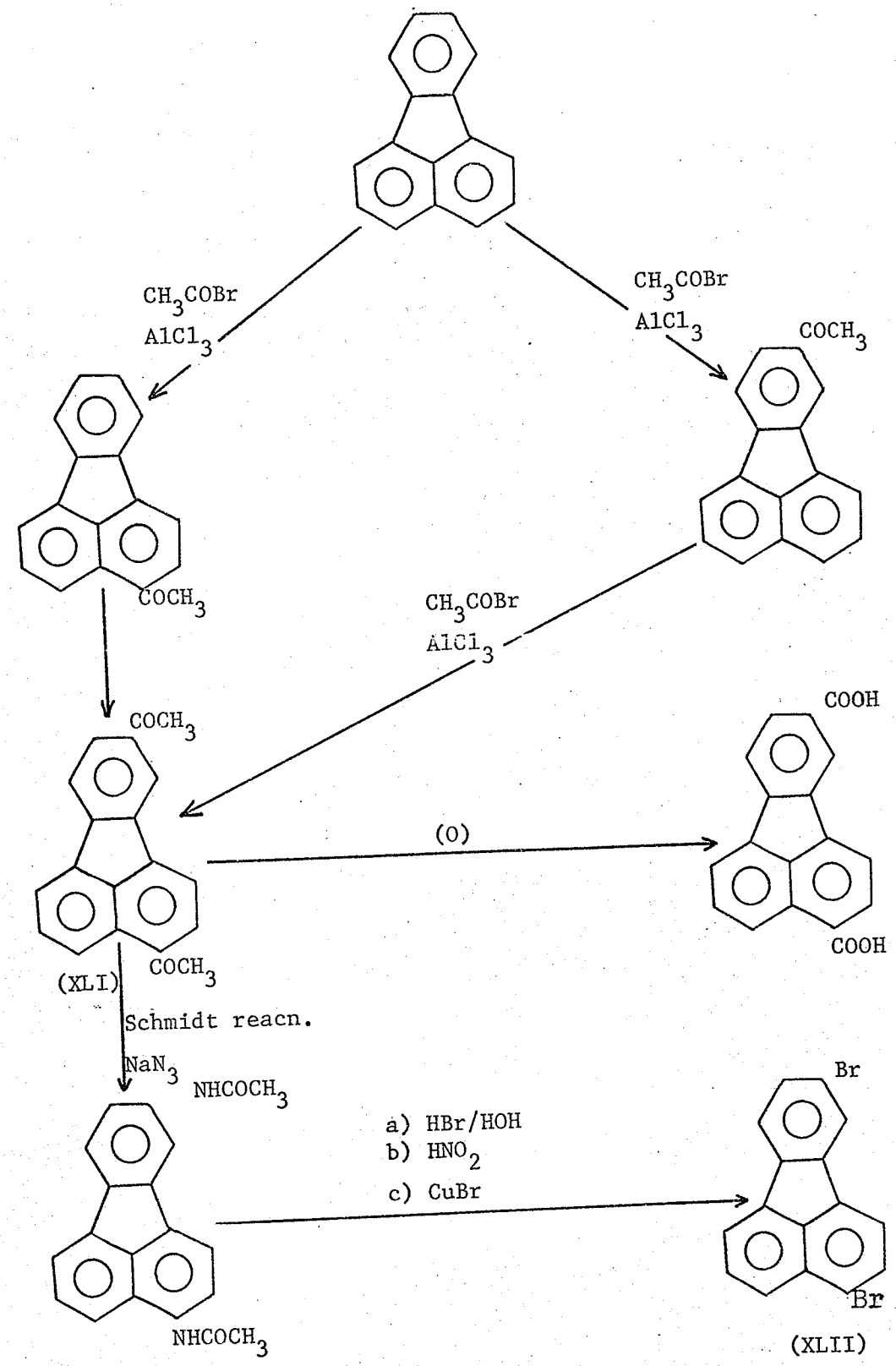
Recently Andrew, Campbell, Craig and Nichol (31) showed that nitration of 3-methoxyfluoranthene yielded 3-methoxy-2- and -8-nitrofluoranthene, each of which on further nitration gave 3-methoxy-2,8-dinitrofluoranthenes. Their work is illustrated on the following page. The orientation of 3-methoxy-2-nitrofluoranthene (XXXIII) was established by comparison with the product obtained by the alkaline hydrolysis of 3-amino-2-nitrofluoranthene (XXXIV) followed by methylation. Further nitration of the mixture of 3-methoxy-mononitrofluoranthenes or of the 2-nitro-isomer yielded 3-methoxy-2,8-dinitrofluoranthene (XXXV). Nitration of 3-toluene-p-sulphonyloxyfluoranthene (XXXVI) occurred in position 8. XXXVII was hydrolysed to the phenol (XXXVIII) which was oxidised and decarboxylated to yield 3-nitrofluorenone (XXXIX) thus establishing the orientation of XXXVIII. 3-Methoxy-8-nitrofluoranthene (XL) which was readily prepared from XXXVIII nitrates further to give 3-methoxy-2,8-dinitrofluoranthene (XXXV). These authors also synthesised 3-hydroxy-9-nitrofluoranthene, 3-methoxy-9-nitrofluoranthene and 3-methoxy-2,9-dinitrofluoranthene and found that 3-acetoxyfluoranthene nitrated in position 8.

3) Other Disubstituents

In 1951, Campbell et al. (29) showed that the product prepared by further acetylation of both 3-acetyl and 8-acetylfluoranthene is 3,9-diacetylfluoranthene (XLI). Oxidation of XLI gave 3,9-fluoranthenedicarboxylic acid. The orientation of the diacetyl compound was proved by converting it to the diacetamido compound using the Schmidt reaction. This was in turn converted to 3,9-dibromofluoranthene (XLII). This work is shown on page 29.



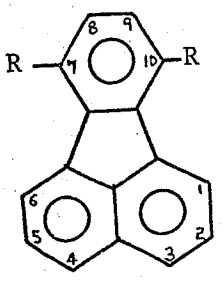
Ts*: p-$CH_3.C_6H_4.SO_2$-


CH3COBr
AlCl3
CH3COBr
AlCl3
COCH3
COCH3
CH3COBr
AlCl3
COCH3
COOH
(O)
COOH
(XLI)
COCH3
Schmidt reacn.
NaN3
NHCOCH3
a) HBr/HOH
b) HNO2
c) CuBr
Br
Br
NHCOCH3
(XLII)

Goldschmiedt prepared fluoranthene disulfonic acid by heating the hydrocarbon in concentrated sulfuric acid. Campbell and Keir (2) proved this to be 3,9-fluoranthenedisulfonic acid by showing that the dimethoxyfluoranthene compound prepared from it was identical to the dimethoxyfluoranthene compound prepared from 3,9-diacetylfluoranthene. They also prepared 3,9-dimethoxyfluoranthene from the disulfonic acid by first obtaining the corresponding dihydroxy compound and then treating it with dimethyl sulfate and base.

Forrest and Tucker (35) synthesized 1,3-dimethylfluoranthene using fluorene and acetone as the starting materials. Campbell and Hasan (39) synthesized 8-bromo-3-methoxyfluoranthene from the accessible 7-bromo-2-methoxyfluorene via the corresponding 9-fluorenepropionic acid.

Recently a large number of 7,10-disubstituted fluoranthenes have been synthesized. As was mentioned on page 9, 7,10-dimethylfluoranthene can be synthesized from 1,8-dehydronaphthalene and p-xylene. 7,10-Dimethylfluoranthene was also synthesized by Campbell and Gow (69) earlier. The following compounds have been made by Craig et al. (70) while they were investigating the possibility of synthesizing "corannulene" from 7,10-disubstituted fluoranthenes.



R = $COOCH_3$

R = $COOC_2H_5$

R = CH_2OH

R = CH_2Br

R = CH_2Cl

R = CH_2CN

R = CH_2COOH

R = CH_2COOCH_3

R = $CH_2COOC_2H_5$

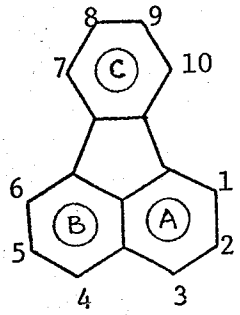
R = COOH

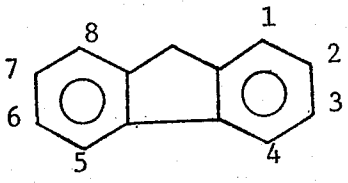
R = COCl

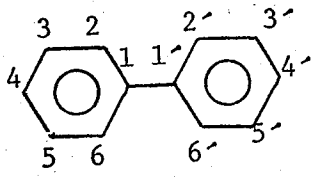
R = $COCHN_2$

R = $COCH_2Cl$

Orientation of Disubstituted Fluoranthenes







Both fluorene and fluoranthene contain the diphenyl system. It has been pointed out by Campbell and Keir (2) that orientation in the diphenyl series is dominated by the phenyl groups. To be more specific, substitution in most cases occurs in the second ring in the 2' and 4' positions irrespective of the nature and position of the substitutent already present in the first ring. The three nitrodiphenyls for example, undergo substitution in the 2' and 4' positions but not in the 3' (meta)-position. It is also known that 4-bromodiphenyl on further bromination yields mainly 4,4'-dibromodiphenyl.

Campbell and Keir in 1955 observed that 3-carboxy-, 3-carbomethoxy-, 3-cyano- and 3-nitrofluoranthene all brominate in position 9. Furthermore, sulfonation of fluoranthene and acetylation of 3-acetyl-

fluoranthene gave 3,9 derivatives. However, further bromination of 3-bromofluoranthene occurred in position 8. It seemed then that 3-substituted fluoranthenes underwent further substitution mainly in the 8 or 9 position according to whether the first substituent was ortho-para, or meta directing. As a possible explanation of the above fluoranthene substitutions, they considered fluoranthene as a diphenyl derivative containing the diphenyl nuclei AC or BC, and postulated the following:

a) Each of the rings A and B direct substituents predominantly to the para-position in ring C. i.e. to positions 8 and 9 respectively.

b) An ortho-para directing group in ring A increases the directive power of this ring with consequent substitution at carbon 8 (and possibly carbon 10).

c) A meta directing group in ring A decreases the directive power of this ring so that ring B dominates further substitution which therefore occurs at carbon 9 (and possibly carbon 7).

The same behavior appears to exist in fluorene. 2-Bromofluorene brominates in position 7 (57a) and 2-nitrofluorene nitrates in position 7 (58a). Considering fluorene as a diphenyl derivative then, it is seen that further substitution occurs in the para position.

In 1956, Kloetzel et al. (3) found that 3-acetamidofluoranthene nitrated in position 2 and stated that Campbell and Keir's rules of orientation were oversimplified since it did not take into account highly activating substituents like acetamido, which would activate the ring to such an extent that further substitution would occur in the same ring. This was shown to be generally true by several later workers (4)(19)(30), although Blackburn (40) found that bromination of 3-acetamidofluoranthene

occurred in position 2 with pyridine as solvent and in position 8 with acetic acid as solvent.

Considering fluorene again, when 2-acetamido fluorene is nitrated substitution occurs mainly in position 3 (57a) agreeing with Kloetzel's observations.

The reactions of diphenyl could have predicted the behavior of 3-acetamidofluoranthene since "4-acetamidodiphenyl, on nitration or chlorination yields the 3-nitro-or the 3-chloro-derivative, yet on bromination 4'-bromo-4-acetamidodiphenyl is reported to be found" (57b). Reaction conditions are therefore quite significant, in that highly activating substituents may direct in the same ring or follow the rules of Campbell and Keir.

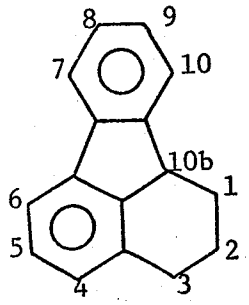
Polysubstituents in Fluoranthene

Tobler et al. (15) prepared a tribromofluoranthene by brominating 3,8-dibromofluoranthene, and a tetrabromofluoranthene by brominating the hydrocarbon itself with excess bromine. Campbell et al.(25) later proved the tribromofluoranthene to be 3,8,9-tribromofluoranthene by oxidation and decarboxylation to 2,3-dibromofluorenone. Fittig et al.(6) obtained a trinitrofluoranthene by treating the hydrocarbon with concentrated nitric acid under somewhat vigorous conditions. Although the orientation was not proved, it is not likely to be 3,8,9-trinitrofluoranthene. McBee et al.(32) obtained a good yield of perfluorofluoranthene ($C_{16}F_{26}$) by fluorinating fluoranthene with silver difluoride, and in 1938, Gerty (5) isolated a tetrachlorofluoranthene.

Substituents in Tetrahydrofluoranthene

It was found that chlorosulfonation, bromination and Friedel-Crafts reaction with phthalic anhydride effects substitution of 1,2,3,10b-

tetrahydrofluoranthene (XLIII) mainly in position 4 together with small amounts of the 8-isomer (21). Iodination occurs in position 4(5). It will be noted that all the above substitutions are in an aromatic ring.



(XLIII)

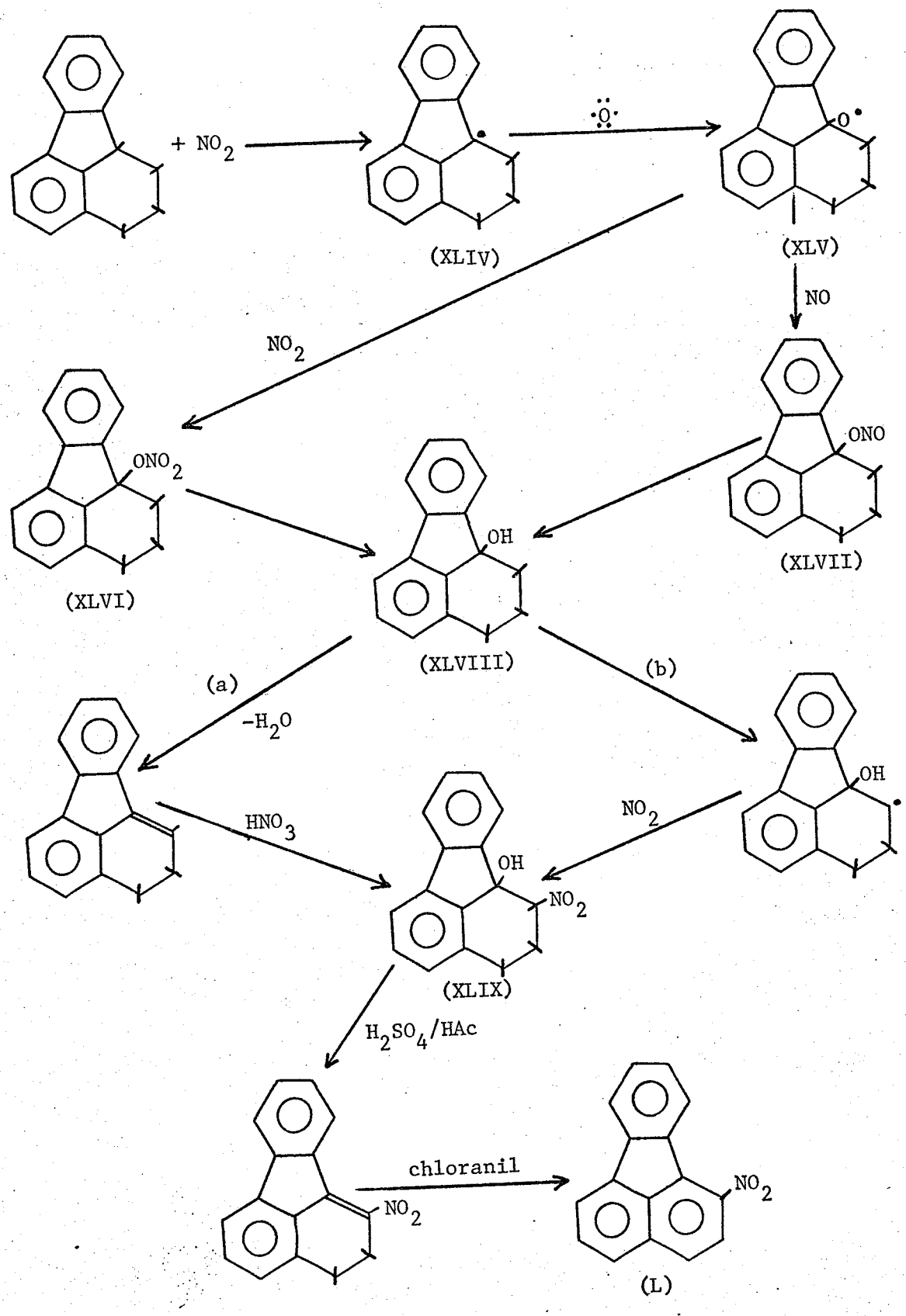
Campbell and Wilshire (33) in an attempt to prepare a dinitrofluoranthene nitrated tetrahydrofluoranthene with fuming nitric acid in acetic acid and ended up with 1-nitrofluoranthene thus providing a good general method for the preparation of 1-substituted fluoranthenes.

It is a well established fact that in nitration of aromatic hydrocarbons with nitric acid and sulfuric acid mixtures or with nitric acid in acetic acid without sulfuric acid, the nitrating species is the nitronium ion (NO_2^+). Fluoranthene when treated with nitric acid in acetic acid nitrates in the expected reactive 3 position. As was mentioned above electrophilic reagents normally attack the 4 position of tetrahydrofluoranthene. The preferential nitration in the alicyclic rather than the aromatic nucleus could be explained by a free radical mechanism. Wilshire(34) found that the reaction occurs at 85° but not at 50°. The strength of acid used was 95%. Titov (36) found that nitric acid of 50-70% strength or greater cannot be successfully freed from nitrogen oxides. He found that pure nitric acid was ineffective in the nitration of cyclohexane and claimed that the nitrating specie was nitrogen tetroxide (NO_2).

Based on this theory then, nitric acid acts only as a source of nitrogen oxides and of NO_2 regeneration from the lower oxides. Titov felt that aromatic nitration involved complex ions or complexes of a crypto-ionic character whereas the nitration of saturated hydrocarbons involved free radicals. On this basis, Wilshire (34) postulated the following mechanism which is illustrated on the following page. Because of aromatic resonance of the fluorene part of the molecule, the tertiary methine bond is weakened and is thus susceptible to attack by the electrophilic, monomeric nitrogen tetroxide to give XLIV.

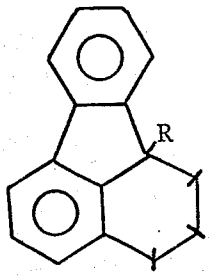
The tetrahydrofluoranthyl radical (XLIV) is oxidised to an oxygen containing radical (XLV) which is attacked by nitric oxide and nitrogen-tetroxide to give unstable intermediate compounds XLVII and XLVI. These are then hydrolysed in the acid medium to 10b-hydroxy-1,2,3,10b-tetra-hydrofluoranthene (XLVIII) which may or may not be stable. If unstable, the dihydrofluoranthene which results on dehydration, immediately adds on nitric acid to give 10b-hydroxy-1-nitro-1,2,3,10b-tetrahydrofluoranthene (XLIX) following path a. If 10b-hydroxy-1,2,3,10b-tetrahydrofluoranthene is stable, the free radical mechanism of path b could occur. Thus the oxides of nitrogen which hindered aromatic nuclear nitration of tetra-hydrofluoranthene promoted nitration and oxidation of the alicyclic ring. Once 1,2,3,10b-tetrahydro-1-nitro-10b-hydroxyfluoranthene is formed, it is dehydrated with either acetic anhydride or sulfuric acid in acetic acid to give 1-nitro-2,3-dihydrofluoranthene. Aromatization of this compound with chloranil gives 1-nitrofluoranthene (L).

Campbell and Wilshire also nitrated 4-bromo-1,2,3,10b-tetrahydro-fluoranthene. They obtained 4-bromo-1-nitro-10b-hydroxy-1,2,3,10b- tetra-hydrofluoranthene which was dehydrated and aromaticized to 1-nitro-4-bromo-fluoranthene. Further bromination of 4-bromo-1,2,3,10b-tetrahydrofluor-


+ NO2
(XLIV)
(XLV)
NO
NO2
ONO2
(XLVI)
ONO
(XLVII)
OH
(XLVIII)
(a)
-H2O
(b)
HNO3
NO2
OH
NO2
(XLIX)
H2SO4/HAc
chloranil
NO2
(L)

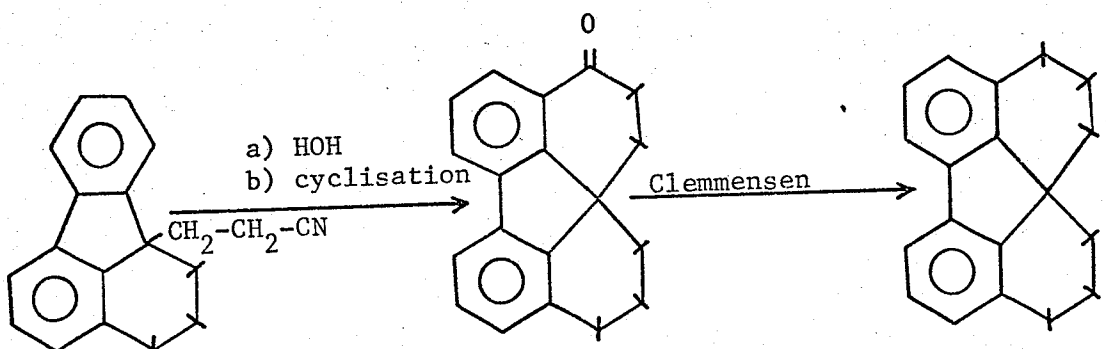
anthene however occurs in position 9 (15).

1,2,3,10b-Tetrahydrofluoranthene and 1,2,3,10b-tetrahydro-1,1,3-trimethylfuoranthene both contain in the five-membered rings methine groups sufficiently reactive to be alkylated. Hofmann and Tagmann (37) showed that in the presence of sodium amide these tetrahydrofluoranthenes react with tertrary amino-alkyl chlorides (e.g. diethylaminoethyl chloride) to give compounds of the type shown below. Also tetrahydrofluoranthene



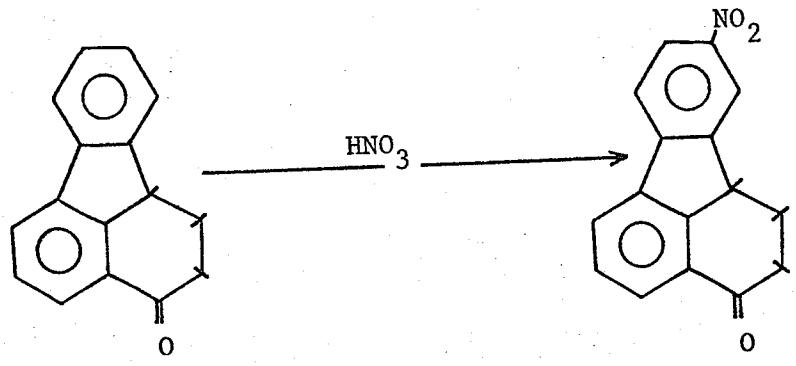
$R = -CH_2-CH_2-N(C_2H_5)(C_2H_5)$

reacted with acrylonitrile to form 10b-(2'-cyanoethyl)-1,2,3,10b-tetrahydrofluoranthene (LI). Hydrolysis gave the acid and cyclisation formed the spiro-ketone LII, from which the parent hydrocarbon LIII could be obtained by Clemmensen reduction (38).



(LI) (LII) (LIII)

In contrast to 1,2,3,10b-tetrahydrofluoranthene which is nitrated in position 1(33), nitration of 1,2,3,10b-tetrahydro-3-oxofluoranthene occurs in position 9 (16) to form LIV.



(LIV)

DISCUSSION OF RESULTS

The purpose of this study was to investigate the directive properties of representative 1-substituted fluoranthenes mainly under brominating conditions and possibly under nitrating conditions also. The representative substituents chosen were nitro- a meta directing deactivating substituent, acetamido- an ortho-para directing activating substituent and bromo- an ortho-para directing but slightly deactivating substituent. Work on bromination and nitration had been done on almost all of these substituents in positions 2 and 3 of fluoranthene. Table II on Page 40 summarizes this work.

Generally speaking, 2- and 3-nitrofluoranthene brominate and nitrate in position 9 and one would expect the same behavior from 1-nitrofluoranthene. As can be observed from Table II, further substitution of 2- and 3-acetamidofluoranthene also generally occurs ortho to the initial substituent. However, there appears to be a solvent effect in the bromination of 3-acetamidofluoranthene, since acetic acid, carbon tetrachloride and mixtures thereof give a different product to pyridine. It is quite likely that both isomers are formed with the various solvents and that one predominates but not to the exclusion of the other. It should be noted that polarity of the solvent could not be the deciding factor here, because the same isomer was isolated with acetic acid and carbon tetrachloride. Indeed, it is debatable whether the reaction in pyridine versus acetic acid is one of solvent effect or brominating species effect. This phenomenon is quite familiar in organic

Table II

BROMINATION OF 2- AND 3-SUBSTITUTED FLUORANTHENES

Initial substituent	Solvent used	Position of entering group	Reference
2-nitro-	nitrobenzene	9	(19)
2-acetamido-	pyridine	3	(19)
2-bromo-		not done	
3-nitro-	nitrobenzene	9	(2)
3-acetamido-	pyridine	2	(4)
	acetic acid	8	(40)
	acetic acid/carbon tetrachloride 2:1	8	(27) page 53
	carbon tetrachloride	8	
3-bromo-	nitrobenzene	8 trisubstitution and tetrasubstitution also occurs.	(2) (15)
3-amino-	acetic acid	2	(4) (40)
3-methoxy-	acetic acid	2 and 8	(65)

NITRATION OF 2- AND 3-SUBSTITUTED FLUORANTHENES

Initial substituent	Solvent used	Position of entering group	Reference
2-nitro-	acetic anhydride	8(?) or 9(?)	(30)
2-acetamido-	acetic acid	3	(30)
2-bromo-		not done	
3-nitro-	acetic anhydride	9	(30)
3-acetamido-	acetic acid	2	(3)
3-bromo-		not done	
3-methoxy-	acetic acid	2 and 8	(31)

synthesis. Acetanilide nitrates in acetic anhydride to form mainly o-nitroacetanilide whereas in acetic acid the main product is p-nitroacetanilide (41). Also, naphthalene undergoes Friedel-Crafts acylation mainly in the 1-position with carbon disulfide or tetrachoroethane as solvent, whereas in nitrobenzene substitution occurs mainly in position 2 (42). Depending on the solvent used one would therefore expect 1-acetamidofluoranthene to substitute in similar fashion.

3-Bromofluoranthene brominates in position 8 and no work has been reported on the bromination of the 2-bromo isomer nor the nitration of 2- and 3-bromofluoranthene. Up to the present time, no work had been done on further substitution of position 1 (the final position in ring A) and we expected similar behavior to the other two positions.

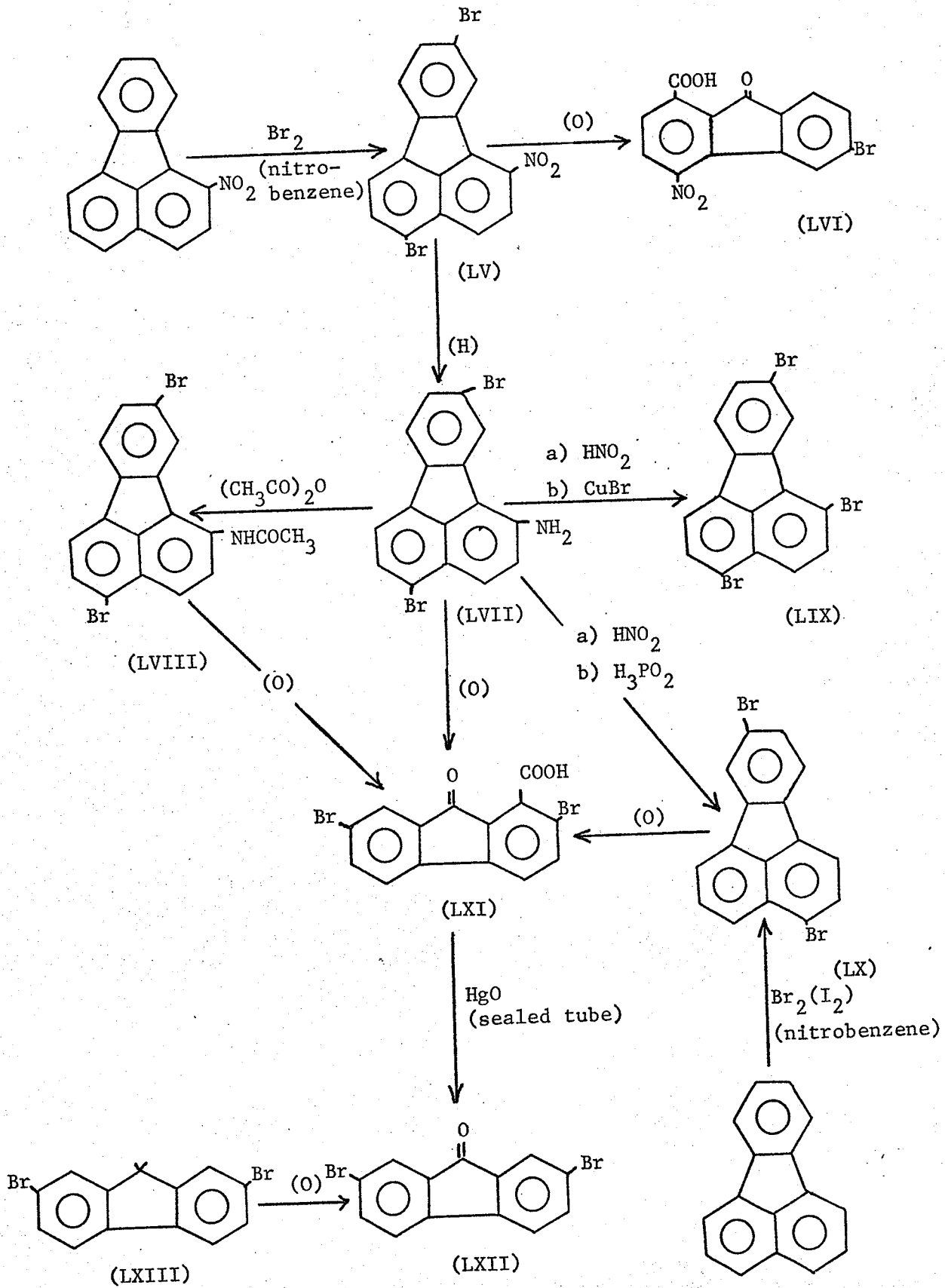
Synthesis of 1-Nitrofluoranthene

This compound was synthesized according to Campbell and Wilshire (33) by nitration of 1,2,3,10b-tetrahydrofluoranthene (see page 64). The tetrahydro compound was obtained in excellent yield by reduction of the hydrocarbon with 10% sodium-amalgam in ethyl alcohol. The yield of 1-nitrofluoranthene obtained by this method is low and the process had to be repeated many times which took several Summers in order to obtain a good supply of starting material. Indeed, whenever we suspected that a desired reaction did not go constant attempts, often unsuccessful, were made to recover 1-nitrofluoranthene.

Bromination of 1-Nitrofluoranthene*

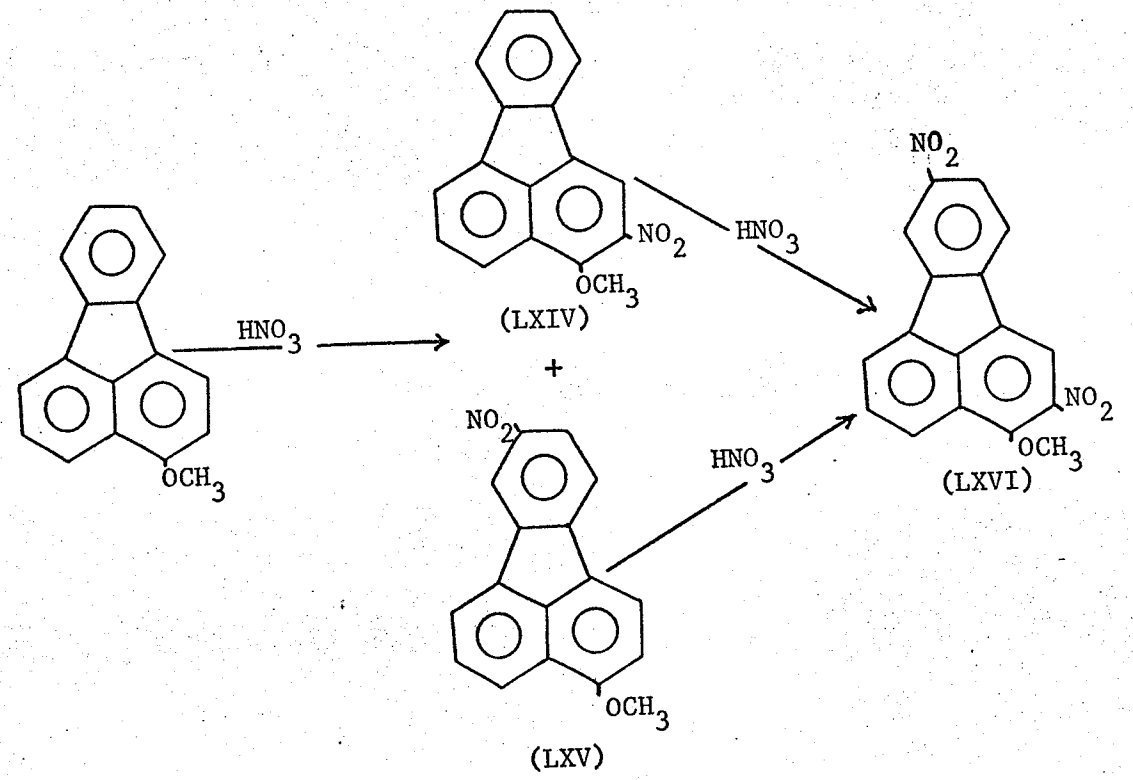
Since nitrobenzene was the solvent used for bromination of both 2- and 3-nitrofluoranthenes, it was also tried here. A red compound of M.P. 267-268° (LV) was obtained and analysis showed that two bromines were present. Oxidation of this compound with chromic acid gave the unknown mono-bromo acid (LVI) which proves that one of the two bromines went into ring B of the parent hydrocarbon. This is the first known instance of a substituent going into ring B when a mono-substituted fluoranthyl compound in ring A is further substituted. As can be observed from Table II page 40, further substitution occurs either in the same ring A or in ring C. The 1-nitro-dibromofluoranthene compound (LV) was reduced to 1-amino-dibromofluoranthene (LVII) both catalytically and with iron filings and concentrated hydrochloric acid in ethyl alcohol. Although 1-nitrofluoranthene undergoes catalytic reduction cleanly, it was found that iron filings and concentrated hydrochloric acid gave a better product with 1-nitro-dibromofluoranthene. The resulting amine (LVII) was acetylated in benzene to give 1-acetamido-dibromofluoranthene (LVIII). The amine (LVII) was also subjected to a Sandmeyer reaction with freshly prepared cuprous bromide to give a tribromofluoranthene (LIX). The orientation of one of the bromines in LIX is obviously position 1. Since on oxidation of LV a bromine was lost, then one bromine must be in ring B with the second bromine in ring A or C. The 1-amino-dibromo compound (LVII) on deamination gave 3,8-dibromofluoranthene (LX) identical with that prepared by bromination of fluoranthene with bromine and a little iodine in nitrobenzene according to Tobler et al.(15). Thus in all the dibromo compounds mentioned above, the bromines

* The flow scheme appears on the following page.


Br
Br_2
(nitro-
benzene)
NO_2
NO_2
(O)
COOH
O
Br
NO_2
(LVI)
Br
(LV)
(H)
Br
Br
NH_2
Br
a) HNO_2
b) CuBr
Br
Br
Br
$(CH_3CO)_2O$
$NHCOCH_3$
Br
(LVII)
(LIX)
(LVIII)
a) HNO_2
b) H_3PO_2
(O)
(O)
Br
O
COOH
Br
Br
(O)
(LXI)
HgO
(sealed tube)
(LX)
$Br_2(I_2)$
(nitrobenzene)
Br
Br
(O)
Br
O
Br
(LXIII)
(LXII)

are in positions 4 and 9. The orientation of the two bromines was further proved when oxidation of 3,8-dibromofluoranthene (LX), 1-amino-4,9-dibromofluoranthene (LVII) and 1-acetamido-4,9-dibromofluoranthene (LVIII) all gave the same acid, namely 2,7-dibromofluorenone-1-carboxylic acid (LXI). This acid was decarboxylated with mercuric oxide at 180° in a sealed tube as was done by Campbell et al.(24) to give 2,7-dibromofluorenone (LXII) identical with a sample prepared by the oxidation of 2,7-dibromofluorene (LXIII). Bromination of 1-nitrofluoranthene with iodine and heat also gave 1-nitro-4,9-dibromofluoranthene both in nitrobenzene and in carbon tetrachloride.

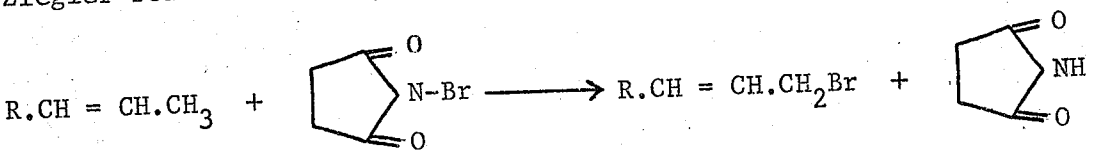
The question now arose as to whether the first bromine entered into position 4 or 9 or whether both isomers were formed together. An illustration of the latter was found by Andrew et al.(31) who showed that mononitration of 3-methoxyfluoranthene gave a mixture of 3-methoxy-2-nitrofluoranthene (LXIV) and 3-methoxy-8-nitrofluoranthene (LXV). Further nitration of the isomers gave 3-methoxy-2,8-dinitrofluoranthene (LXVI). This is illustrated below. It would appear that in LXIV the directive



power of the methoxy group overcomes the directive power of the nitro group since a second nitro enters position 8 and not 9. This is undoubtedly so in compound LXV.

Nevertheless in an attempt to answer the question of where the first bromine entered in 1-nitro-4,9-dibromofluoranthene, monobromination was tried on 1-nitrofluoranthene. The calculated amount of bromine for monobromination was added to 1-nitrofluoranthene in nitrobenzene and the solution was stirred at 5-10° for two days. Only starting material was recovered. The same result was obtained when the reaction was tried at room temperature. An attempt was then made to monobrominate 1-nitrofluoranthene with N-bromosuccinimide and pyridinium hydrobromide perbromide.

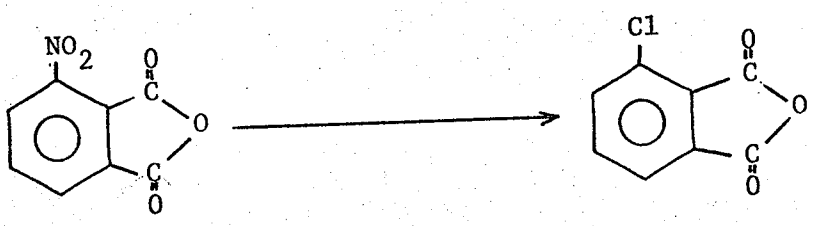
N-Bromosuccinimide (NBS) is usually associated with the Wohl-Ziegler reaction of allylic bromination, e.g.



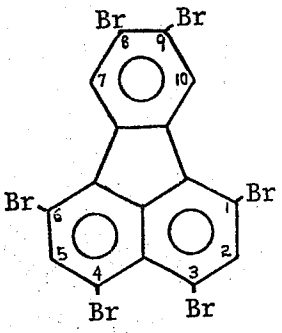
and side chain free radical bromination of aromatic compounds. It was found however (43), that nuclear bromination of aromatic hydrocarbons with NBS is possible if certain metal chlorides (aluminum, zinc and ferric) are used as catalysts. In the case of polynuclear aromatic hydrocarbons (44) catalysts were unnecessary, naphthalene and phenanthrene reacting in about six hours to give the 1 and 9-bromo derivatives, respectively; with acenaphthene and anthracene reaction was complete in a matter of minutes, the corresponding 5- and 9-bromo derivatives being formed. With this in mind, commer cial grade NBS was purified and added to 1-nitrofluoranthene in carbon tetrachloride. The solution was refluxed and the resulting product precipitated. A mixed melting point with starting material showed no depression and it was assumed that bromination did not occur.

The next brominating agent tried was pyridinium hydrobromide perbromide $C_5H_5\overset{+}{N}H\bar{B}r_3$. This compound was prepared from pyridine, hydrobromic acid and bromine according to Fieser and Fieser (45). The red crystalline solid is more convenient and agreeable to handle than bromine and there are instances in which it is a distinctly superior brominating agent (46). Bromination of 1-nitrofluoranthene with pyridinium hydrobromide perbromide was tried both in acetic acid and nitrobenzene at room temperature and with heating. As before no bromination occurred and only starting material was recovered.

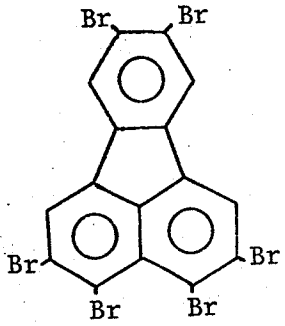
An attempt was then made to polybrominate 1-nitrofluoranthene with the aim of getting 1-nitrotribromofluoranthene. Bromine and a little iodine were added to 1-nitrofluoranthene in nitrobenzene at room temperature. This reaction yielded only 1-nitro-4,9-dibromofluoranthene. The same result was obtained when carbon tetrachloride with refluxing was used instead of nitrobenzene. Another attempt was made at polybromination in nitrobenzene. This time iodine was also used but with excess bromine and the solution was refluxed for two days. A high melting product was obtained and analysis indicated complete loss of NO_2 and the presence of six bromines (i.e. $C_{16}H_4Br_6$). It is quite likely that the $-NO_2$ group had been displaced by bromine. The displacement of $-NO_2$ by chlorine has been shown by Heller (48) in substituted phthalic anhydride. In the compound $C_{16}H_4Br_6$, there is good reason to believe



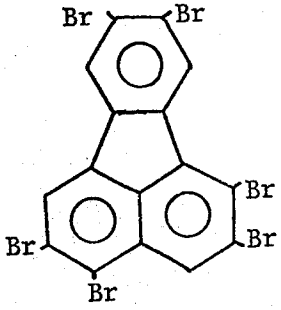
that three of the six bromines are in positions 4, 8 and 9 (see page 51). If displacement of $-NO_2$ by bromine occurred, the structure could be symmetrical (LXVII). This however, is unlikely since bromines 1 and



(LXVII)



(LXVIII)



(LX X)

6 are meta to bromines 3 and 4 respectively. This argument will also apply if bromines were in the 7 and 10 positions. The proposed structure might then be LXVIII. This is not likely since positions 3 and 4 are peri to each other. Peri groups are closer to each other than ortho groups (66), and steric hindrance would prevent bromines from being in positions 3 and 4. Structure LX X is fairly symmetrical and all the bromines are in ortho positions with one of them occupying the displaced nitro group. This is a plausible structure. If a solvent could be found to dissolve enough of this compound to give a workable concentration, the NMR spectrum would do much to help elucidate the structure.

Bromination of 1-Acetamidofluoranthene*

As can be seen from Table II page 40, bromination of both 2- and 3-acetamidofluoranthene occurs readily in pyridine. Attempted bromination of 1-acetamidofluoranthene in pyridine was unsuccessful in spite of various reaction conditions such as concentration of bromine, reaction time and variation of temperature. Since acetic acid was also used for bromination of 3-acetamidofluoranthene (40) it was the next solvent tried. Varying conditions still resulted in failure. The same occurred with dimethyl sulfoxide as solvent. Campbell and Keir (2) successfully brominated 2-acetamido-7-nitrofluorene in carbon tetrachloride with refluxing to yield 2-acetamido-3-bromo-7-nitrofluorene in fairly good yield. Similar conditions proved quite successful with 1-acetamidofluoranthene. After a series of recrystallizations with various solvents 1-acetamidotribromofluoranthene (LXIX) and 1-acetamidotetrabromofluoranthene (LXXI) were obtained. These compounds were only slightly solu ble in the usual organic solvents and separation by both thin layer and column chromatography proved fruitless. Since mono- and dibromination was the present object the reaction was again tried but this time in an ice-water bath. 1-Acetamidodibromofluoranthene (LVIII) but none of the monobromo compound was obtained. When the theoretical amount of bromine for monobromination was used, no reaction occurred.

Since 2-acetamido and 3-acetamidofluoranthene monobrominated in the same ring as the original substituent and ortho to it, it was expected that one of the bromines of 1-acetamidodibromofluoranthene would be in position 2. From previous behavior of further bromination of monobromofluoranthene and because of the directive power of the acetamido group, the second bromine would likely be in position 8. The structure would then be a (page 50).

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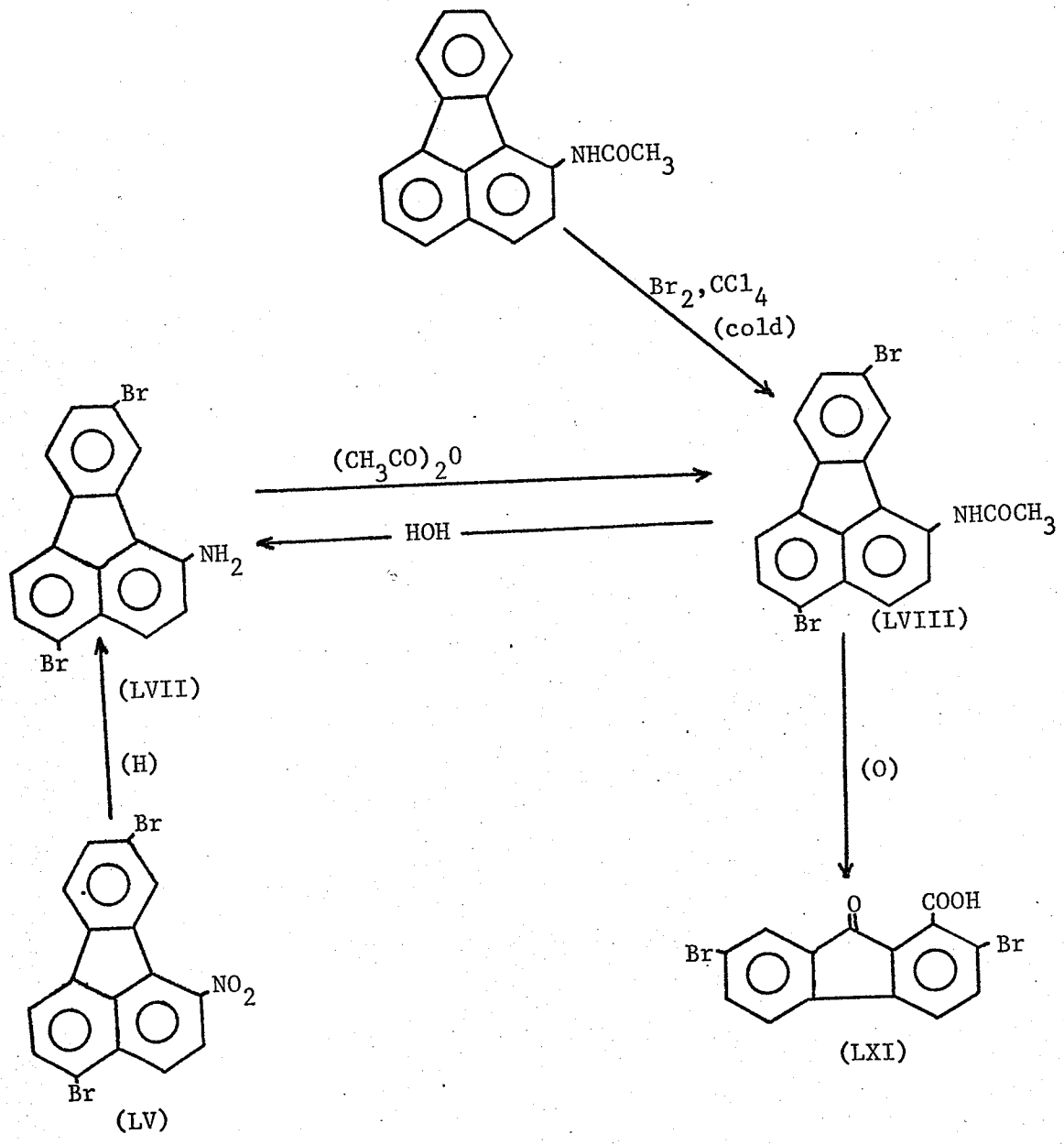
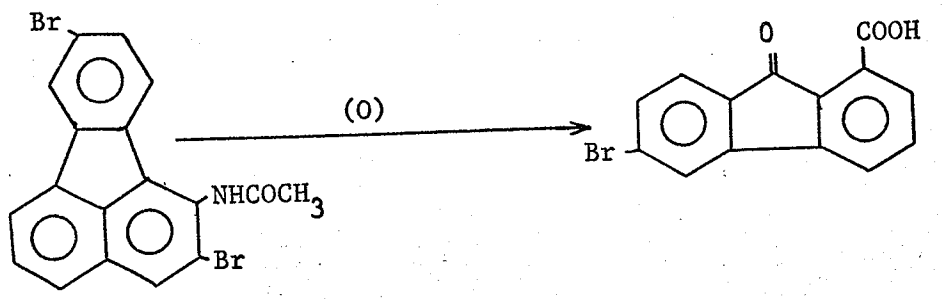
* The flow scheme appears on the following page.


NHCOCH3
Br2, CCl4
(cold)
Br
NHCOCH3
Br
(LVIII)
(CH3CO)2O
HOH
Br
NH2
Br
(LVII)
(H)
(O)
Br
NO2
Br
(LV)
O
COOH
Br
Br
(LXI)

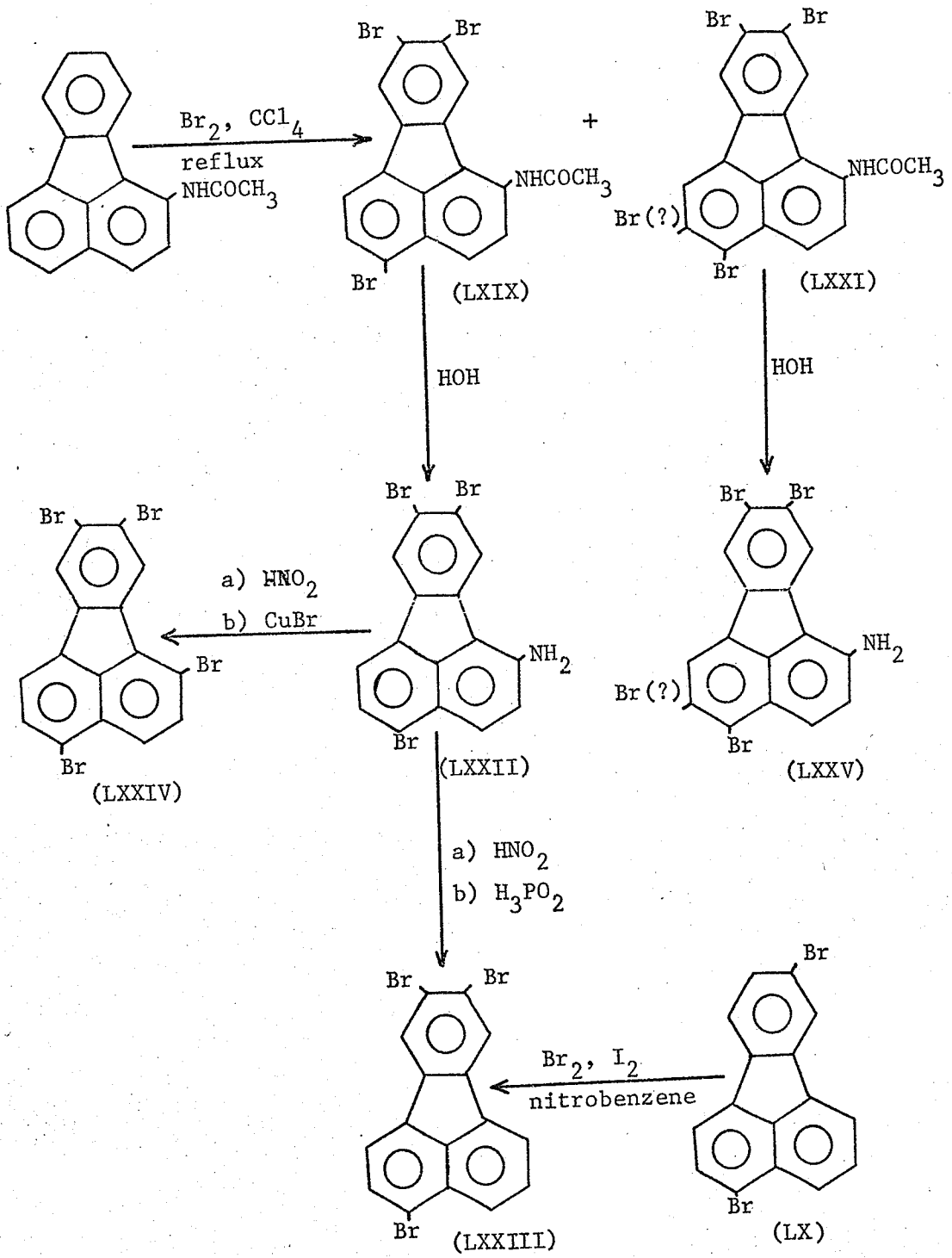


a b

Oxidation of a should give 6-bromofluorenone-1-carboxylic acid b. However, oxidation of the 1-acetamidodibromofluoranthene gave the known 2,7-dibromofluorenone 1-carboxylic acid (LXI). This indicates that bromine is present both in rings B and C. Futhermore hydrolysis gave 1-amino-dibromofluoranthene (LVII) identical to the amino compound obtained by reduction of 1-nitro-4,9-dibromofluoranthene (LV). Finally this 1-acetamidodibromofluoranthene (LVIII) proved to be identical to the acetamido compound obtained by acetylation of the 1-amino-4,9-dibromofluoranthene, which in turn was obtained by reduction of 1-nitro-4,9-dibromofluoranthene. Therefore, 1-acetamidofluoranthene dibrominated in the same positions as 1-nitrofluoranthene in spite of the vastly different directing substituents.

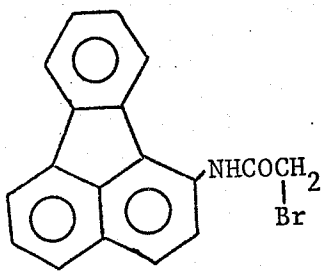
The structure of the 1-acetamidotribromofluoranthene (LXIX) was proved as shown on the following page. Hydrolysis of the amide gave the amine (LXXII). Deamination of this amine gave 3,8,9-tribromofluoranthene (LXXIII), identical with a sample prepared by bromination of 3,8-dibromofluoranthene (LX) according to the method of Tobler et al.(15). 1,4,8,9-Tetrabromofluoranthene (LXXIV) was synthesized by subjecting 1-amino-3,8,9-tribromofluoranthene (LXXII) to Sandmeyer conditions. The position of the fourth bromine in 1-acetamido-4,8,9,(?)-tetrabromofluoranthene (LXXI) has not been established. The fourth bromine could not be in position 3 because it is meta to acetamido and also peri to position 4. Position 2 is reasonable since it is ortho to acetamido and similar substitution with acetamido in the 2 or 3 position is known. However, position 5 is even more attractive since it is ortho to a bromine, para to a bromophenyl and gives a symmetrical fluorene system. Oxidation to the fluorenone and analysis would indicate whether bromine was present in ring A. Lack of material and time has so far prevented such an investigation. An attempt was made to hydrolyse the amide to the amine (LXXV) with the view of deamination but no amine was isolated with the small amount of amide used. Hydrolysis of 1-acetamidobromofluoranthene was found to be increasingly difficult as more bromines entered the molecule.

Good NMR spectra of fluoranthene and benzofluoranthenes have been obtained in carbon tetrachloride (51)(63). Several attempts were made to obtain NMR spectra of 1-acetamidotribromo and tetrabromofluoranthenes and also 1,4,7,8-tetrabromofluoranthene. These compounds were only slightly solu ble in the ordinary organic solvents. They were even appreciable in solu ble in trifluoro-acetic acid. Nevertheless a supersaturated solution at room temperature was made up using dimethyl sulfoxide as solvent. The


Br2, CCl4
reflux
NHCOCH3
Br
Br
NHCOCH3
Br
(LXIX)
+
Br
Br
NHCOCH3
Br(?)
Br
(LXXI)
HOH
HOH
Br
Br
a) HNO2
b) CuBr
Br
Br
(LXXIV)
Br
Br
NH2
Br
(LXXII)
Br
Br
NH2
Br(?)
Br
(LXXV)
a) HNO2
b) H3PO2
Br
Br
Br
(LXXIII)
Br2, I2
nitrobenzene
Br
Br
(LX)

NMR peaks thus obtained at 130°C were too weak (because of the low concentration) to deduce anything about the position of the protons. Even scanning for two hundred times with the time averaging computer at 130°C gave spectra with high noise level.

Several attempts were made at monobromination of 1-acetamidofluoranthene. When the theoretical amount of bromine for monobromination was used no reaction occurred even with iodine as catalyst. Since with excess bromine reaction occurs in carbon tetrachloride but not at all in acetic acid, mixtures of various compositions of these two solvents were tried for monobromination. Either no reaction occurred or dibromination occurred. When pyridine hydrobromide perbromide was used as the brominating agent in acetic acid an impure monobromo compound was obtained. Since hydrolysis gave 1-aminofluoranthene, this suggests that side chain bromination had occurred to give the compound LXXVI.



(LXXVI)

The bromine is not likely to be on the N of LXXVI because no base was used in the reaction. Synthesis of both N-bromoacetamide from acetamide (59) and N-bromosuccinimide from succinimide (60) requires potassium or sodium hydroxide.

Bromination of 3-Acetamidofluoranthene

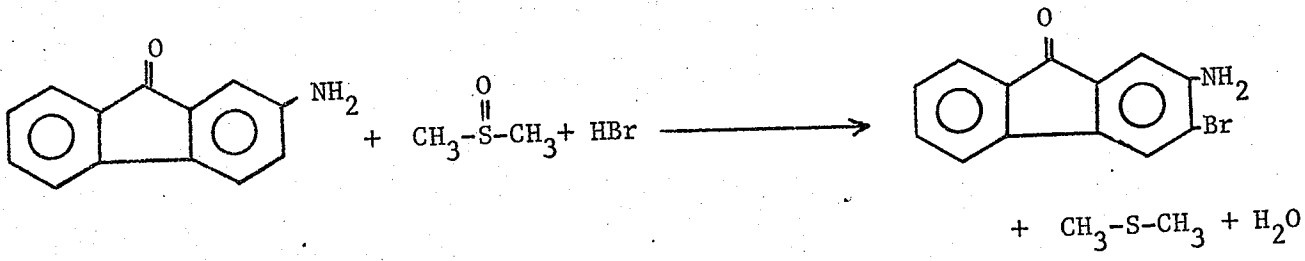
As is seen from Table II page 40, 3-acetamidofluoranthene brominated in position 2 in pyridine and in position 8 in acetic acid and in

carbon tetrachloride: acetic acid in the ratio 1:2. It was suspected that bromination in carbon tetrachloride alone would also occur in position 8 and this was proved to be so by the method of mixed melting points and infrared comparison with 3-acetamido-8-bromofluoranthene prepared by using the other solvent systems.

Bromination of 1-Aminofluoranthene

Bromination of 3-aminofluoranthene in acetic acid gives 3-amino-2-bromofluoranthene. Bromination of 1-aminofluoranthene was attempted in acetic acid and the resulting product subjected to column chromatography followed by several attempts at purification by thin layer chromatography. Although at one stage unreacted 1-amino compound was isolated, the other compound was quite tarry and unworkable.

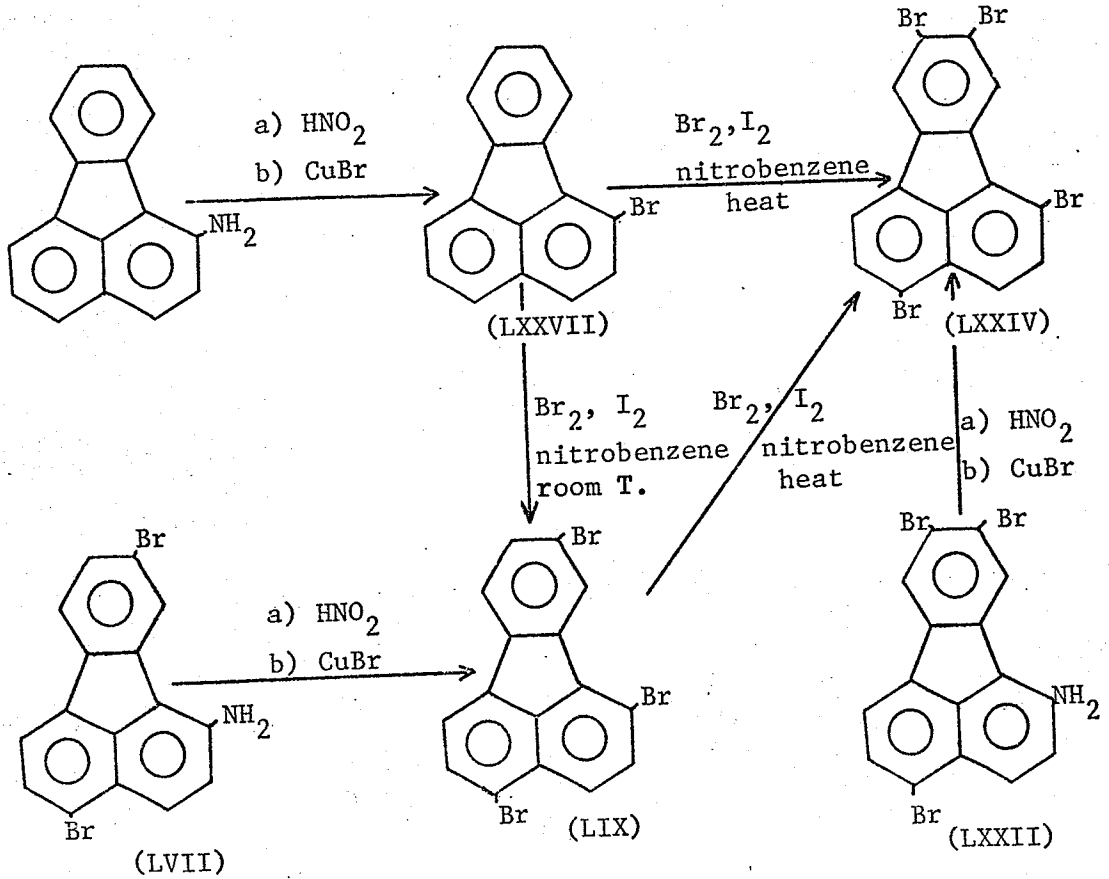
Fletcher et al.(49) demonstrated that better yields of the 3-bromo derivative of 2-aminofluorenone were obtained when 48% HBr and dimethyl sulfoxide were used rather than direct bromination.



The same conditions were tried for bromination of 1-aminofluoranthene. Here again purification of products by column and thin layer chromatography were of no avail.

Bromination of 1-Bromofluoranthene

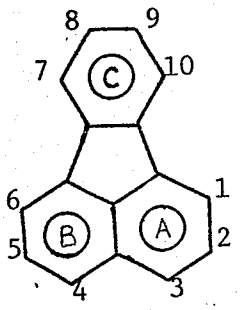
1-Bromofluoranthene (LXXVII) was synthesized by subjecting 1-aminofluoranthene to Sandmeyer conditions with freshly prepared cuprous bromide. 1-Hydroxyfluoranthene (LXXVIII) was obtained as a by-product. Attempted bromination of 1-bromofluoranthene in carbon tetrachloride and in nitrobenzene failed. However, when a little iodine was used as the Lewis acid in nitrobenzene, reaction occurred. The number of bromines entering the ring depends on the temperature at which the reaction was carried out. On heating a tetrabromofluoranthene (LXXIV) was isolated whereas at room temperature a tribromofluoranthene (LIX) resulted. The structure of these were proved as follows. The tribromofluoranthene (LIX) was identical with that obtained by doing a Sandmeyer reaction on 1-amino-4,9-di bromofluoranthene (LVII). Also the tetrabromofluoranthene was identical with that obtained by doing a Sandmeyer reaction on 1-amino-4,8,9-tribromofluoranthene (LXXII). Further bromination of LIX gave LXXIV. This work is illustrated below.



Several attempts were made to monobrominate 1-bromofluoranthene in various solvents with and without catalysts using the theoretical amount of bromine for monobromination. However, the desired compound was not obtained.

In all these bromination studies, several mass spectra were obtained with the hope of gaining a clue to elucidation of structure. However, it appears that on ionization, the substituents come off the fluoranthene nucleus first before fragmentation of the nucleus occurs. The mass spectra were therefore only helpful in that they showed the number of substituents. Identity of compounds was based on analysis, infrared spectra and mixed melting points.

Theoretical Implications of Dibromination of 1-Nitro-, 1-Acetamido- and 1-Bromofluoranthene



A summary of the bromination of the three 1-substituted fluoranthenes is shown in Table III on the following page. Attempts at monobromination proved fruitless. Dibromination in all three cases occurred in positions 4 and 9, irrespective of the directing group in position 1.

The dibromination of 1-nitrofluoranthene to give 1-nitro-4,9-dibromofluoranthene may be explained in the following way. Both 2- and 3-nitrofluoranthene brominate in position 9. Therefore on the basis of known stated rules, 1-nitrofluoranthene might be expected to do the same. Assuming this did occur to direct the first bromine into position 9, it is understandable that the bromophenyl group of the diphenyl system formed

Table III

BROMINATION OF 1-SUBSTITUTED FLUORANTHENES

1-Nitrofluoranthene

a) Br_2, nitrobenzene, room T.		
b) Br_2, I_2, nitrobenzene, heat		1-Nitro-4,9-dibromofluoranthene
c) Br_2, I_2, CCl_4, reflux		
d) NBS*, CCl_4 (or nitrobenzene) heat		No Reaction
e) PHP**, acetic acid (or nitrobenzene) heat		
f) Br_2, I_2, nitrobenzene, boiled 2 days		Hexabromofluoranthene

1-Acetamidofluoranthene

a) Br_2, pyridine, varying temperatures	
b) Br_2, acetic acid, varying temperatures	No Reaction
c) Br_2, dimethyl sulfoxide, varying temperatures	
d) NBS*, CCl_4, reflux	
e) Br_2, CCl_4, cold	1-Acetamido-4,9-dibromofluoranthene
f) Br_2, CCl_4, reflux	1-Acetamido-4,8,9-tribromofluoranthene and 1-Acetamido-4,8,9(?)-tetrabromofluoranthene
g) PHP**, acetic acid, heat	Side chain bromination

1-Bromofluoranthene

a) Br_2, nitrobenzene, room T.	
b) Br_2, I_2, CCl_4, reflux	No Reaction
c) NBS*, nitrobenzene, heat	
d) Br_2, I_2, nitrobenzene, room T.	1,4,9-Tribromofluoranthene
e) Br_2, I_2, nitrobenzene, heat	1,4,8,9-Tetrabromofluoranthene

NBS* N-Bromosuccinimide PHP** Pyridinium hydrobromide perbromide.

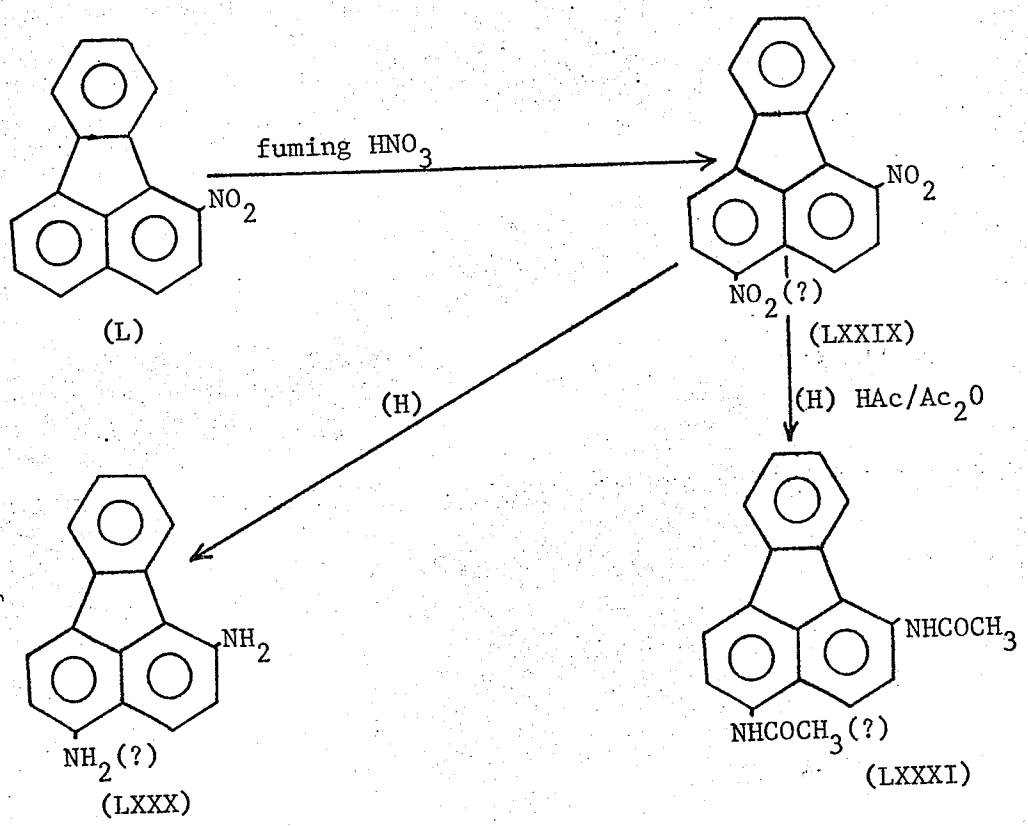
by rings B and C would direct to the para position of the system. i.e. to position 4.

However, the dibromination of 1-acetamidofluoranthene also occurred in positions 4 and 9, whereas on the basis of known stated rules, one might have expected dibromination in positions 2 and 8. Dibromination of 1-bromofluoranthene also occurred in positions 4 and 9. It is unlikely that bromination of 1-nitrofluoranthene would follow the known stated rules whereas bromination of 1-acetamido-and 1-bromofluoranthene would not.

It is possible then, that a substituent in position 1 of the fluoranthene molecule does not influence bromination to the same extent as if it were in positions 2 and 3. For all practical purposes then bromination occurs as if the 1 position was unsubstituted. Monobromination then should occur in position 3. However, the nitro group normally prevents bromination in the same ring and position 3 is meta to the acetamido and bromo groups in position 1. An equivalent position therefore is 4. Since 3-bromofluoranthene on further bromination gives 3,8-dibromofluoranthene, the second bromine of the 1 substituted fluoranthenes entering position 9 is understandable. Furthermore, 3,8-dibromofluoranthene on further bromination yields 3,8,9-tribromofluoranthene (15). 1-Acetamido-4,9-dibromofluoranthene and 1,4,9-tribromofluoranthene further brominate in an equivalent position i.e. position 8. In other words the last two compounds are reacting just as if they were 3,8-dibromofluoranthene.

Nitration of 1-Nitrofluoranthene

1-Nitrofluoranthene (L) was nitrated with fuming nitric acid in freshly distilled acetic anhydride at room temperature. A dinitro compound (LXXIX) was obtained. Catalytic reduction in ethyl alcohol, or acetic acid gave an impure diaminofluoranthene (LXXX). Diacetylation of the reduced dinitrofluoranthene via catalytic reduction "in situ" in acetic acid and acetic anhydride gave the diacetamidofluoranthene (LXXXI). Oxidation of both the dinitro- and diacetamido- compounds failed. Therefore, the position of the second nitro group has not as yet been established. From Table II page 40, it is seen that nitro groups in position 2 or 3 brominate and nitrate in the same way. Assuming that nitro in position 1 will also brominate and nitrate in the same way, then the second nitro group might be either in position 4 or 9. Because of the difficulty of oxidation, one might favor position 4. This is illustrated below. Preparation of 1,4-dinitrofluoranthene would show whether substitution occurred in position 4. A synthesis of 1,4-dinitrofluoranthene is proposed in Recommendation 3 on page 96.



Nitration of 1-Acetamidofluoranthene*

Nitration of both 2- and 3-acetamidofluoranthene occurs readily in acetic acid. However, nitration of 1-acetamidofluoranthene in acetic acid both at room temperature and with heating gave only minute amounts of nitration products if any at all. The same results were experienced when acetic anhydride was used as solvent. However, when carbon tetrachloride was used as the solvent more product was obtained. Reaction with fuming nitric acid at room temperature gave mainly a dinitro product (LXXXII), whereas when concentrated nitric acid was used a mononitro product (LXXXIII) was isolated. Hydrolysis of 1-acetamidodinitrofluoranthene (LXXXII) in ethyl alcohol and concentrated hydrochloric acid gave the amine hydrochloride (LXXXIV) and it was analyzed as such. Reduction of 1-acetamidonitrofluoranthene (LXXXIII) gave 1-acetamidoaminofluoranthene (LXXXV). There was not enough 1-acetamidonitrofluoranthene left to do a hydrolysis and deamination and this will be done in the future. This will give a mononitrofluoranthene and by mixed melting points the orientation of the nitro group could be established. For the present purpose it is assumed as stated on page 58 that the acetamido group in the 1 position like for bromination effects mono nitration in position 4. Following through the net non-directive influence of the 1-acetamido group, the second nitro group should enter into position 8. Therefore, a probable structure of the 1-acetamidodinitrofluoranthene would be 1-acetamido-4,8-dinitrofluoranthene.

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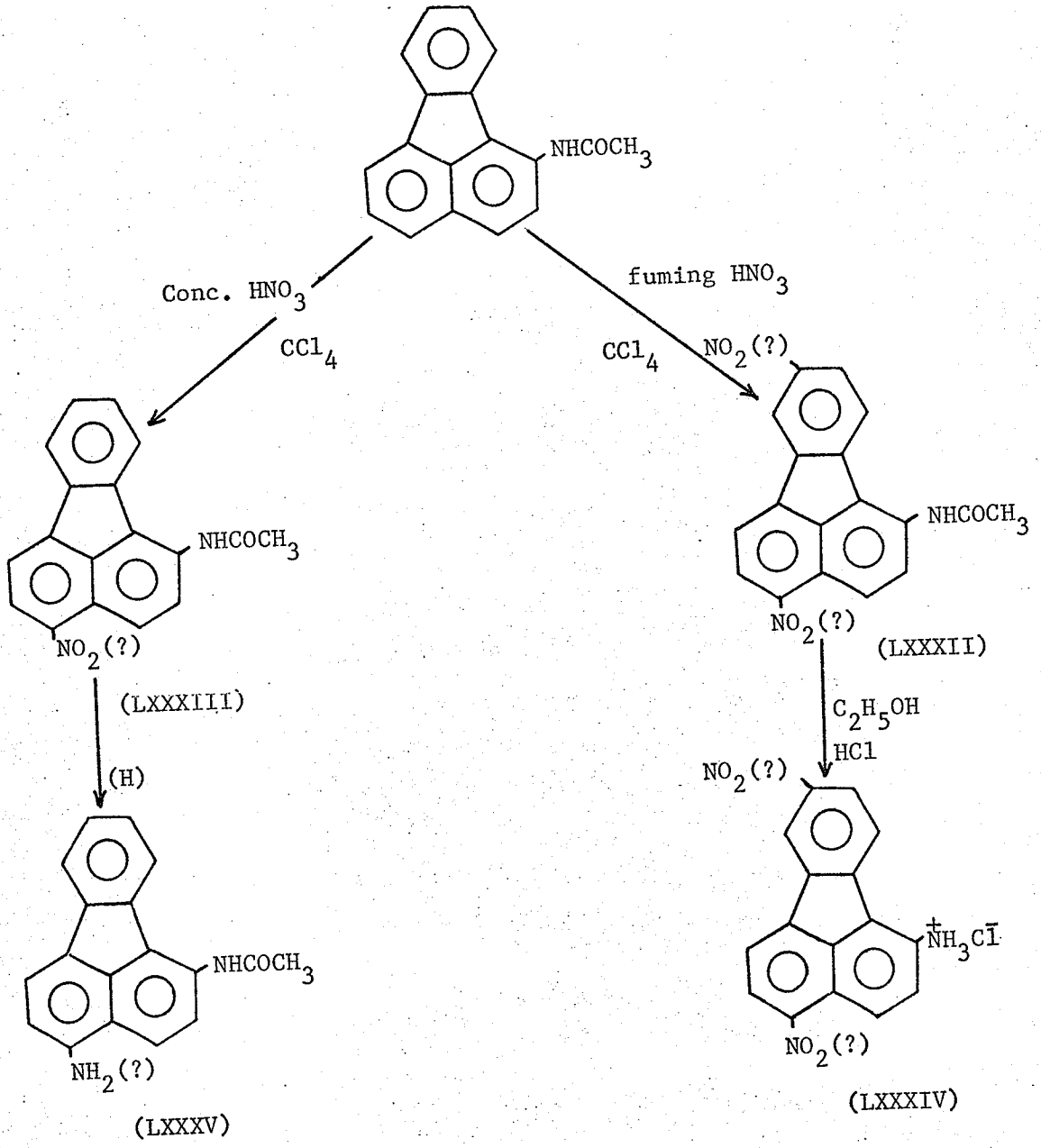
* The flow scheme appears on the following page.


NHCOCH3
Conc. HNO3
CCl4
fuming HNO3
CCl4
NO2(?)
NHCOCH3
NO2(?)
(LXXXIII)
(H)
NHCOCH3
NH2(?)
(LXXXV)
NHCOCH3
NO2(?)
(LXXXII)
C2H5OH
HCl
NO2(?)
NH3Cl
NO2(?)
(LXXXIV)

EXPERIMENTAL

Instruments and Materials Used

Hitachi Perkin - Elmer RMU 6 D Mass Spectrometer.

Perkin - Elmer 137 Spectrophotometer for infra red spectra.

Varian A-56/60A Analytical NMR Spectrometer fitted with a Varian C-1024 Time Averaging Computer.

Parr Low Pressure Catalytic Hydrogenation Apparatus.

Improved Fisher - Johns Melting Point Apparatus for melting points up to 300°.

Melting Point Vanderkamp Apparatus for melting points beyond 300°.

Adams' Catalyst (Platinum Oxide PtO_2) supplied by Matheson Coleman and Bell.

Aluminium Oxide (507-C) for Column Chromatography (Camag).

Silica gel (DF-5) for Thin Layer Chromatography (Camag).

Analyses were done by:

a) Chemalytics, Inc. Tempe, Arizona.

b) Geller Laboratories, Saddle River, N.J.

1) Preparation of 10% Sodium Amalgam

This was essentially prepared by the method (55) that was used for the preparation of 5% sodium amalgam. The sodium amalgam was prepared in a 500 ml flask fitted with a two-hole rubber stopper carrying a dropping funnel and an outlet tube. Sodium (95 g.) and mineral oil (200 ml.) were put into the flask. With a stream of nitrogen passing through the side arm of the flask, it was heated until the sodium melted and then mercury (855 g.) was added rapidly from the dropping funnel with swirling. Heavy asbestos gloves were worn to keep the flask swirling since the vigorous exothermic reaction caused the temperature to approach about 400°. After cooling the amalgam became solid. The flask was broken and the solid broken into small pieces with a hammer.The pieces were then stored under petroleum ether.

2) Synthesis of 1,2,3,10b-Tetrahydrofluoranthene

The procedure used for this preparation was that of Steinberg et al.(56). A solution of fluoranthene (100 g.; 0.5 moles) in absolute alcohol (200 ml.) was heated to 60° in a 4-liter flask fitted with a Hershberg stirrer. To this solution 681 g. of 10% sodium amalgam (equivalent to 68.1 g., 2.96 moles of sodium) were added in about 40 g. portions. The temperature was maintained between 55 - 60°. After the reaction was completed the reaction mixture was stirred for four hours at the same temperature. At the end of this time the reaction mixture was diluted with water (500 ml.) and the solution adjusted to pH4 with concentrated hydrochloric acid. The warm solution was then filtered to remove mercury and precipitated sodium chloride, and placed in the refrigerator overnight. The crystallized product (92 g.) was filtered and dried m.p. 72-77°. Recrystallization from

95% ethanol gave 85 g. m.p. 75-77°.

3) Synthesis of 1-Nitrofluoranthene (L)

The procedure used for this preparation was that of Campbell and Wilshire (33). Fuming (95%) nitric acid (7.17 ml.) was added dropwise with stirring to 1,2,3,10b-tetrahydrofluoranthene (20.6 g.) in glacial acetic acid (200 ml.) and the solution maintained at 80° (external bath temperature). After 1 hour the solution was cooled and poured into iced water. The product was extracted with ether, the extract washed with aqueous sodium carbonate, then with water, and dried (Na_2SO_4). Evaporation gave a syrup which when triturated with benzene yielded 1,2,3,10b-tetrahydro-10b-hydroxy-1-nitrofluoranthene. Recrystallization from acetic acid gave colorless crystals. m.p. 192-193°. The filtrate on evaporation gave a red syrup which was dissolved in benzene-ligroin and chromatographed through a column. More of the hydroxynitro-compound was thus obtained together with impure 2,3-dihydro-1-nitrofluoranthene. Recrystallization from ethyl alcohol gave orange crystals. m.p. 92-94°. All the hydroxynitro-compound was converted to the nitro compound with acetic acid containing a few drops of sulfuric acid. 2,3-Dihydro-2-nitrofluoranthene (8 g.) was then boiled in xylene (120 ml.) with chloranil (16 g.) for 24 hours. The solution was decanted and diluted with benzene, washed with 5% aqueous sodium hydroxide (3 X 200 ml.), once with 10% sodium hydroxide, and finally with water. The dried (Na_2SO_4) solution was evaporated to small volume, and ligroin (b.p. 80-100°) was added. The solution was boiled with charcoal and filtered hot and on cooling deposited 1-nitrofluoranthene (4.5 g.). m.p. 151-153°. The infra red spectrum is shown on page 105.

4) Synthesis of 1-Nitro-4,9-Dibromofluoranthene (LV)

1-Nitrofluoranthene (2 g.) was dissolved in nitrobenzene (35 ml.) and filtered. The solution was stirred and bromine (0.8 ml.) was added in portions (0.1 ml.) over 30 minutes. After 4 hours, a precipitate was observed. Stirring was continued for another hour followed by filtration. The precipitate was washed with cold 95% ethanol (50 ml.) in order to remove some of the nitrobenzene. m.p. 221-240°. It was then washed successively with 10% aqueous solution of sodium hydroxide and sodium bisulfite and then water. It was then recrystallized twice from chlorobenzene and gave beautiful red crystals (1.2 g.) m.p. 265-267°. The infra red spectrum is shown on page 106.

Analysis

Found: N, 3.34; Br, 39.27
Calculated for $C_{16}H_7O_2NBr_2$: N, 3.46; Br, 39.55

5) Synthesis of 1-Amino-4,9-Dibromofluoranthene (LVII) by Reduction of the Nitro Compound

Catalytic reduction of 1-nitro-4,9-dibromofluoranthene in ethanol using Adam's catalyst did not give a product as pure as when iron filings and concentrated hydrochloric acid were used. 1-Nitro-4,9-dibromofluoranthene (1 g.) was boiled in ethanol (100 ml.) with iron powder (1 g.) and concentrated hydrochloric acid (10 ml.) for 4 hours, during which hydrochloric acid (5 ml.) and iron powder (0.5 g.) were added. The mixture was cooled, made alkaline with ammonia, poured into water and extracted 3 times with chloroform. The chloroform solution was filtered and a little concentrated hydrochloric acid added which caused the separation of the amine hydrochloride. The amine salt was filtered and addition of ammonia liberated the impure amine m.p. 200-210°. Three recrystallizations from

petroleum ether (b.p. 60-80°) and charcoal yield 1-amino-4,9-dibromo-fluoranthene as light greenish-yellow platelets (0.5 g.) of m.p. 209-211°. The infra red spectrum is shown on page 107.

Analysis

Found: N, 3.75; Br, 42.08
Calculated for $C_{16}H_9NBr_2$: N, 3.74; Br, 42.70

6) Synthesis of 1-Acetamido-4,9-Dibromofluoranthene (LVIII) by Acetylation of the Amine

1-Amino-4,9-dibromofluoranthene (1 g.) was dissolved in benzene (150 ml.) and stirred with slight warming. A calcium chloride tube was used to exclude moisture. Freshly distilled acetic anhydride (50 ml.) was added from a dropping funnel. After about 15 minutes a precipitate appeared. Stirring was continued for another hour. The solution was then cooled, filtered and washed with benzene. Pure 1-acetamido-4,9-dibromofluoranthene was thus obtained as greenish-white platelets (0.8 g.). m.p. 316.5-318°. The infra red spectrum is shown on page 108.

Analysis

Found: N, 3.42; Br, 38.84
Calculated for $C_{18}H_{11}ONBr_2$: N, 3.36; Br, 38.40

7) Oxidation of 1-Nitro-4,9-Dibromofluoranthene to give 4-Nitro-6- Bromo-fluorenone-1-Carboxylic Acid (LVI)

1-Nitro-4,9-dibromofluoranthene (1 g.) was suspended in acetic acid (100 ml.). Chromic acid (2 g.) in water (13 ml.) and acetic acid (9 ml.) was added to the cold stirred solution and left overnight. Next day the solution was refluxed for 2 hours and half the solvent removed by distillation. The solution was poured into iced water and extracted with ether. The ether layer was extracted with aqueous sodium carbonate and

the carbonate extract on acidification with hydrochloric acid gave impure acid m.p. 238-250°. Recrystallization from acetic acid and charcoal gave pure 4-nitro-6-bromofluorenone-1-carboxylic acid as yellow-orange needles. (0.2 g.) m.p. 252-254°. The infra red spectrum in shown on page 109.

Analysis

Found: N, 3.44; Br, 23.09
Calculated for $C_{14}H_6O_5NBr$: N, 4.03; Br, 23.00

8) Preparation of Cuprous Bromide

This was prepared essentially by the method of Buck et al.(61). Sodium metabisulfite (41 g.) and sodium hydroxide (27 g.) were dissolved in water (600 ml.). Sodium bromide (91 g.) was then added to the solution and stirring was continued until everything dissolved. Copper sulfate (189 g.) was suspended in water (300 ml.) and added to the above solution with stirring. The white precipitate was filtered, rinsed with a little acetone to hasten drying and stored in the dark in a brown bottle. If the cuprous bromide is not used the same day it was prepared, it could be reprecipitated from 48% HBr and water.

9) Synthesis of 1,4,9-Tribromofluoranthene (LIX) from 1-Amino-4,9-Dibromofluoranthene (LVII)

The procedure for the Sandmeyer reaction used here is similar to that used by Campbell and Keir (2) for the synthesis of 3,8-dibromofluoranthene from 3-amino-4-bromofluoranthene. Sodium nitrite (1 g.) was dissolved in concentrated sulfuric acid (10 ml.) by adding in portions and stirring. The dibromo-amine (0.6 g.) was dissolved in acetic acid (50 ml.) and filtered. This was chilled and then slowly added to the cold (0-5°) nitrous acid solution with stirring. The blood red solution

was stirred another hour. After that time it was added to a boiling solution of freshly prepared cuprous bromide (3 g.) in 48% HBr (50 ml.). The solution was refluxed for 2 hours, cooled and poured into iced water. The solution was extracted with benzene. The insolu ble residue was boiled with benzene and the combined extracts were washed with water, dried with sodium sulfate and subjected to column chromatography with alumina. A yellow band separated and on elution with benzene yielded a light yellow compound. m.p. 190-198°. Recrystallization from benzene, petroleum ether and charcoal gave light yellow platelets (0.1 g.), of m.p. 196-198°. The infra red spectrum is shown on page 110.

Analysis

Found: Br, 54.61

Calculated for $C_{16}H_7Br_3$: Br, 53.87

10) Oxidation of 1-Amino-4,9-Dibromofluoranthene (LVII)

A solution of chromic anhydride (1.5 g.) in water (2 ml.) and glacial acetic acid (2 ml.) was added over a period of ten minutes to a boiling solution of 1-amino-4,9-dibromofluoranthene (0.3 g.) in glacial acetic acid (20 ml.) The remaining oxidation mixture was rinsed into the reaction mixture with a small amount (2 ml.) of glacial acetic acid. The mixture was refluxed for four hours and then it was poured into 1:4 v/v sulfuric acid solution (50 ml.) and allowed to stand at room temperature overnight. The impure solid was filtered off, washed with dilute acid and distilled water, and allowed to dry. It was purified by dissolving it in 5% sodium carbonate solution and filtering out a small amount of insolu ble residue, and finally by re-precipitating the acid with (1:4 v/v) aqueous sulfuric acid solution. The solid was filtered and allowed to dry. Recrystallization from acetic acid and charcoal gave 2,7-dibromo-

fluorenone-1-carboxylic acid as light orange needles (50 mg), of m.p. 267-269°. The infra red spectrum is shown on page 111.

Analysis

Found: Br, 39.8

Calculated for $C_{14}H_6O_3Br_2$: Br, 41.9

11) Oxidation of 1-Acetamido-4,9-Dibromofluoranthene (LVIII)

This compound was oxidized in the same manner as described for 1-amino-4,9-dibromofluoranthene (see 10 page 68). The yield of 2,7-dibromofluorenone-1-carboxylic acid was only slightly better than that obtained from the amino compound. Mixed melting points and comparison of infra red spectra showed that the two acids were identical.

12) Synthesis of 3,8-Dibromofluoranthene (LX)

The experimental procedure used here is that of Tobler et al. (15). Bromine (67 g.) in nitrobenzene (60 g.) was added dropwise to a stirred solution of fluoranthene (67 g.) in nitrobenzene (360 g.) at room temperature. Stirring was continued for 48 hours during which time HBr evolved. The reaction mixture was then heated to 120° dissolving everything, and air was blown through to remove the HBr. A precipitate formed when the reaction mixture was cooled. The precipitate was filtered and steam passed over it to remove the last traces of nitrobenzene. Recrystallization from chlorobenzene and charcoal gave 3,8-dibromofluoranthene as bright yellow needles (48 g.), m.p. 206-207°. Literature 205°. The infra red spectrum is shown on page 112.

13) Oxidation of 3,8-Dibromofluoranthene (LX)

Aqueous permanganate oxidizes fluoranthene readily to give pink

platelets of 9-fluorenone-1-carboxylic acid, but a similar oxidation of 3,8-dibromofluoranthene proved unsuccessful. The method used then was essentially the same as was used for 1-amino-3,8-dibromofluoranthene (see no. 10 page 68). The 2,7-dibromofluorenone-1-carboxylic acid obtained melted at 268-270°. Mixed melting points with the acids from the amino and acetamido compounds showed that they were identical. This conclusion was also drawn from comparison of infra red spectra.

14) Decarboxylation of 2,7-Dibromofluorenone-1-Carboxylic Acid (LXI) to 2,7-Dibromo-9-Fluorenone (LXII)

This was essentially done by the method of Campbell et al.(24). Mercuric oxide (14.6 g.) was freshly precipitated from basic mercuric acetate (19.33 g.) with 20% sodium hydroxide and washed to neutrality according to Dziewonski et al.(62).

2,7-Dibromo-9-fluorenone-1-carboxylic acid (0.4 g.) obtained from the oxidation of 1-amino-4,9-dibromofluoranthene, freshly precipitated mercuric oxide from above (0.3 g.) and water (5 ml.) were heated in a sealed tube at 180-185° for 30 hours. The tube was cooled, the tip broken off and the contents refluxed with concentrated hydrochloric acid (15 ml.) for 3 hours. The residue was extracted first with ether, then benzene, and the combined extracts were washed with 5% aqueous sodium carbonate and dried (Na_2SO_4). Evaporation gave a solid which was dissolved in benzene and chromatographed through alumina. A yellow band separated and was eluted with benzene. Evaporation of the solvent gave 2,7-dibromofluorenone as yellow platelets (30 mg) m.p. 201-203°. This compound proved to be identical with 2,7-dibromofluorenone obtained by the oxidation of 2,7-dibromofluorene.

15) Oxidation of 2,7-Dibromofluorene (LXIII) to 2,7-Dibromofluorenone (LXII)

2,7-Dibromofluorene (0.7 g, K and K Rare fine Chemicals) was dissolved in acetic acid (65 ml.). Chromic anhydride (1.8 g.) was dissolved in water (6 ml.) and acetic acid (12 ml.) and added to the above solution. After refluxing for 2 hours, the solution was cooled and poured into iced water. The precipitate obtained was filtered and recrystallized from benzene and charcoal to give 2,7-dibromofluorenone as yellow platelets (0.5 g.) m.p. 206-208°. This proved to be identical with the decarboxylation product of 2,7-dibromo-9-fluorenone-1-carboxylic acid.

16) Deamination of 1-Amino-3,8-Dibromofluoranthene (LVII) to 3,8- Dibromofluoranthene (LX)

Experimental details for this reaction were obtained from Kornblum (12) who used it for deaminating o-toluidine. Sodium nitrite (0.6 g.) was added cautiously with stirring to a solution of concentrated sulfuric acid (45 ml.) and water (3.2 ml.) at room temperature. When all the sodium nitrite had finally dissolved the solution was cooled to -5° by means of an ice-salt bath. Finely ground 1-amino-3,8-dibromofluoranthene (1.0 g.) was added slowly with vigorous stirring to the above solution over a period of 15 minutes, the temperature being maintained at -5°. Stirring was continued at approximately the same temperature for one hour. Precooled 50% hypophosphorous acid (65 ml.) was then added to the stirred solution at such a rate (2 1/2 hours) that the temperature at no time rose above 5°. The reaction mixture was then left at 2-3° for 6 days. After that time water (800 ml.) was added and the colloidal precipitate allowed to coagulate and was then filtered and dried. It was stirred in hot benzene and a small amount of insolu ble residue discarded. The

benzene solution was washed with concentrated sulfuric acid until the acid layer no longer became colored, then with 10% sodium carbonate solution and finally with water. It was then dried over anhydrous magnesium sulfate. After removal of the solvent with a Buchi evaporator, the residue was recrystallized twice from ethanol with charcoal. 3,8-Dibromofluoranthene was obtained as bright yellow needles (0.3 g.) m.p. 205-207°. It proved to be identical with authentic 3,8-dibromofluoranthene synthesized according to 12) page 69.

17) Attempted Monobromination of 1-Nitrofluoranthene with Bromine in Nitrobenzene

Bromine (0.3 g.) in nitrobenzene (10 ml.) was added dropwise to a solution of 1-nitrofluoranthene (1 g.) in nitrobenzene (20 ml.) and the solution was stirred at room temperature for 2 days. No precipitate formed and evaporation of the solution gave unreacted 1-nitrofluoranthene.

18) Attempted Monobromination of 1-Nitrofluoranthene with N-Bromosuccinimide

Commercial N-bromosuccinimide was recrystallized from hot water and charcoal. 1-Nitrofluoranthene (1g.) was suspended in carbon tetrachloride (50 ml.) and N-bromosuccinimide (1 g.) added. The mixture was refluxed for 4 hours during which time everything dissolved to give an orange solution. On cooling with slight evaporation a precipitate formed. It was filtered and washed with a little hot water. However, both this and the residue obtained on complete evaporation proved to be unreacted 1-nitrofluoranthene. The same results were obtained with nitrobenzene as solvent.

19) Preparation of Pyridine Hydrobromide Perbromide ($C_5H_5\overset{+}{N}H\bar{B}r_3$)

This compound was prepared according to the method of Fieser et al. (45). Pyridine (15 ml.) was mixed with 48% hydrobromic acid (30 ml.) and the solution was cooled. Bromine (25 g.) was slowly added with stirring. The precipitate was filtered and washed with acetic acid. Recrystallization from acetic acid gave bright red needles (32 g.) m.p. 132-134°.

20) Attempted Monobromination of 1-Nitrofluoranthene with Pyridine Hydrobromide Perbromide

1-Nitrofluoranthene (1 g.) was dissolved in acetic acid (60 ml.) by warming on the steam bath. Pyridine hydrobromide perbromide (1 g.) was suspended in acetic acid (15 ml.) and added to the above solution on the steam bath. The solution was refluxed with stirring overnight. Next day the solution was cooled and evaporated to one half of its volume. A precipitate appeared but it proved to be unreacted 1-nitrofluoranthene. When nitrobenzene was used instead of acetic acid, the same results were obtained.

21) Attempted Polybromination of 1-Nitrofluoranthene Beyond the Dibromo Stage

1-Nitrofluoranthene (1 g.) was dissolved in nitrobenzene (25 ml.) and a small amount of iodine added. The solution was stirred at room temperature until everything dissolved and then bromine (2 ml.) was added dropwise. The solution was left stirring overnight and next day a precipitate was observed. After filtration and recrystallization from chlorobenzene, it turned out to be 1-nitro-4,9-dibromofluoranthene identical with a sample prepared without the use of iodine. (see 4 page 65). The

reaction was also tried with carbon tetrachloride as the solvent both at room temperature and with reflux but once again the dibromo compound resulted.

22) Polybromination of 1-Nitrofluoranthene to Give Hexabromofluoranthene (LX X)

1-Nitrofluoranthene (1 g.) was dissolved in nitrobenzene (30 ml.) and a small amount of iodine added. The solution was stirred at room temperature until everything dissolved and then bromine (3 ml.) was added dropwise. The solution was then refluxed for 2 days, cooled and the precipitate filtered. Recrystallization from chlorobenzene and charcoal gave bright yellow crystals (0.8 g.) m.p. 310-312°. Analysis indicated complete loss of the nitro group, and suggested the presence of six bromines. The infra red spectrum is shown on page 114.

Analysis

Found: C, 27.3; H, 0.42; Br, 72.8; N <0.1 if any.
Calculated for $C_{16}H_4Br_6$: C, 28.4; H, 0.58; Br, 71.0

23) Synthesis of 1-Aminofluoranthene

This substance was synthesized according to Streitwieser et al. (22). 1-Nitrofluoranthene (1 g.) prepared according to 3) page 64 was suspended in ethanol (150 ml.) with a small amount of Adam's catalyst. The solution was shaken on the hydrogenator for 2 hours during which time it changed from yellow to green. The amine was precipitated with water and filtered. Recrystallization from hexane gave 1-aminofluoranthene as greenish-yellow needles (0.2 g.) m.p. 131-133°. The infra red spectrum is shown on page 115.

Analysis

Found: N = 6.46
Calculated for $C_{16}H_{11}N$: N = 6.46

24) Synthesis of 1-Acetamidofluoranthene

This substance was synthesized according to Streitwieser et al.(22). 1-Aminofluoranthene (1 g.) was dissolved in benzene (170 ml .) and the solution filtered. Freshly distilled acetic anhydride (30 ml .) was added and the solution stirred with slight warming. After about 15 minutes a precipitate appeared. The reaction was continued for 1 hour and the solution then cooled and filtered. The precipitate was washed with a little cold benzene and sucked dry. 1-Acetamidofluoranthene was thus obtained as greenish-white crystals (0.8 g.) m.p. 258-260°. (lit. 257-258°). The infra red spectrum is shown on page 116.

25) Attempted Bromination of 1-Acetamidofluoranthene in Pyridine

The method used was that of Charlesworth and Blackburn (4) for the bromination of 3-acetamidofluoranthene. Bromine (0.5 ml.) was added with stirring, to a solution of 1-acetamidofluoranthene (1 g.) in pyridine (70 ml.). The reaction was allowed to proceed at room temperature for 10 hours. The product was precipitated by addition of water (200 ml.), filtered off, and washed successively with 10% aqueous solutions of sodium hydroxide and sodium bisulfite. After recrystallization from pyridine and charcoal, unreacted 1-acetamidofluoranthene was obtained.

The reaction was then tried with higher concentrations of bromine at elevated temperatures but no acetamidobromo compound was obtained.

26) Attempted Bromination of 1-Acetamidofluoranthene in Acetic Acid

The method used was that of Charlesworth and Lithown (30) for the bromination of 3-acetamidofluoranthene. Bromine (0.5 ml.) in acetic

acid (12 ml.) was added dropwise over a period of 15 minutes to a stirred solution of 1-acetamidofluoranthene (1.0 g.) in acetic acid (100 ml.) at 80°. Stirring was continued at this temperature for 3 hours during which time no precipitate appeared. Evaporation of the solution gave unreacted 1-acetamidofluoranthene. The reaction was also tried unsuccessfully with higher concentrations of bromine.

27) Attempted Bromination of 1-Acetamidofluoranthene in Dimethyl Sulfoxide

1-Acetamidofluoranthene (1 g.) was dissolved in dimethyl sulfoxide (150 ml.) and bromine (2 ml.) added dropwise. The solution was stirred at room temperature overnight. Next day water was added and a precipitate formed. After the usual work up it turned out to be unreacted 1-acetamidofluoranthene. The reaction was repeated with higher concentrations of bromine and at elevated temperatures but without success.

28) Synthesis of 1-Acetamido-4,8,9-Tribromofluoranthene (LXIX) and 1-Acetamido-4,8,9(?)-Tetrabromofluoranthene (LXXI)

1-Acetamidofluoranthene (0.8 g.) was suspended in carbon tetrachloride (20 ml.). Bromine (5 ml.) in carbon tetrachloride (10 ml.) was added dropwise with stirring. The solution was refluxed for 45 minutes and then evaporated. The residue was washed successively with 10% aqueous solutions of sodium hydroxide and sodium bisulfite and then with water. The melting range at this point was quite broad (300-360°). Several attempts were made at purification by passing through a column of alumina or with thin layer chromatography with silica gel but the compounds were not sufficiently solu ble in the usual chromatographic solvents. The residue on the filter paper was treated with hot pyridine (300 ml.)

and the insolu ble part discarded. Recrystallization yielded a compound of melting point 340-360°. This was treated with hot xylene (150 ml.) and the insolu ble residue will be dealt with later. Charcoal was added to the xylene solu ble substance, and the solution filtered. On cooling light green platelets (o.1 g.) of 1-acetamido-4,8,9-tribromofluoranthene formed m.p. 323-325°. The infra red spectrum is shown on page 117.

Analysis

Found: N, 2.99; Br, 48.50
Calculated for $C_{18}H_{10}ONBr_3$: N, 2.83; Br, 48.49

The xylene insolu ble residue melted at 355-365°. It was washed with warm benzene and then recrystallized from pyridine twice, to give 1-acetamidotetrabromofluoranthene (50 mg) quite similar in appearance to the tribromo compound. m.p. 370-372° (estimated). The infra red spectrum is shown on page 118.

Analysis

Found: N, 2.44; Br, 55.12
Calculated for $C_{18}H_9ONBr_4$: N, 2.44; Br, 55.70

29) Bromination of 1-Acetamidofluoranthene to Give 1-Acetamido-4,9-Dibromofluoranthene (LVIII)

1-Acetamidofluoranthene (1.5 g.) was suspended in carbon tetrachloride in an ice-water mixture (approx. 0°). Bromine (2.5 ml.) was added to the stirred suspension over a period of 30 minutes. After 1 hour a reddish precipitate formed; however, stirring was continued for another hour. The precipitate was filtered m.p. 200-290°. It was washed successively with 10% aqueous solutions of sodium hydroxide and sodium bisulfite and then with water. The precipitate was recrystallized twice from pyridine (charcoal). 1-Acetamido-4,9-dibromofluoranthene was thus obtained as light green platelets (0.7 g.) m.p. 314-316°. It was found

to be identical with the acetylation product of 1-amino-4,9-dibromofluoranthene. (see 6) page 66).

1-Acetamido-4,9-dibromofluoranthene prepared this way was oxidized according to (10 page 68)to give 2,7-dibromofluorenone-1-carboxylic acid.

30) Hydrolysis of 1-Acetamido-4,9-Dibromofluoranthene (LVIII) to Give 1-Amino-4,9-Dibromofluoranthene (LVII)

The experimental procedure is similar to that used by Charlesworth and Blackburn (4) for the hydrolysis of 2-bromo-3-acetamidofluoranthene. 1-Acetamido-4,9-dibromofluoranthene (1.5 g.) was dissolved in pyridine (60 ml.) and sodium hydroxide (3.5 g.) dissolved in methanol (70 ml.) added. The solution which immediately changed from yellow to orange was then refluxed for 12 hours. After cooling to room temperature a small amount of insolu ble material was filtered off and discarded. The crude product was precipitated by dilution with water (600 ml.). The collected material was washed with water, dried and dissolved in boiling pyridine. A small amount of insolu ble material was filtered off and the filtrate was heated with charcoal. Sufficient water was added to cause crystallization when the solvent cooled. 1-Amino-4,9-dibromofluoranthene was thus obtained as greenish-yellow platelets (0.6 g.) m.p.208-210°. This compound proved to be identical with the reduction product of 1-nitro-4,9-dibromofluoranthene (see 5) page 65).

31) Synthesis of 1-Amino-4,8,9-Tribromofluoranthene (LXXII) by Hydrolysis of the Amide (LXIX)

The experimental procedure for this reaction is similar to that used by Charlesworth and Blackburn (4) for the hydrolysis of 2-bromo-3-

acetamidofluoranthene. 1-Amino-4,8,9-tribromofluoranthene (0.8 g.) was dissolved in pyridine (45 ml.) and sodium hydroxide (2.8 g.) dissolved in methanol (50 ml.) added. The solution which immediately changed from yellow to orange and later to a light red, was refluxed for 16 hours. It was then cooled, filtered and diluted with water (400 ml.) to give a yellow flocculent precipitate. Recrystallization with charcoal, pyridine and water gave a precipitate m.p. 180-196°. This was dissolved in benzene and chromatographed through alumina. No clean separation was observed on the column, however, elution with benzene left a light brown residue in the column. Evaporation of the benzene left crystals which melted at 206-220°. A further recrystallization from pyridine, charcoal and water gave 1-amino-4,8,9-tribromofluoranthene as light green needles (0.3 g.) m.p. 227-229°.

The infra red spectrum is shown on page 119.

Analysis

Found: N, 3.09; Br, 52.65

Calculated for $C_{16}H_8NBr_3$: N, 3.09; Br, 52.81

32) Attempted Hydrolysis of 1-Acetamido-4,8,9,(?)-Tetrabromofluoranthene (LXXI) to 1-Amino-4,8,9,(?)-Tetrabromofluoranthene (LXXV)

The method of Charlesworth and Blackburn (4) who used pyridine, sodium hydroxide and methanol for the hydrolysis of 2-bromo-3-acetamido-fluoranthene was tried but no tetrabromo amine was isolated even after several attempts at purification by column chromatography. Hydrolysis was also tried with concentrated hydrochloric acid and ethanol according to Kloetzel et al.(3) but this also met with failure. It appears as though the more bromines there are in the acetamidofluoranthene, the more difficult it is to hydrolyse the amide and obtain a pure amine.

33) Synthesis of 3,8,9-Tribromofluoranthene (LXXIII) From 3,8-Dibromofluoranthene (LX)

The experimental procedure used was that of Tobler et al. (15). 3,8-Dibromofluoranthene (3 g.) (for synthesis see 12) page 69) was dissolved in nitrobenzene (25 ml.), a few grains of iodine added and the solution stirred and heated to 90°. Bromine (0.8 g.) was added dropwise and the solution stirred at 90-95° for 20 hours. It was then allowed to cool to room temperature whereupon a yellow solid precipitated. Air was blown through to get rid of HBr. The precipitate was filtered and washed with a little nitrobenzene and then ethanol. Recrystallization from nitrobenzene and charcoal twice gave 3,8,9-tribromofluoranthene as yellow needles (2.1 g.) m.p. 208-210°. (literature 208-210.5). A mixed melting point with 3,8-dibromofluoranthene m.p. 206-207° melted at 173-193°.

34) Deamination of 1-Amino-4,8,9-Tribromofluoranthene (LXXII) to Give 3,8,9-Tribromofluoranthene (LXXIII)

The experimental details for this deamination are similar to 16) page 71 up to the drying stage with anhydrous magnesium sulfate. The amount of 1-amino-4,8,9-tribromofluoranthene used was (0.5 g.) and the amount of sodium nitrite, sulfuric acid, water and hypophosphorous acid used was varied correspondingly.

After drying over anhydrous magnesium sulfate, the crude product was recrystallized twice from ethanol and charcoal to give a yellow precipitate 180-190°. It was dissolved in benzene spotted on a thin layer chromatography plate (silica gel) and developed with 50% petroleum ether—benzene. A bright yellow band separated. This was scraped off and eluted with benzene. Evaporation gave 3,8,9-tribromofluoranthene as yellow needles (30 mg) m.p. 204-207°. A mixed melting point confirmed that this was the

same as authentic 3,8,9-tribromofluoranthene prepared according to 33) page 80.

35) Synthesis of 1,4,8,9-Tetrabromofluoranthene (LXXIV) From 1-Amino-4,8,9-Tribromofluoranthene (LXXII)

The experimental procedure used here is similar to 9) page 67. Sodium nitrite (0.8 g) was dissolved in concentrated sulfuric acid (8 ml.) by adding in portions and stirring. The tribromo-amine (0.5 g.) was dissolved in acetic acid (45 ml.) and filtered. This was chilled and then slowly added to the cold (0-5°) nitrous acid solution with stirring. The reddish-brown solution was stirred at that temperature for an hour and then added to a boiling solution of freshly prepared cuprous bromide (2.5 g.) in 48% HBr (45 ml.). The solution was refluxed for 2 hours and then poured into iced water. The solution was extracted with benzene. The insoluable residue was boiled with benzene and the combined extracts were washed with water, dried with sodium sulfate and passed through an alumina column. Evaporation of the solvent gave the impure tetrabromo compound. Two recrystallizations from benzene and charcoal gave 1,4,8,9-tetrabromofluoranthene (0.1 g.) as green-yellow platelets m.p. 243-247°. The analysis of this compound at this stage was unsatisfactory so it was sublimed under reduced pressure. Green-yellow needles (50 mg) were obtained m.p. 248-249°. The infra red spectrum is shown on page 120.

Analysis

Found: Br, 60.62

Calculated for $C_{16}H_6Br_4$: Br, 61.72

36) Side Chain Bromination of 1-Acetamidofluoranthene with Pyridine Hydrobromide Perbromide to Give LXXVI

1-Acetamidofluoranthene (0.5 g.) was dissolved in acetic acid (70 ml.) and heated to 90°. Pyridine hydrobromide perbromide (0.62 g.) (prepared according to 19) page 73) was dissolved in acetic acid (5 ml.) and added to the above solution. After about 5 minutes the bright orange color changed to a straw yellow. Acetic anhydride (3 ml.) was added and the solution heated for about 2 hours more. After standing at room temperature overnight a cream colored precipitate was observed. The reaction mixture was nevertheless poured into water (300 ml.) and filtered. Recrystallization from pyridine and charcoal gave a yellow compound of melting point 207-224°. Purification through an alumina column proved unsuccessful. The compound was finally recrystallized twice from pyridine and charcoal. Even then it was not quite pure m.p. 217-224°. The infra red spectrum is shown on page 121.

Analysis

Found: N, 4.05; Br, 27.02
Calculated for $C_{18}H_{12}ONBr$: N, 4.15; Br, 23.65

An attempt at purification was made by hydrolysis of the bromoamide with concentrated hydrochloric acid and ethanol to the bromoamine followed by re-acetylation. However, on hydrolysis 1-aminofluoranthene was obtained. Bromination then must have occurred in the side chain.

37) Bromination of 3-Acetamidofluoranthene with Bromine in Carbon Tetrachloride

3-Nitrofluoranthene was prepared according to the method of Garascia et al.(64), reduced to 3-aminofluoranthene, and acetylated to the 3-acetamido derivative by following the directions of Kloetzel et al. (3).

3-Acetamidofluoranthene (1.5 g.) was suspended in carbon tetrachloride, bromine (0.8 ml.) added and the solution stirred overnight at room temperature. Next day the solution was filtered and the precipitate washed successively with 10% aqueous solutions of sodium hydroxide, sodium bisulfite and then water. It was then recrystallized from chlorobenzene and charcoal m.p. 240-248°. Two recrystallizations from pyridine and charcoal gave 3-acetamido-8-bromofluoranthene as yellow crystals (0.2 g.) m.p. 247-249°. This proved to be identical with a sample brominated in acetic acid according to the method of Blackburn (40).

38) Attempted Bromination of 1-Aminofluoranthene

a With bromine in acetic acid

1-Aminofluoranthene (0.5 g.) was dissolved in acetic acid (20 ml.) and bromine (0.2 ml.) in acetic acid (10 ml.) added dropwise at room temperature. The reaction mixture was stirred for 3 hours. A reaction apparently occurred because a precipitate settled out. It was filtered, washed with 10% sodium hydroxide and water and dried. Purification by means of the hydrochloride salt and liberation of the bromoamine with ammonia was fruitless. The compound was dissolved in benzene, spotted on thin layer chromatography plates (silica gel) and subjected to separation using a variety of solvents (e.g. benzene, chloroform). Several different colored bands were obtained. Elution gave compounds with wide melting ranges.

b With 48% HBr in dimethyl sulfoxide

1-Aminofluoranthene (0.5 g.) was dissolved in dimethyl sulfoxide (20 ml.) and 48% HBr (6 ml.) added dropwise with stirring. The solution was heated to about 100° for 3 hours and then allowed to cool to room temperature with stirring for another 3 hours. The reaction mixture was

diluted with water (200 ml.) and the precipitate which formed filtered. It was recrystallized successively from pyridine, benzene, hexane and ethanol but the melting range of the precipitate was still quite wide. Sublimation improved the melting range somewhat but it was still unacceptable.

Other samples were done and purification attempted by column and thin layer chromatography but still to no avail.

39) Synthesis of 1-Bromofluoranthene (LXXVII) and 1-Hydroxyfluoranthene (LXXVIII)

The experimental procedure is similar to that used by Charlesworth and Blackburn (4) for the synthesis of 3-bromofluoranthene. 1-Aminofluoranthene (2 g.) was dissolved in anhydrous ether (150 ml.) and filtered. Concentrated sulfuric acid (2 ml.) was added with stirring to the amine solution. The amine salt was filtered off, allowed to dry, and finely ground. The salt was then dissolved in a vigorously stirred solution of sulfuric (75 ml.) and acetic acid (75 ml.) with gentle warming. The solution was cooled and ice and water (150 g.) were added rapidly with stirring to precipitate the amine salt in a finely divided condition. The salt was diazotized at 0-5° by addition of sodium nitrite (1 g.) in water (6 ml.). The diazonium solution was poured, with stirring, into a solution of freshly prepared cuprous bromide (15 g.) in 48% hydrobromic acid (80 ml.) and water (25 ml.). The mixture was heated slowly, with stirring, to 95°. Stirring was continued at this temperature for 3 hours after which the solution was cooled to room temperature and left overnight. Next day the reaction mixture was diluted with water and the precipitate filtered off. The dried material was stirred with hot benzene (150 ml.) four times and the insolu ble residue discarded. The

filtrate from above was also extracted with benzene and the benzene extracts combined and washed with 10% sodium hydroxide solution. Quite an amount of yellow substance dissolved in the aqueous base and this will be dealt with below. The benzene layer was separated and washed further with 10% sodium bisulfite, concentrated sulfuric acid (until further extraction gave no further coloration of the acid layer), 10% sodium carbonate solution and finally with water. It was then dried over anhydrous magnesium sulfate and the solvent evaporated off. The residue was recrystallized twice from 95% ethanol to give a yellow precipitate m.p. 90-102°. This was dissolved in benzene and chromatographed through alumina. Elution with benzene gave a compound of melting point 103-106°. Sublimation under vacuum gave 1-bromofluoranthene as yellow needles (0.1 g.) m.p. 106-108°. The infra red spectrum is shown on page 122.

Analysis

Found: Br, 28.03
Calculated for $C_{16}H_9Br$: Br, 28.45

The 10% sodium hydroxide solution from above was made acidic with concentrated hydrochloric acid. The precipitate was filtered and recrystallization attempted both with benzene and ethanol. The still impure compound was then sublimed to give crystals of melting point 142-145°. The analysis at this stage was not satisfactory so it was resublimed to give 1-hydroxyfluoranthene as straw colored needles (75 mg) m.p. 145-147°. The infra red spectrum is shown on page 123.

Analysis

Found: C, 86.4; H, 4.7
Calculated for $C_{16}H_{10}O$: C, 88.1; H, 4.6

40) Attempted Bromination of 1-Bromofluoranthene

1-Bromofluoranthene (0.2 g.) was dissolved in nitrobenzene (15 ml.) and bromine (0.2 ml.) added with stirring, at room temperature. Stirring

was continued overnight. Next day the solvent was evaporated to give unreacted 1-bromofluoranthene. The same results were obtained in carbon tetrachloride at room temperature, and in carbon tetrachloride with iodine under reflux.

41) Bromination of 1-Bromofluoranthene to 1,4,8,9-Tetrabromofluoranthene (LXXIV)

1-Bromofluoranthene (0.5 g.) was dissolved in nitrobenzene (35 ml.) and a little iodine added. Bromine (0.2 ml.) was added and the stirred solution was heated at 100° for 20 hours, during which time a precipitate formed. It was filtered and recrystallized from nitrobenzene twice but was still impure. It was dissolved in excess benzene and poured on an alumina column. Elution with benzene appeared to cause everything to pass through the column. Two recrystallizations from benzene and charcoal gave 1,4,8,9-tetrabromofluoranthene as green-yellow needles (0.1 g.) m.p. 247-248°. This compound proved to be identical to 1,4,8,9-tetrabromofluoranthene synthesized from 1-amino-4,8,9-tribromofluoranthene (35) page 81).

42) Bromination of 1-Bromofluoranthene to 1,4,9-Tribromofluoranthene (LIX)

1-Bromofluoranthene (0.5 g.) was dissolved in nitrobenzene (35 ml.) and a little iodine added. Bromine (0.2 ml.) was added and the solution stirred at room temperature for 20 hours, during which time a precipitate formed. It was filtered and the filtrate evaporated to dryness to give a residue which melted close to that of 1-bromofluoranthene. The precipitate from above was recrystallized once from nitrobenzene and once from benzene to give 1,4,9-tribromofluoranthene as light yellow platelets (0.2 g.) m.p. 194-196°. This compound proved to be identical as 1,4,9-tribromofluor-

anthene synthesized from 1-amino-4,9-dibromofluoranthene (9) page 67).

1,4,9-Tribromofluoranthene was brominated in nitrobenzene and iodine with heat according to 41) page 86 to give 1,4,8,9-tetrabromofluoranthene.

43) Synthesis of 1,(?)-Dinitrofluoranthene (LXXIX)

Fuming nitric acid (1.5 ml.) was added dropwise to a solution of 1-nitrofluoranthene (2 g.) in freshly distilled acetic anhydride (300 ml.). The solution at first became cloudy and then a precipitate formed. Stirring was continued for 4 hours at room temperature and the precipitate filtered. It was washed with a little cold acetone and then recrystallized from acetic acid. The still impure compound was suspended in benzene and put on an alumina column. A large volume of benzene was used to get most of the compound through the column. Recrystallization from acetic acid gave 1,(?)-dinitrofluoranthene as bright yellow needles (0.5 g.) m.p. 301-303°. The infra red spectrum is shown on page 124.

Analysis

Found: N, 9.59

Calculated for $C_{16}H_8O_4N_2$: N, 9.59

44) Reduction of 1,(?)-Dinitrofluoranthene to 1,(?)-Diaminofluoranthene (LXXX)

Several attempts were made at this reduction but pure diamino compound was never obtained. Reduction was first tried with iron powder and concentrated hydrochloric acid but purification of product formed was fruitless. Reduction was then done in ethanol with Adam's catalyst and hydrogen. Here again purification was unsuccessful. Catalytic reduction with acetic acid as solvent was also unsuccessful.

Acetylation of the impure diamine was also unsuccessful.

45) Acetylation of 1,(?)-Dinitrofluoranthene (LXXIX) to 1,(?)-Diacetamidofluoranthene (LXXXI) "in situ"

1-Nitrofluoranthene (1 g.) was suspended in a mixture of glacial acetic acid (150 ml.) and freshly distilled acetic anhydride (75 ml.) and Adam's catalyst added. The reaction mixture was shaken on the hydrogenator for 3 hours. The solution was evaporated and the residue recrystallized twice from pyridine, charcoal and water. 1,(?)-Diacetamidofluoranthene was obtained as light green platelets (0.6 g.) m.p. 320-322°. The infra red spectrum is shown on page 125.

Analysis

Found: N, 8.33
Calculated for $C_{20}H_{16}O_2N_2$: N, 8.86

46) Synthesis of 1-Acetamido-Mononitrofluoranthene (LXXXIII)

1-Acetamidofluoranthene (0.5 g.) was suspended in carbon tetrachloride (25 ml.) and stirred in an ice-water bath. Concentrated nitric acid (30 drops) was added slowly and the reaction mixture stirred at this temperature for 2 hours. A yellow-light brown ball formed in the colorless liquid. The precipitate was filtered, ground fine and washed successively with a little hot benzene, acetone and acetic acid. Recrystallization from acetic acid gave 1-acetamido-mononitrofluoranthene as orange crystals (0.1 g.) m.p. 315-317°. The infra red spectrum is shown on page 126.

Analysis

Found: N, 9.03
Calculated for $C_{18}H_{12}O_3N_2$: N, 9.21

47) Synthesis of 1-Acetamido-Monoaminofluoranthene (LXXXV)

1-Acetamido-mononitrofluoranthene (0.2 g.) was suspended in ethanol (200 ml.), Adam's catalyst added, and the reaction mixture shaken on the hydrogenator for 3 hours. The color of the mixture changed from yellow to green. The reaction mixture was filtered and the solvent evaporated. It was washed with cold benzene and recrystallized from hexane to give 1-acetamido-monoaminofluoranthene as a dark green precipitate (50 mg) m.p. 195-200°. The infra red spectrum is shown on page 127.

Analysis

Found: N, 9.60
Calculated for $C_{18}H_{14}ON_2$: N, 10.20

48) Synthesis of 1-Acetamido-Dinitrofluoranthene (LXXXII)

1-Acetamidofluoranthene (1 g.) was suspended in carbon tetrachloride (40 ml.) at room temperature. Fuming (95%) nitric acid (50 drops) was added dropwise to the stirred solution. The reaction mixture was stirred at this temperature for 10 hours during which time it appeared as a red sticky mass suspended in a clear solution. After filtration, the solid was ground fine and washed successively with hot ethanol and hot acetic acid. 1-Acetamido-dinitrofluoranthene was thus obtained as bright orange platelets (0.1 g.) m.p. 335-337°. The infra red spectrum is shown on page 128.

Analysis

Found: N, 11.79
Calculated for $C_{18}H_{11}O_5N_3$: N, 12.02

49) Hydrolysis of 1-Acetamido-Dinitrofluoranthene to Give the Dinitroamine Hydrochloride (LXXXIV)

1-Acetamido-dinitrofluoranthene (0.5 g.) was suspended in ethanol (30 ml.), concentrated hydrochloric acid added (30 ml.) and the reaction

mixture refluxed for 20 hours. During this time, a red precipitate formed. It was filtered and recrystallized twice from chlorobenzene. Brick red crystals (75 mg) of the dinitroamine hydrochloride were obtained this way m.p. 347-350°. The infra red spectrum is shown on page 129.

Analysis

Found: N, 12.23

Calculated for $C_{16}H_9O_4N_3.HCl$: N, 12.23

SUMMARY *

1) a) Bromination of 1-nitrofluoranthene (L) in nitrobenzene or carbon tetrachloride with or without iodine gave 1-nitro-4,9-dibromofluoranthene (LV). Reduction of the nitro compound gave 1-amino-4,9-dibromofluoranthene (LVII). Acetylation of the amine gave 1-acetamido -4,9-dibromofluoranthene (LVIII). A Sandmeyer reaction with cuprous bromide on the amine gave 1,4,9-tribromofluoranthene (LIX).

b) Oxidation of 1-nitro-4,9-dibromofluoranthene (LV) gave 4-nitro-6-bromofluorenone-1-carboxylic acid. This indicates the presence of a bromine in ring B of the fluoranthene molecule. This is the first report of a substituent being directed to ring B by an initial substituent in ring A.

2) The orientation of the two bromines in 1-nitro-4,9-dibromofluoranthene (LV) was shown by two methods.

a) Deamination of 1-amino-4,9-dibromofluoranthene (LVII) obtained from the corresponding nitro compound gave 3,8-dibromofluoranthene (LX) identical with an authentic sample obtained according to Tobler et al. (15).

b) Oxidation of 1-amino-4,9-dibromofluoranthene (LVII), 1-acetamido-4,9-dibromofluoranthene (LVIII) and 3,8-dibromofluoranthene (LX) all produced 2,7-dibromofluorenone-1-carboxylic acid (LXI). On decarboxylation this acid formed 2,7-dibromofluorenone (LXII) identical with

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* For numbers 1-8 see page 95.

that obtained by oxidizing commercially available 2,7-dibromofluorene.

3) Bromination of 1-nitrofluoranthene with iodine and excess bromine in nitrobenzene and with heating for two days gave a compound (LXIX) for which analysis shows the presence of six bromines and the complete loss of the nitro group. The orientation of the bromines has been suggested but not established.

4) Bromination of 1-acetamidofluoranthene in carbon tetrachloride in the cold gave 1-acetamido-4,9-dibromofluoranthene (LVIII). This compound is identical with the acetamido compound obtained from 1-nitro-4,9-dibromofluoranthene via the amine. Furthermore, the amine produced by the hydrolysis of the acetamido compound is identical with that produced by the reduction of 1-nitro-4,9-dibromofluoranthene. The oxidation product of this 1-acetamido-4,9-dibromofluoranthene was also 2,7-dibromofluorenone-1-carboxylic acid (LXI).

5) a) Bromination of 1-acetamidofluoranthene in carbon tetrachloride with refluxing gave a mixture of 1-acetamido-4,8,9-tribromofluoranthene (LXIX) and 1-acetamido-4,8,9,(?)-tetrabromofluoranthene (LXXI). The orientation of the latter compound has not been established.

b) The orientation of 1-acetamido-4,8,9-tribromofluoranthene (LXIX) was established as follows. Hydrolysis of the amide gave 1-amino-4,8,9-tribromofluoranthene (LXXII). Deamination of this amine gave 3,8,9-tribromofluoranthene (LXXIII) identical with a sample prepared by further bromination of 3,8-dibromofluoranthene according to Tobler et al. (15).

c) A Sandmeyer reaction with cuprous bromide on 1-amino-4,8,9-tribromofluoranthene (LXXII) gave 1,4,8,9-tetrabromofluoranthene (LXXIV).

6) Bromination of 1-acetamidofluoranthene with pyridinium hydrobromide perbromide in acetic acid at room temperature effected side chain bromination on the methyl group to give 1-bromoacetamidofluoranthene (LXXVI).

7) a) 1-Bromofluoranthene (LXXVII) was synthesized by doing a Sandmeyer reaction with cuprous bromide on 1-aminofluoranthene. 1-Hydroxy-fluoranthene (LXXVIII) was also obtained as a by-product of the reaction.

b) Bromination of 1-bromofluoranthene with iodine in nitrobenzene in the cold gave 1,4,9-tribromofluoranthene (LIX) identical with that prepared by a Sandmeyer reaction with cuprous bromide on 1-amino-4,9-dibromofluoranthene (LVII).

c) Bromination of 1-bromofluoranthene with iodine in nitrobenzene and heat gave 1,4,8,9-tetrabromofluoranthene (LXXIV) identical with that prepared by a Sandmeyer reaction with cuprous bromide on 1-amino-4,8,9-tribromofluoranthene (LXXII).

d) Further bromination of 1,4,9-tribromofluoranthene (LIX) gave 1,4,8,9-tetrabromofluoranthene (LXXIV).

8) Regardless of the nature of the substituents (nitro, acetamido, bromo) in the 1 position of fluoranthene, dibromination occurs in positions 4 and 9. When these substituents are in the 2 or 3 positions they direct similarly to each other but quite different to the 1 position.

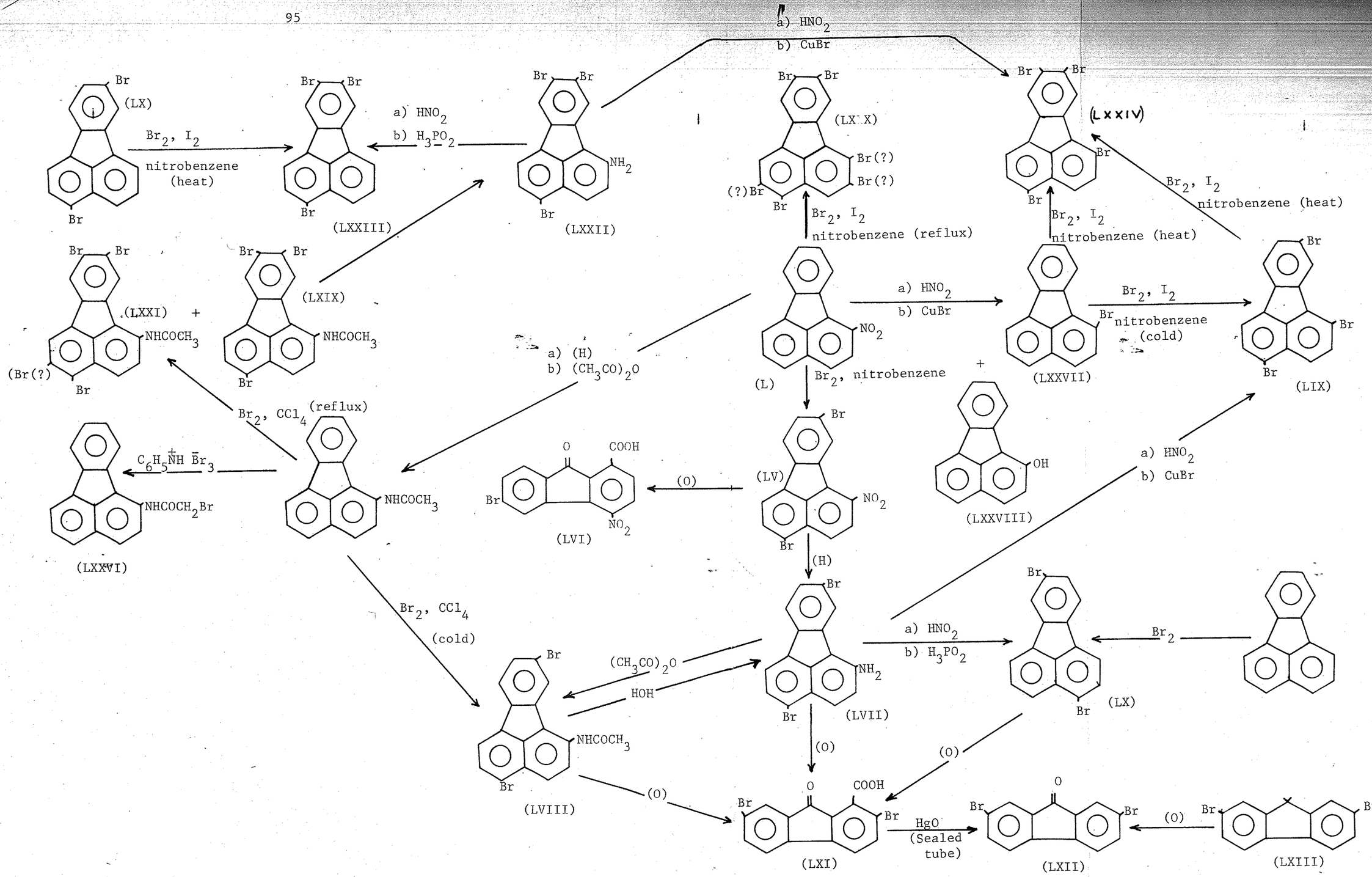
9) Nitration of 1-nitrofluoranthene in acetic anhydride with fuming nitric acid gave 1,(?)-dinitrofluoranthene (LXXIX). Catalytic reduction gave an impure diamino compound whereas acetylation "in situ" gave 1-(?)-diacetamidofluoranthene (LXXXI). The position of nitration has not been established.

10) Nitration of 1-acetamidofluoranthene in carbon tetrachloride with fuming nitric acid gave mainly 1-acetamido-(??)-dinitrofluoranthene (LXXXII). Hydrolysis with concentrated hydrochloric acid in ethyl alcohol gave the dinitroamine hydrochloride (LXXXIV). The orientation of the two nitro groups has not been established.

11) Nitration of 1-acetamidofluoranthene in carbon tetrachloride with concentrated nitric acid gave 1-acetamido-(?)-nitrofluoranthene (LXXXIII),reduction of which gave 1-acetamido-(?)-aminofluoranthene (LXXXV). The position of nitration has not been established.

12) Bromination of 3-acetamidofluoranthene with bromine in carbon tetrachloride gave 3-acetamide-8-bromofluoranthene, just as it did in carbon tetrachloride: acetic acid, 1:2, and in acetic acid alone.

13) In the course of this research, twenty-one new compounds have been prepared, a few of which were not purified satisfactorily. The orientation of ten of these compounds has been rigidly established.

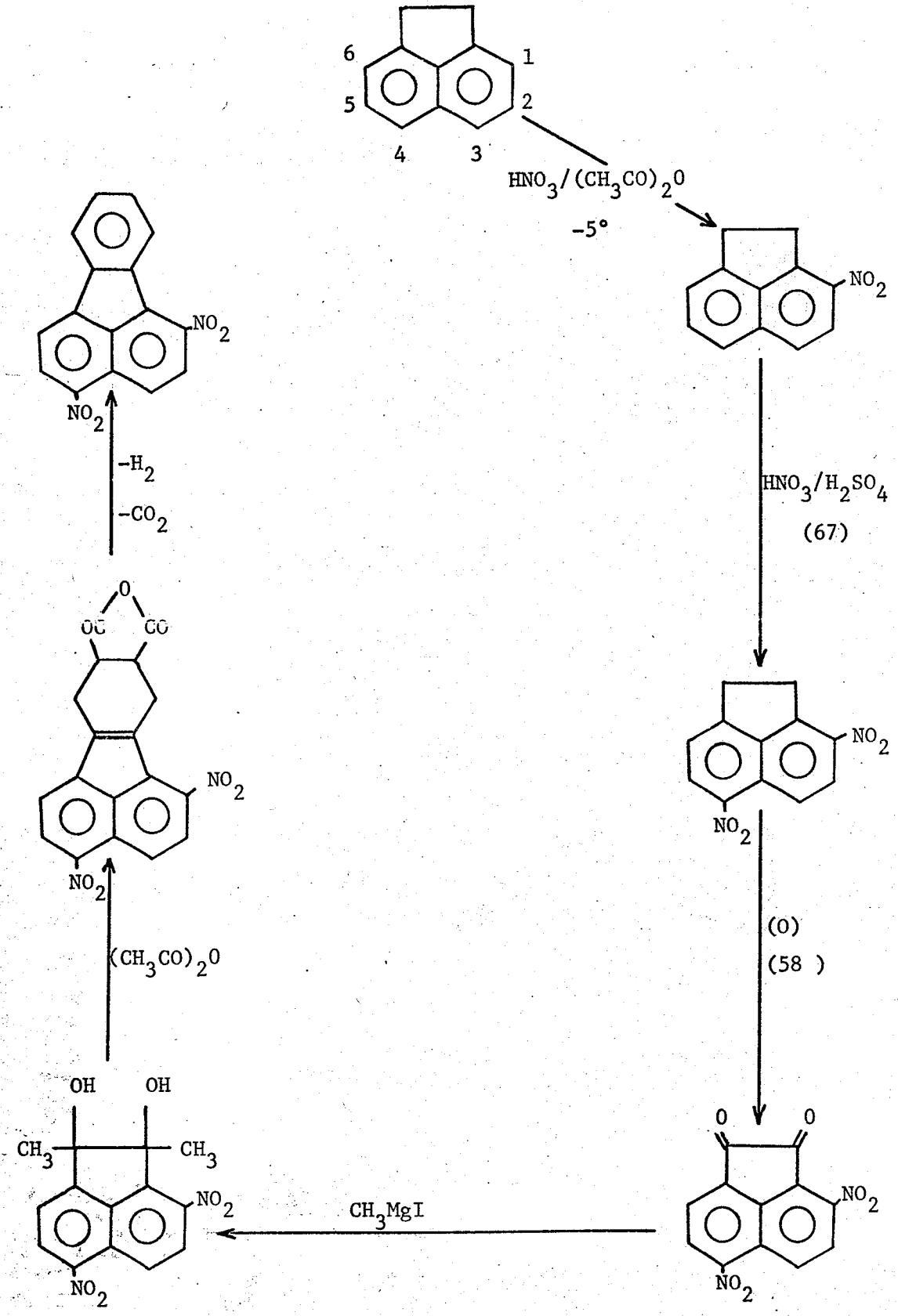

(LX)
Br2, I2
nitrobenzene
(heat)
a) HNO2
b) H3PO2
(LXXIII)
(LXXII)
a) HNO2
b) CuBr
(LXXIV)
(LXX)
Br2, I2
nitrobenzene (reflux)
Br2, I2
nitrobenzene (heat)
Br2, I2
nitrobenzene (heat)
(LXXI) +
(LXIX)
NHCOCH3
(Br(?)
a) (H)
b) (CH3CO)2O
(L)
a) HNO2
b) CuBr
(LXXVII)
Br2, I2
nitrobenzene
(cold)
(LIX)
Br2, CCl4 (reflux)
Br2, nitrobenzene
(LV)
(LXXVIII)
a) HNO2
b) CuBr
C6H5NH Br3
NHCOCH2Br
(LVI)
(O)
(H)
(LXXVI)
Br2, CCl4
(cold)
(CH3CO)2O
HOH
a) HNO2
b) H3PO2
Br2
(LVIII)
(LVII)
(LX)
(O)
(O)
(O)
(LXI)
HgO
(Sealed
tube)
(LXII)
(O)
(LXIII)

RECOMMENDATIONS FOR FUTURE WORK

1. Nitration of 1-acetamidofluoranthene in carbon tetrachloride with concentrated nitric acid to give the mono nitration product should be carried out again. The acetamido group could be hydrolysed to the amine. Deamination might be expected to give either 3-nitro- or 8-nitrofluoranthene if substituents in position 1 nitrate in the same positions as they brominate as they do for 2 and 3-acetamidofluoranthene.

2. Nitration of 1-acetamidofluoranthene in carbon tetrachloride with fuming nitric acid to give the dinitration product should also be done again. Hydrolysis and deamination might give 3,9-dinitrofluoranthene as was discussed on page 60. 3,9-Dinitrofluoranthene was synthesized by Charlesworth and Lithown (30) and would be available for comparison.

3. Nitration of 1-nitrofluoranthene in acetic anhydride with fuming nitric acid to give the mono nitration product should be redone. It is predicted that this compound might be 1,4-dinitrofluoranthene. If the structure in (1) above is proved, then comparison of their diacetamido compounds would show whether mononitration occurred at the same positions in both compounds. Otherwise the preparation on the following page might be attempted. This synthesis, similar to that of Campbell, Gow and Wang (68) could probably be used for 1-nitrofluoranthene as well as 1,4-dinitrofluoranthene.


6
1
5
2
4
3
HNO3/(CH3CO)2O
-5°
NO2
HNO3/H2SO4
(67)
(O)
(58)
CH3MgI
OH
OH
CH3
CH3
-H2
-CO2
(CH3CO)2O
O
O

4) The structure of 1-acetamido-4,8,9,(?)-tetrabromofluoranthene has not been established. Oxidation of this compound followed by an elemental analysis of the resulting fluorenone carboxylic acid would show whether all four bromines were in rings B and C. An NMR spectrum of this acid would undoubtedly be of great value.

5) It would be interesting to attempt bromination of 1-aminofluoranthene again either by the conventional methods or with HBr in dimethyl-sulfoxide (49). Since the amino group is so intensely activating, bromination in the same ring might be expected.

6) 8-Nitrofluoranthene has been isolated by Kloetzel et al.(3) from the nitration mixture remaining after the nitration of fluoranthene. To date no further substitution of 8-monofluoranthenes has been done. Direction of bromination and nitration by substituents in the benzenoid part of the fluoranthene molecule would prove interesting.

7) 7-Substituted fluoranthenes have been synthesized by Campbell et al. (16), Stubbs et al.(50), Tucker et al.(5), Kloetzel et al.(52) and Bergman et al. (53). As above, brominations and nitrations on 7-substituted fluoranthenes would prove interesting. Further substitution of the two monosubstituents in the benzenoid ring (i.e. points 4 and 5) would complete the study of at least some kind of substitution of all five mono substituted fluoranthenes.

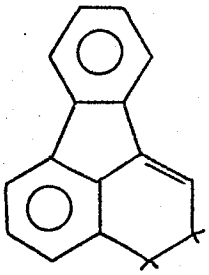
8) Andrew, Campbell et al.(31) found that 3-methoxyfluoranthene nitrated in the same manner as the acetamido compound. 1-Methoxyfluoranthene

should be prepared and both brominated and nitrated to see whether it behaves in a similar manner to 1-acetamidofluoranthene.

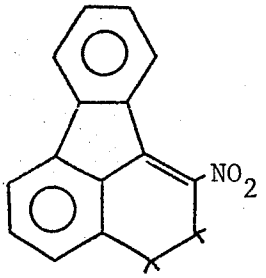
9) Monobromination in the 1-substituted fluoranthenes would be desirable to experimentally show the position of monobromination.

10) As can be seen from Table II page 40, bromination of 2-bromofluoranthene and nitration of 2 and 3-bromofluoranthenes have not been done. These reactions should be carried out to verify predictions about them.

11) It might prove interesting to see how 2,3-dihydrofluoranthene (a)



(a)



(b)

and 1-nitro-2,3-dihydrofluoranthene (b) would brominate and nitrate. The latter is an intermediate in the preparation of 1-nitrofluoranthene. One would expect addition across the double bond in the alicyclic ring.

12) Bromination of 3-aminofluoranthene in acetic acid gives 3-amino-2-bromofluoranthene (4). Bromination should be tried with HBr in dimethyl sulfoxide (49) to see if there is any effect in this drastic change of conditions.

13) 1-Chloro, fluoro and iodofluoranthenes can be made from 1-aminofluor-

anthene via diazonium reactions.

14) 6b, 10a-Dihydrofluoranthene has recently been synthesized by Rees et al.(54). Nitration and bromination of this compound would undoubtedly give novel compounds.

15) 1-Nitro-4-bromofluoranthene has been prepared by Campbell and Wilshire (33) by nitrating 1,2,3,10b-tetrahydro-4-bromofluoranthene. More of the nitrobromo compound should be synthesized and further brominated. Further bromination would most likely occur in position 9. The nitro group could also be reduced and acetylated to give 1-acetamido-4-bromofluoranthene. Further bromination on this compound would show which group directed the second incoming bromine.

16) 1-Acetamidofluoranthene has been mononitrated (page 60) but the orientation has not been proved. Bromination of this 1-acetamido-mononitrofluoranthene might prove interesting.

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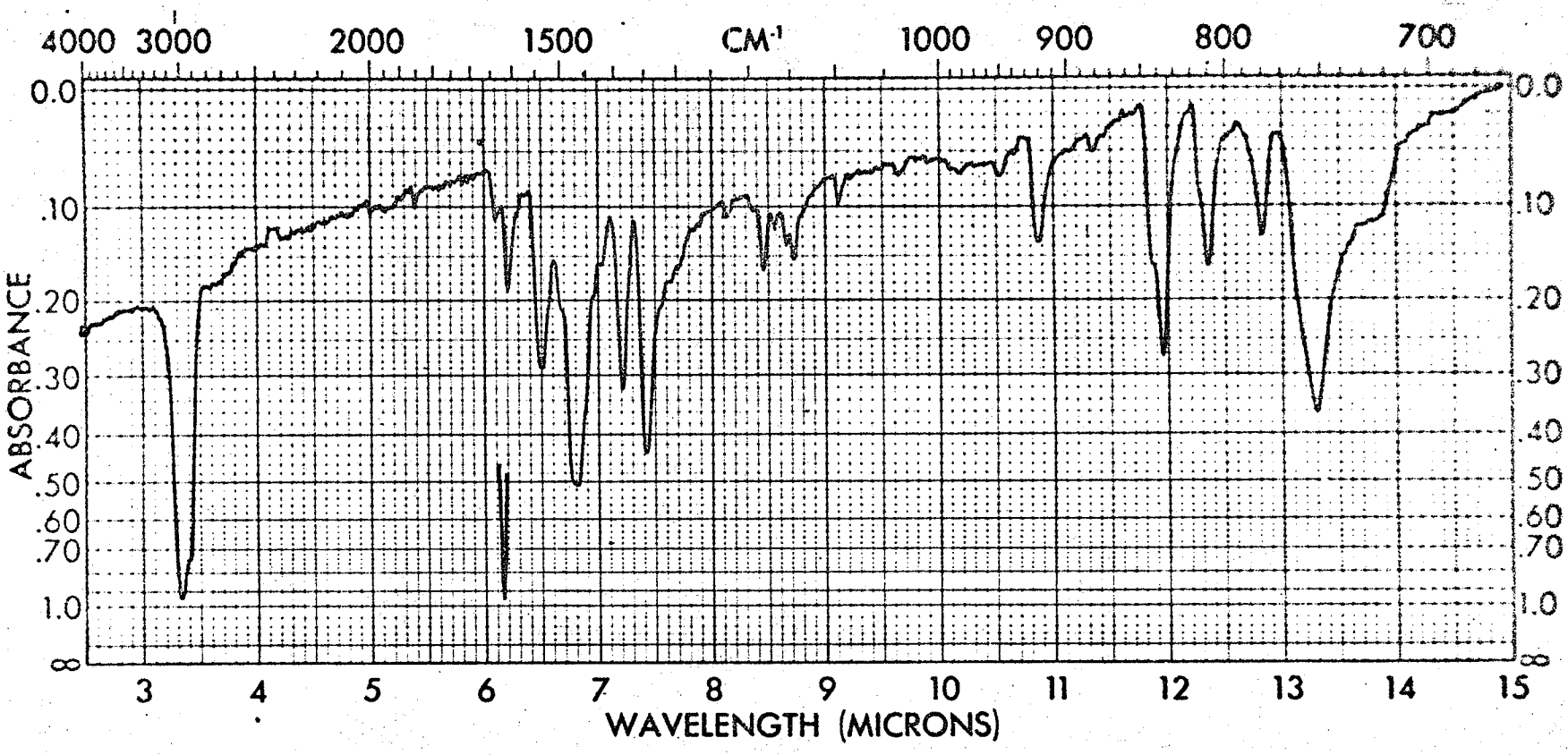
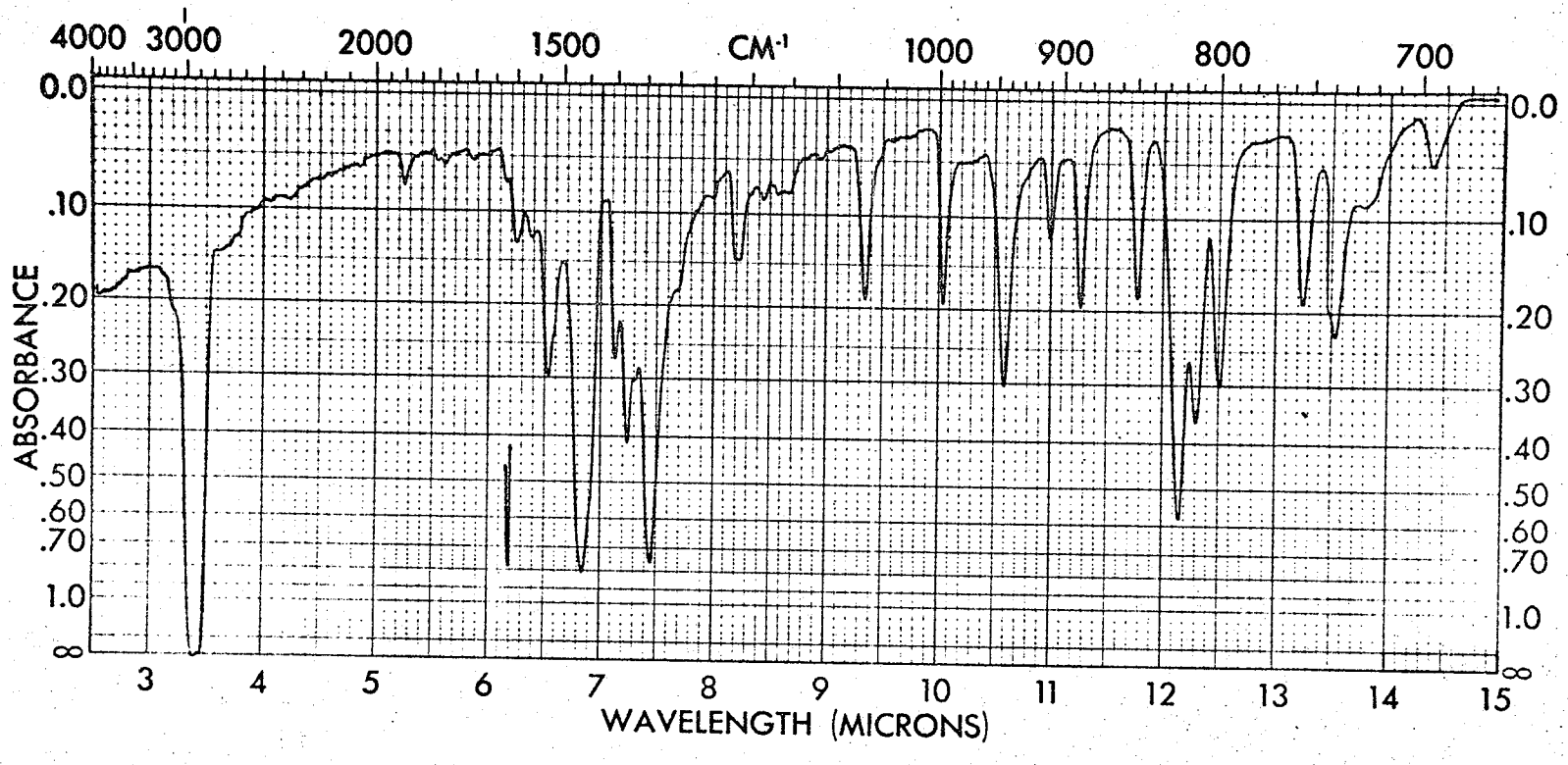
INFRA RED SPECTRA



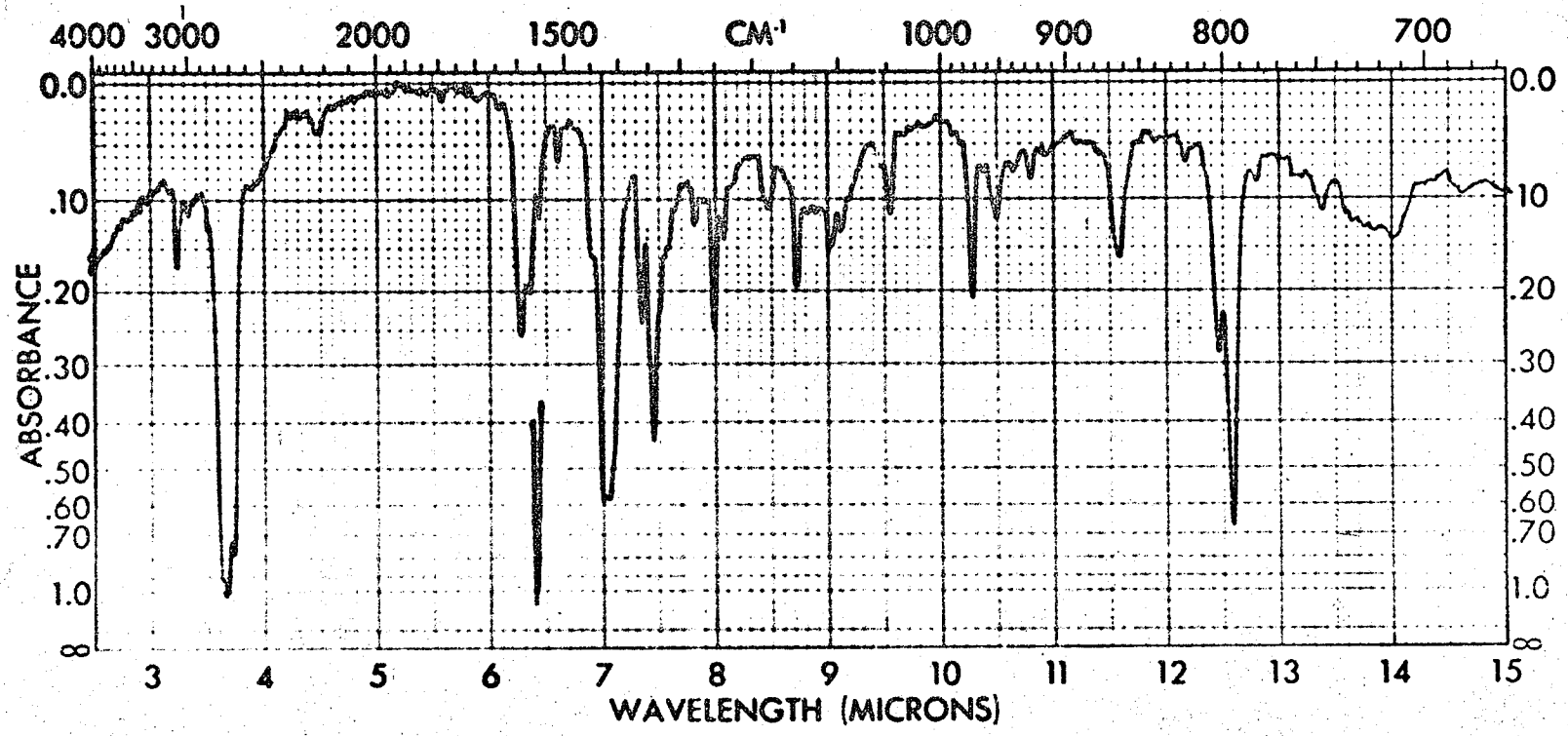
I. R. Spectrum of 1-Nitrofluoranthene (L).

Phase-Nujol Mull.



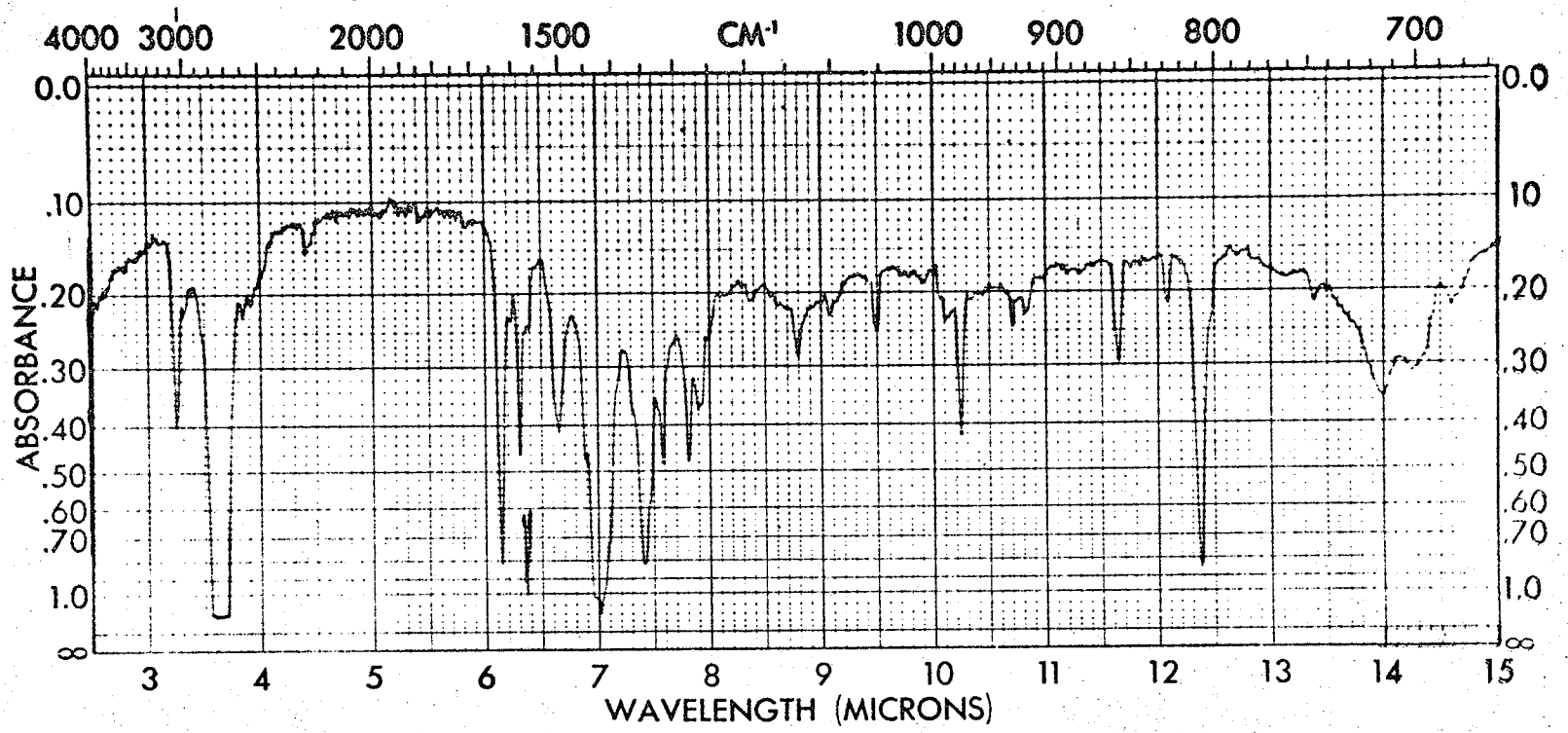
I. R. Spectrum of 1-Nitro-4,9-Dibromofluoranthene (LV).

Phase-Nujol Mull.



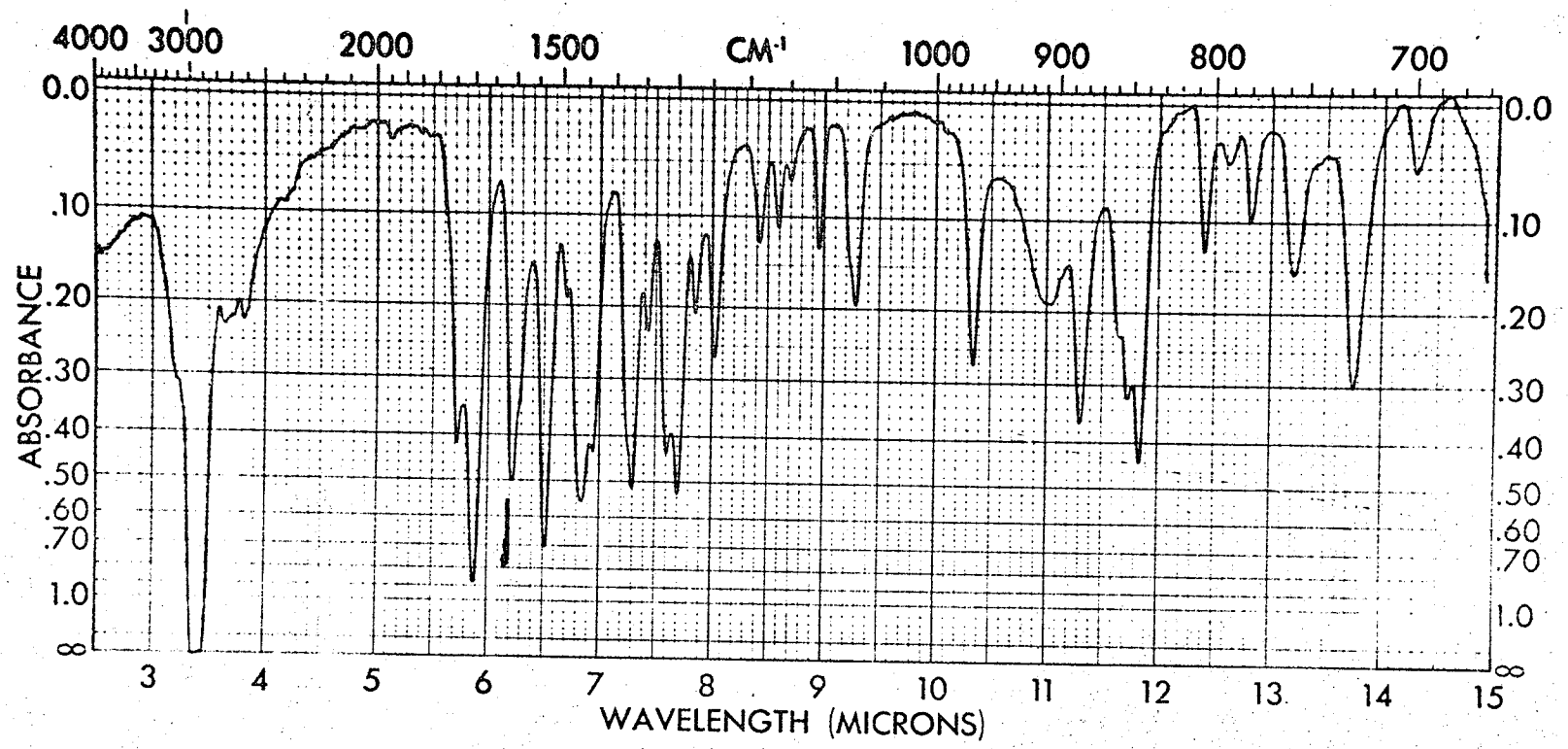
I. R. Spectrum of 1-Amino-4,9-Dibromofluoranthene (LVII).

Phase-Nujol Mull.



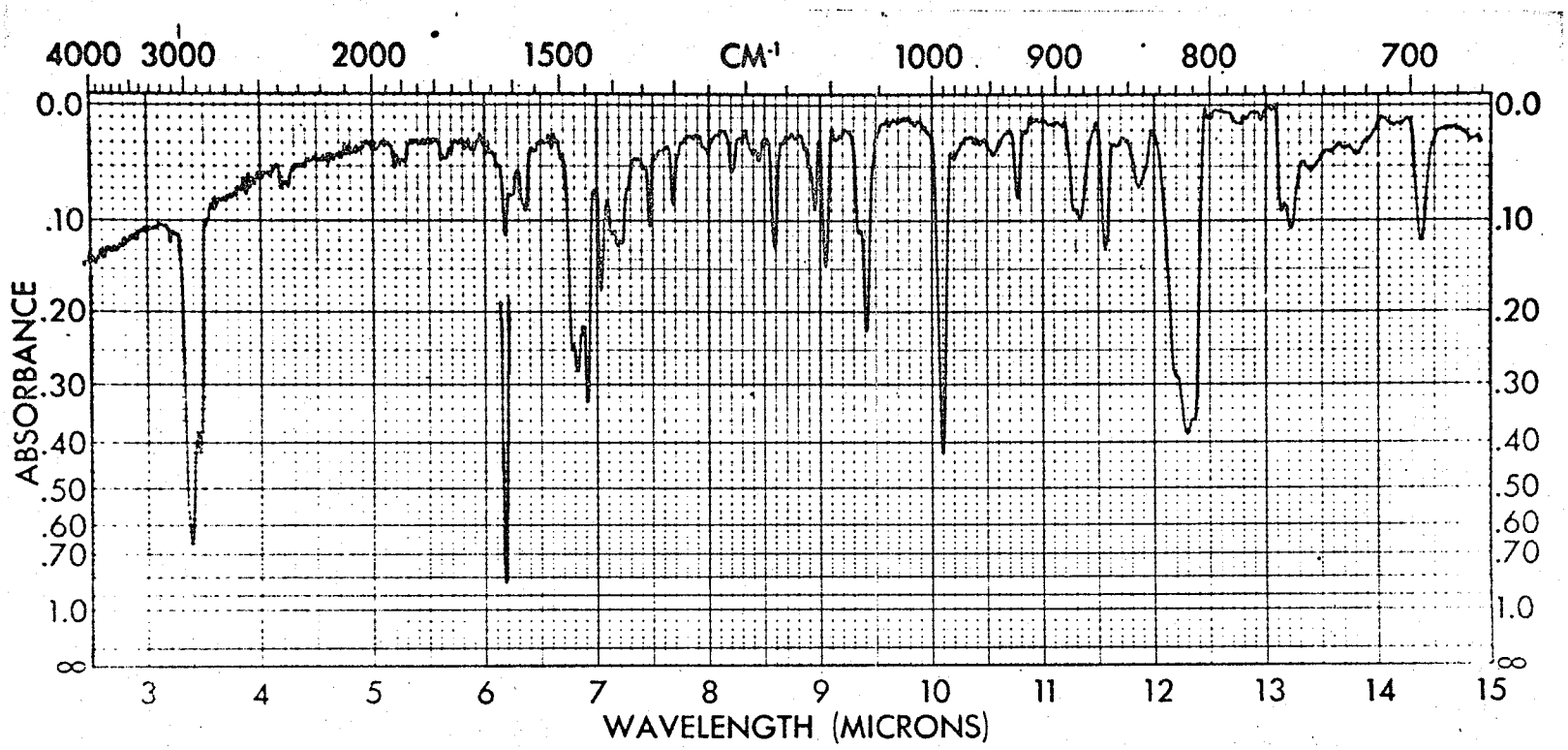
I. R. Spectrum of 1-Acetamido-4,9-Dibromofluoranthene (LVIII).

Phase-Nujol Mull.



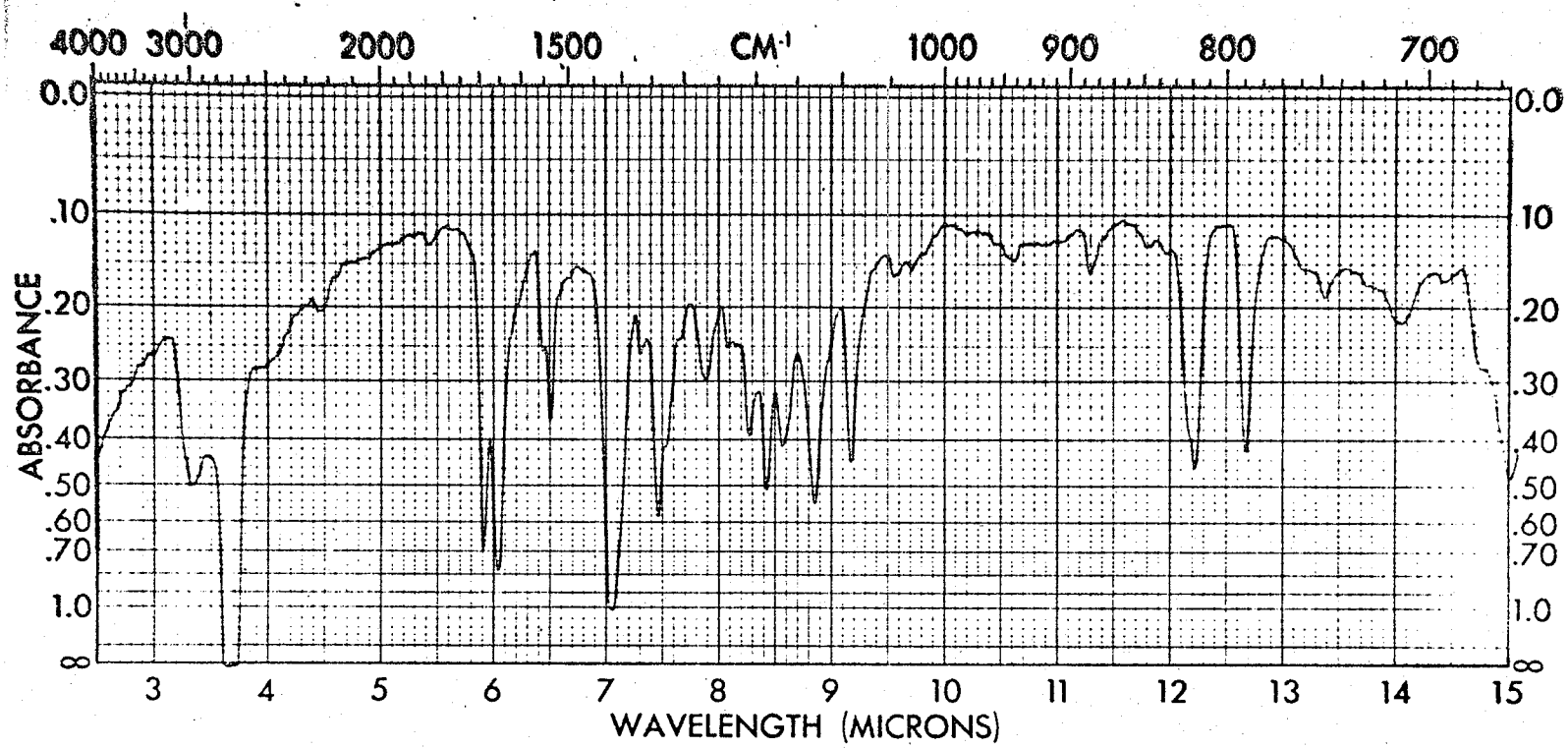
I. R. Spectrum of 4-Nitro-6-Bromofluorenone-1-Carboxylic Acid (LVI).

Phase-Nujol Mull.



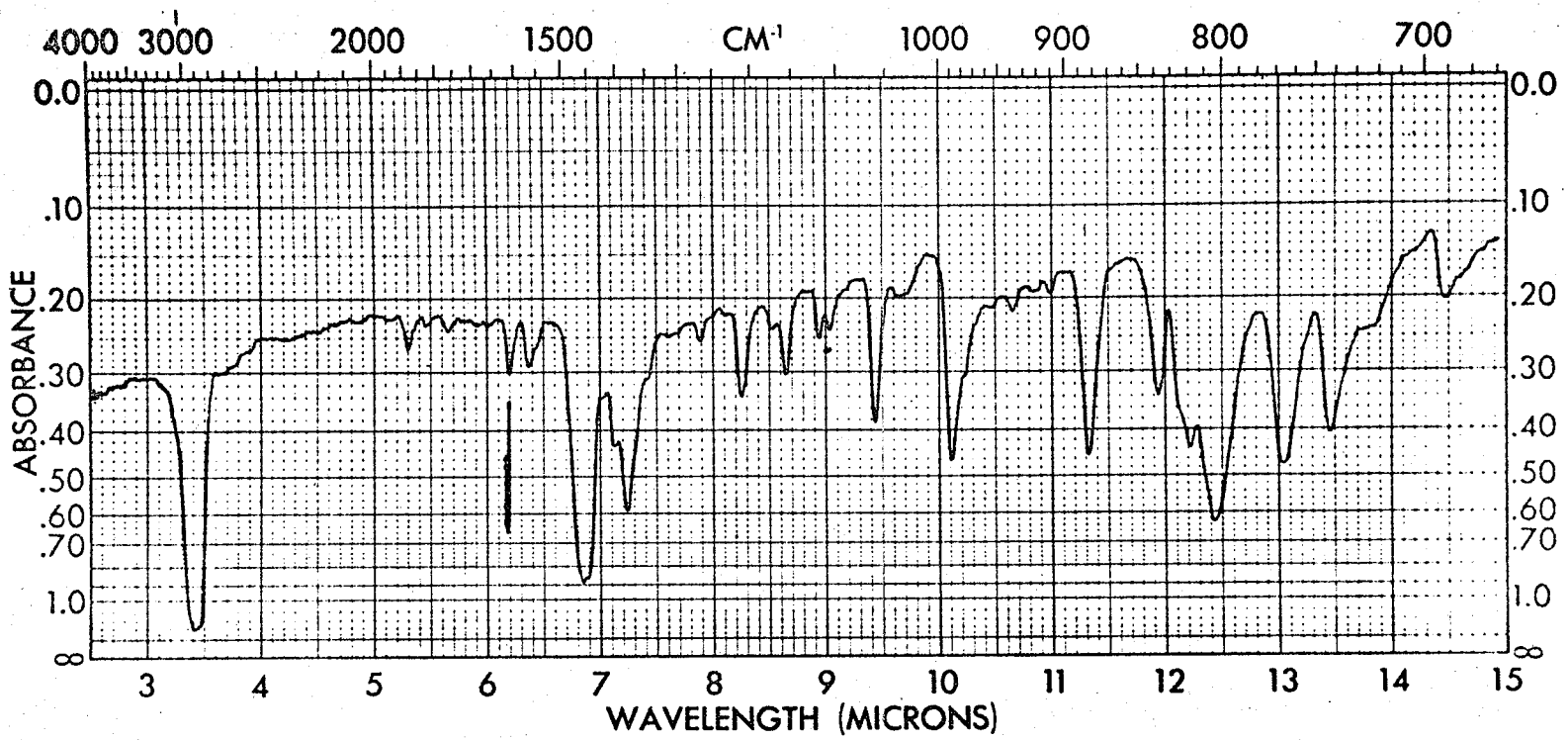
I. R. Spectrum of 1,4,9-Tribromofluoranthene (LIX).

Phase-Nujol Mull.



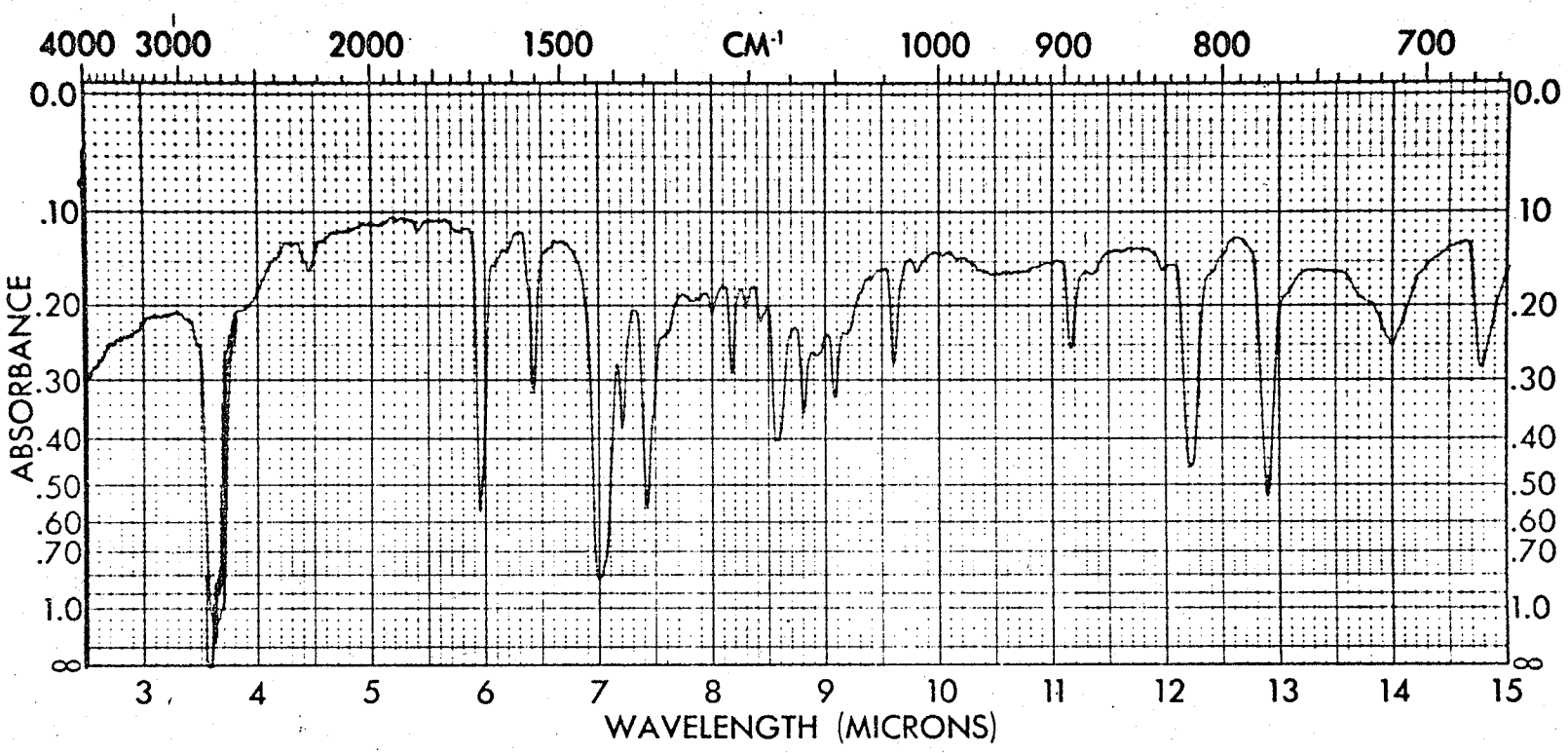
I. R. Spectrum of 2,7-Dibromofluorenone-1-Carboxylic Acid.

Phase-Nujol Mull.



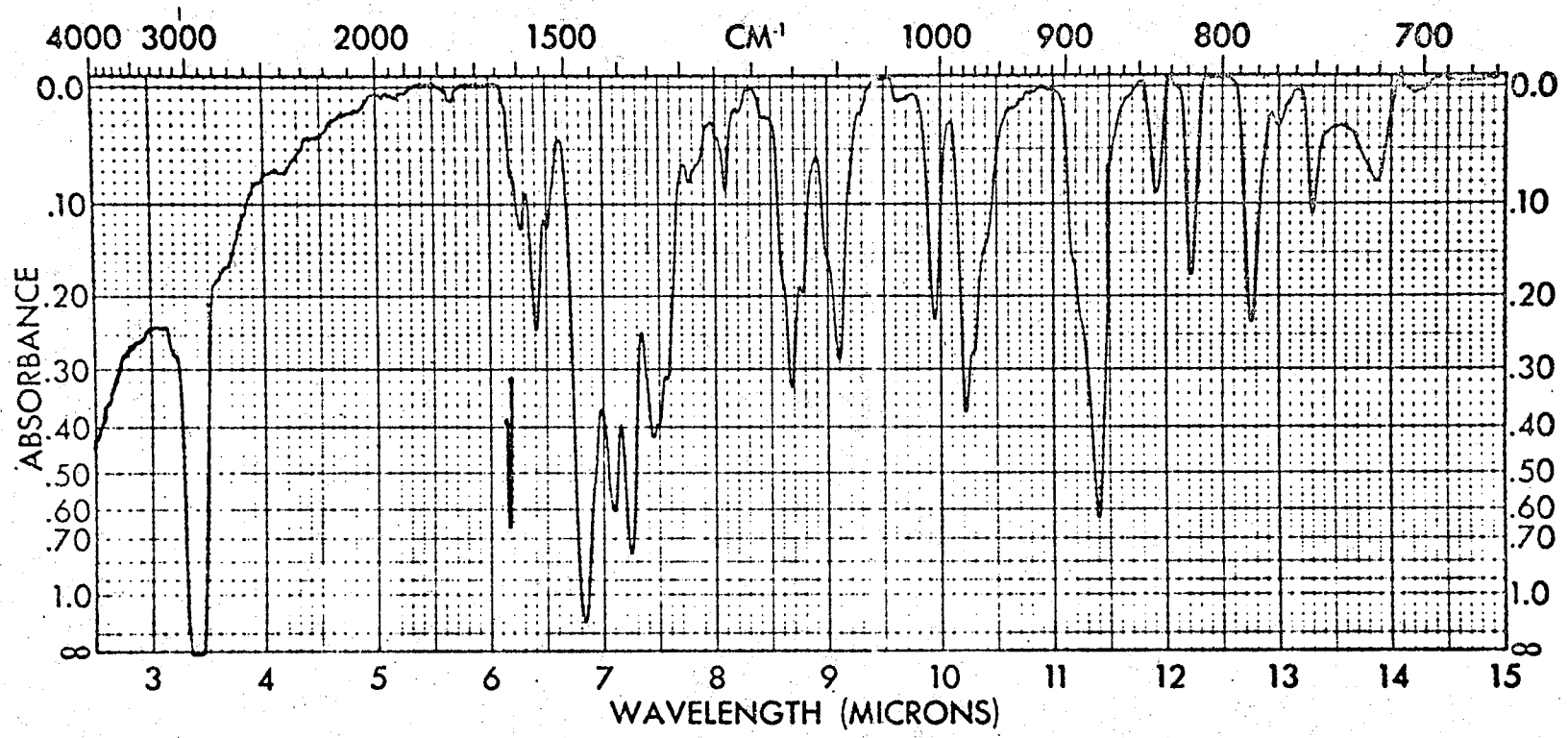
I. R. Spectrum of 3,8-Dibromofluoranthene (LX).

Phase-Nujol Mull.



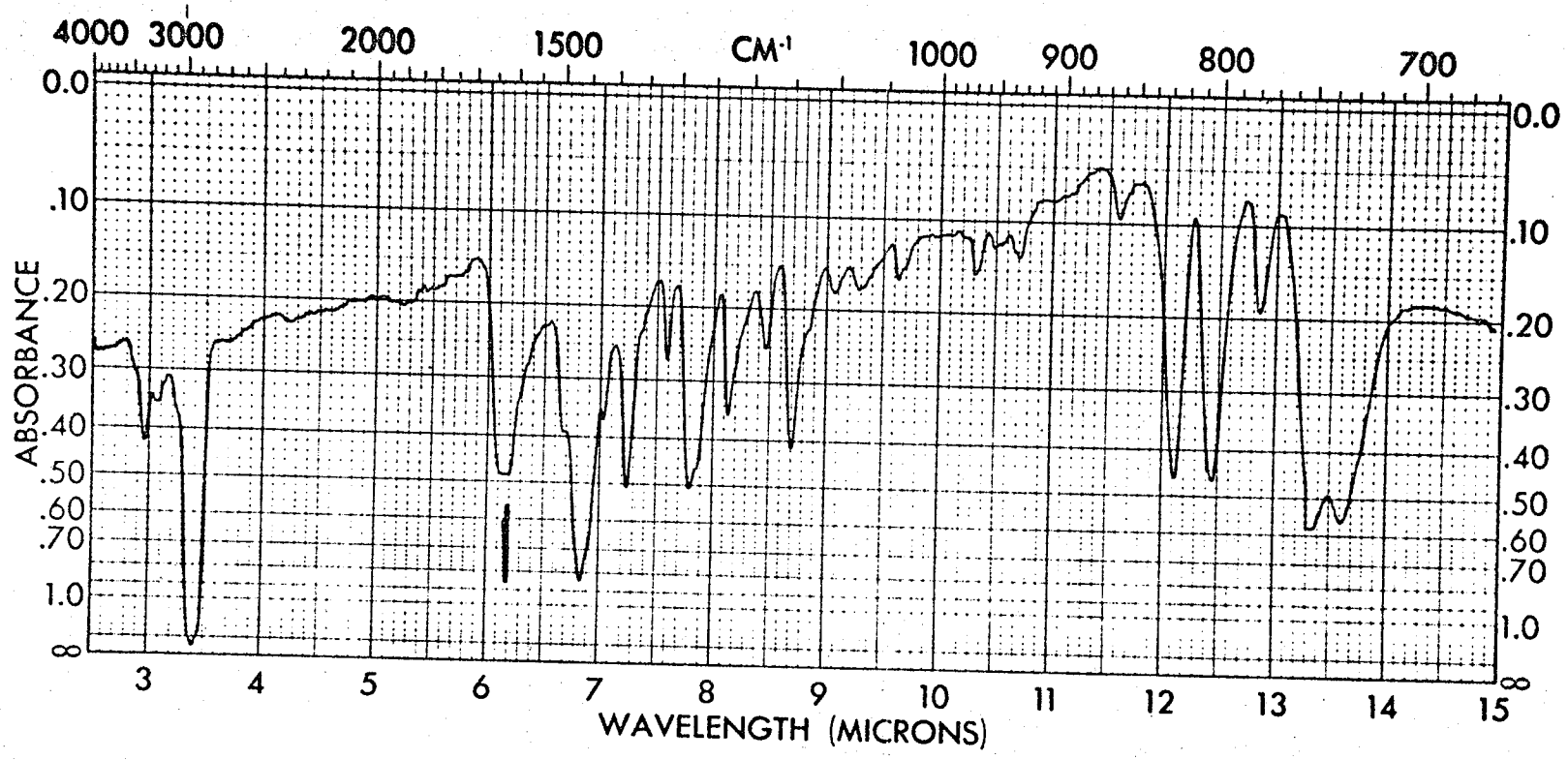
I. R. Spectrum of 2,7-Dibromofluorenone (LXII).

Phase-Nujol Mull.



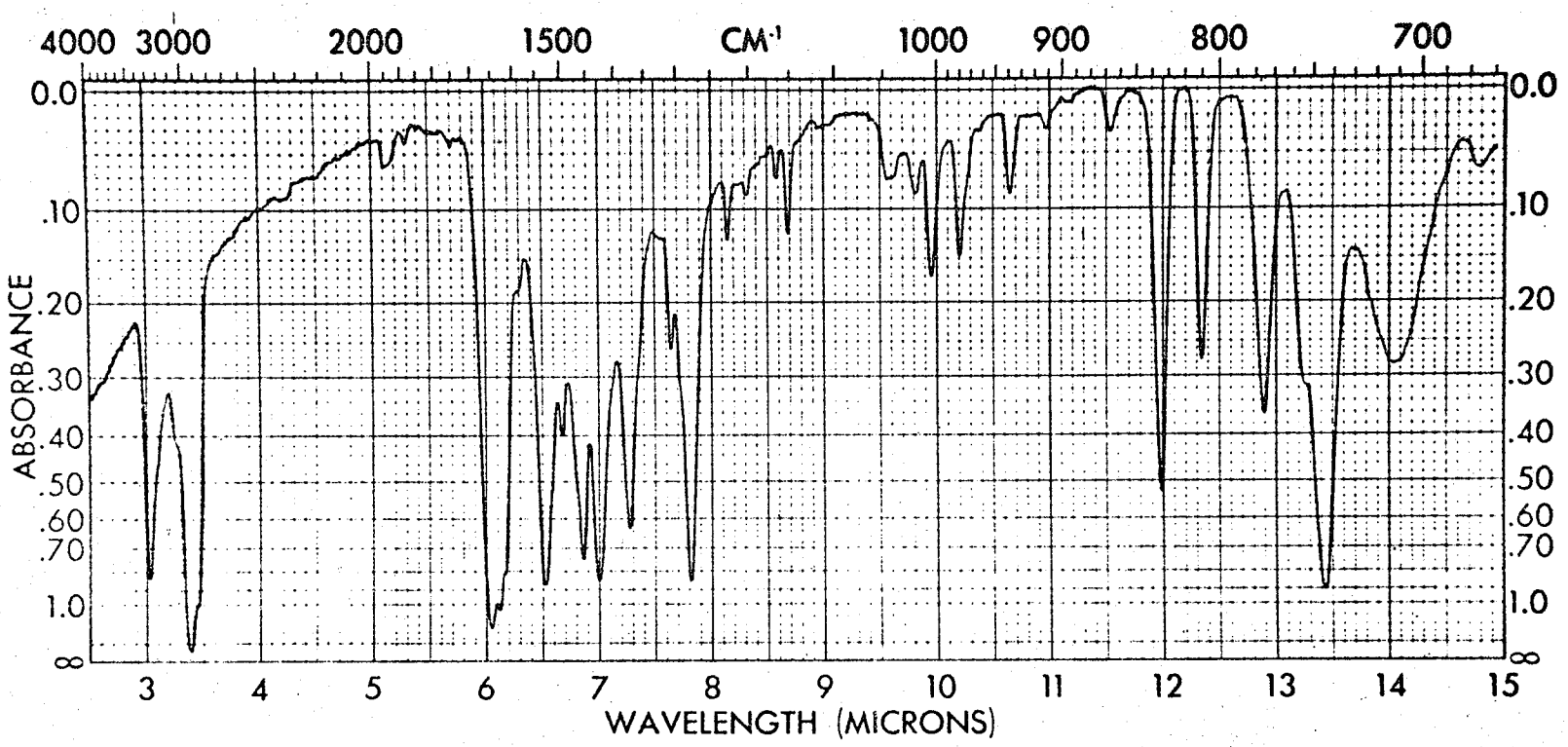
I. R. Spectrum of Hexabromofluoranthene (LX X).

Phase-Nujol Mull.



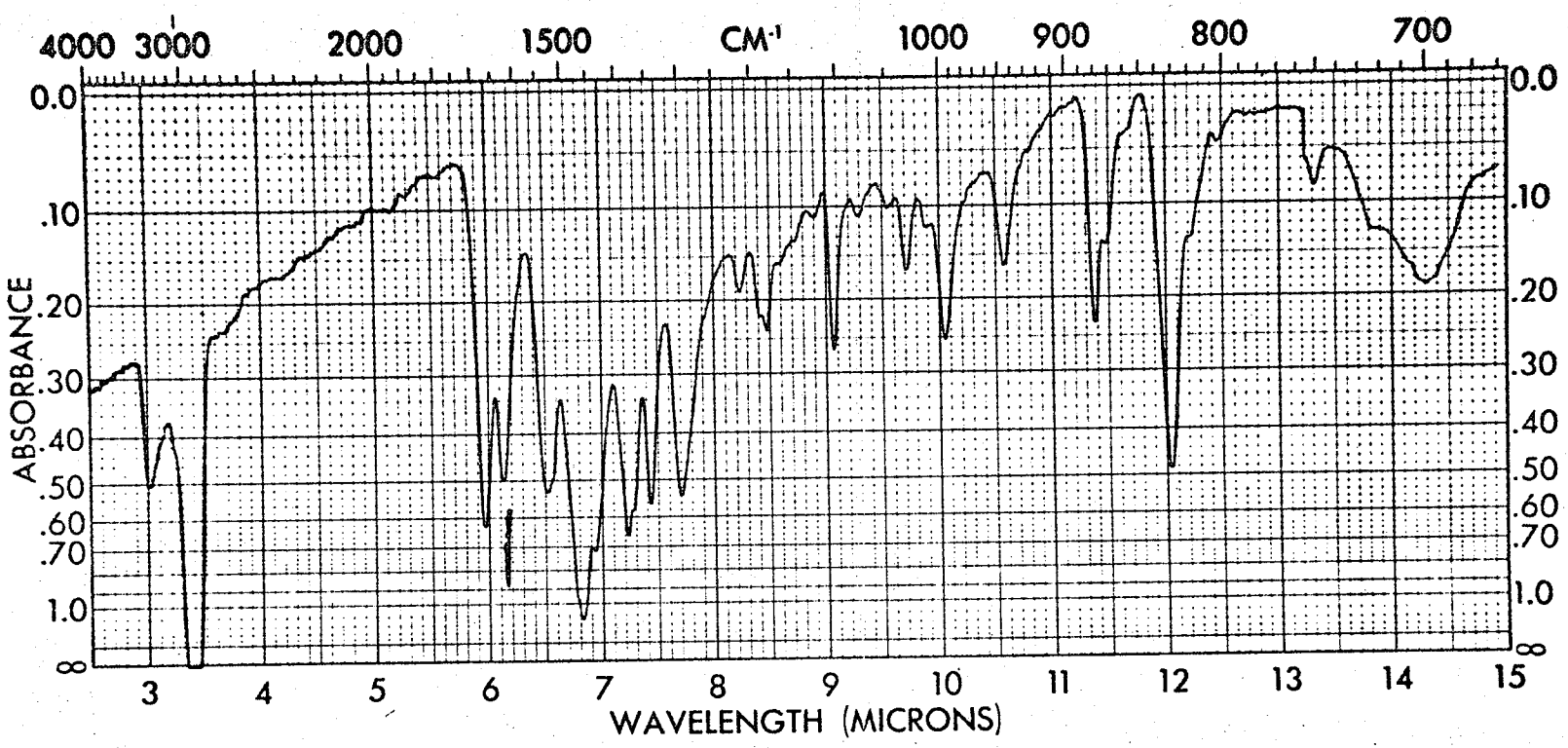
I. R. Spectrum of 1-Aminofluoranthene.

Phase-Nujol Mull.



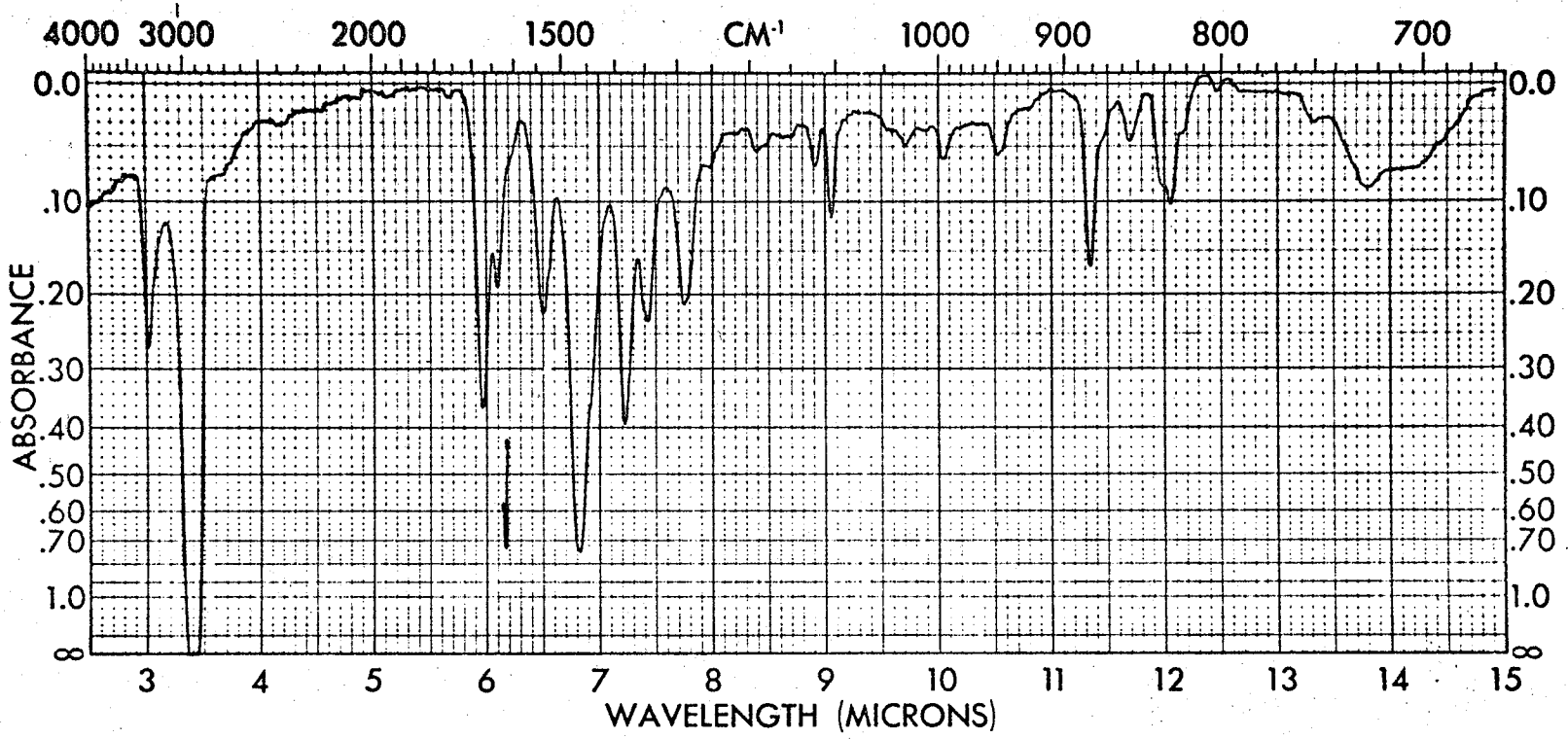
I. R. Spectrum of 1-Acetamidofluoranthene.

Phase-Nujol Mull.



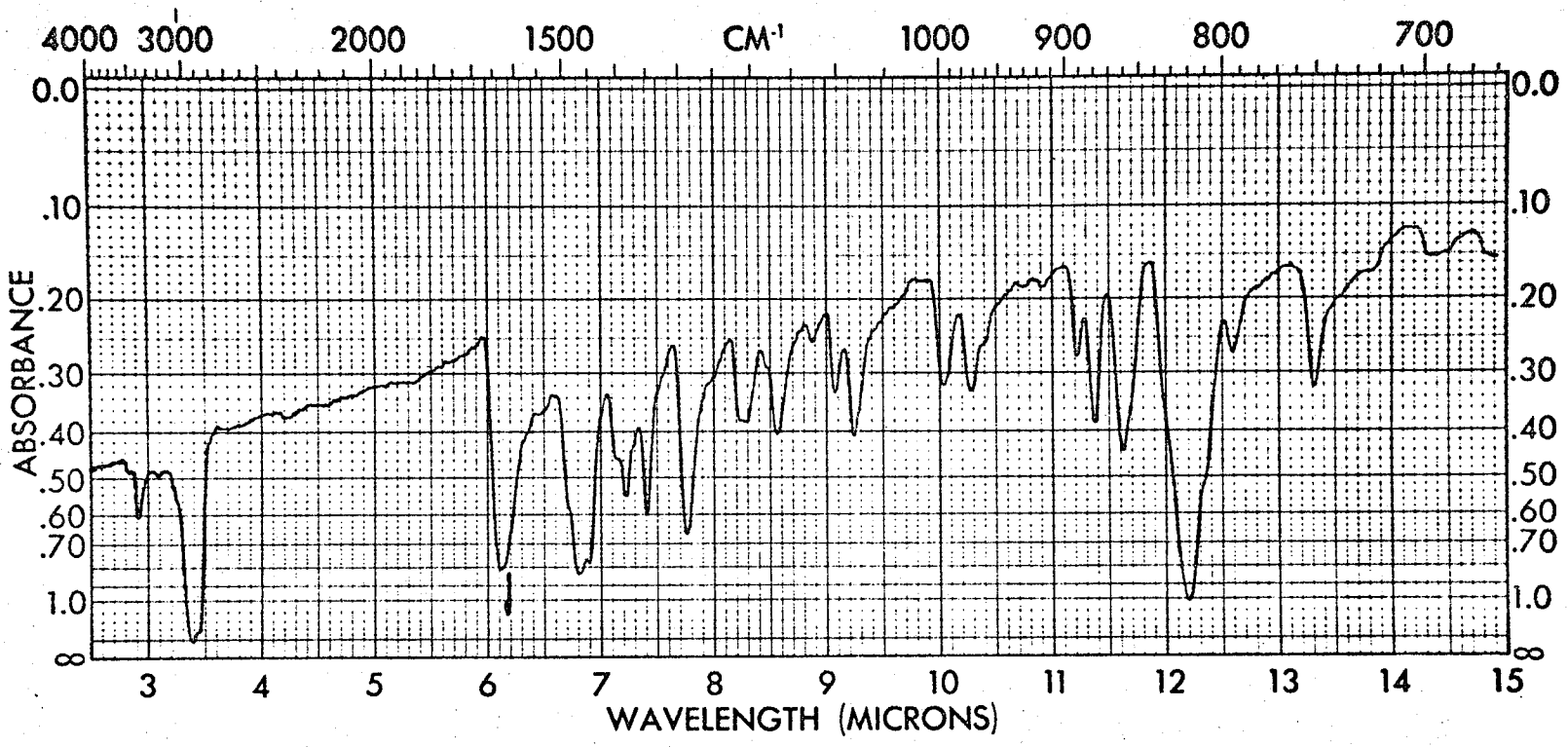
I. R. Spectrum of 1-Acetamido-4,8,9-Tribromofluoranthene (LXIX).

Phase-Nujol Mull.



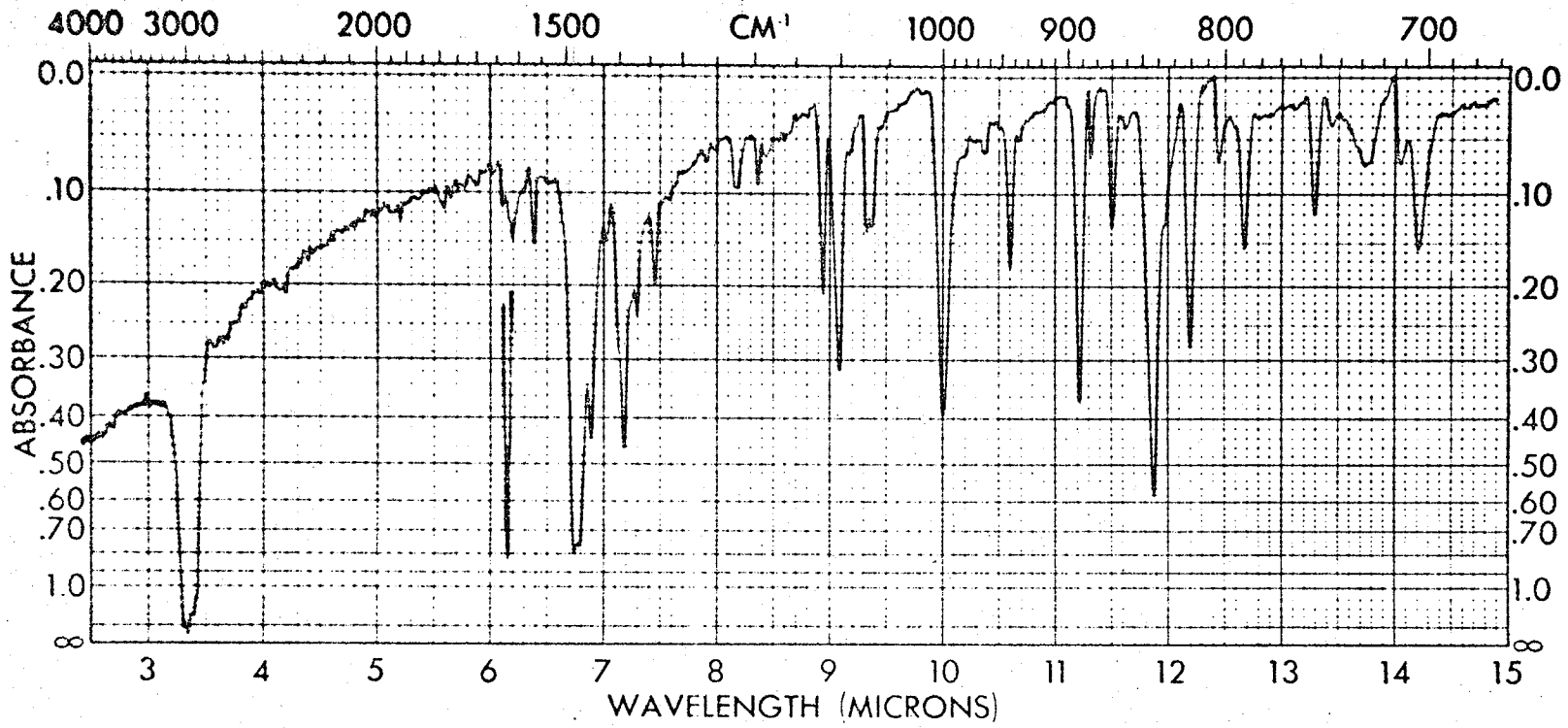
I. R. Spectrum of 1-Acetamido-4,8,9,(?)-Tetrabromofluoranthene (LXXI).

Phase-Nujol Mull.



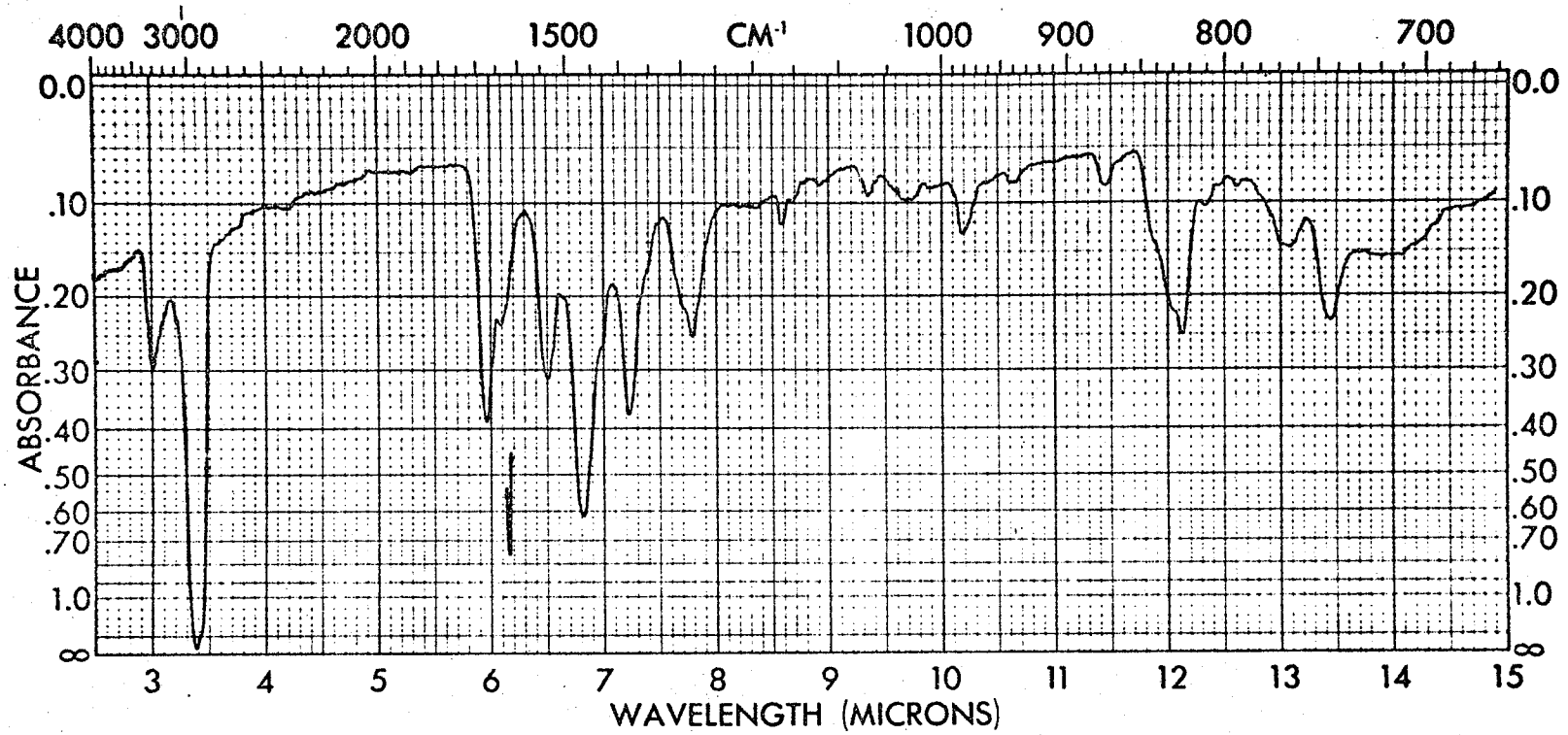
I. R. Spectrum of 1-Amino-4,8,9-Tribromofluoranthene (LXXII).

Phase-Nujol Mull.



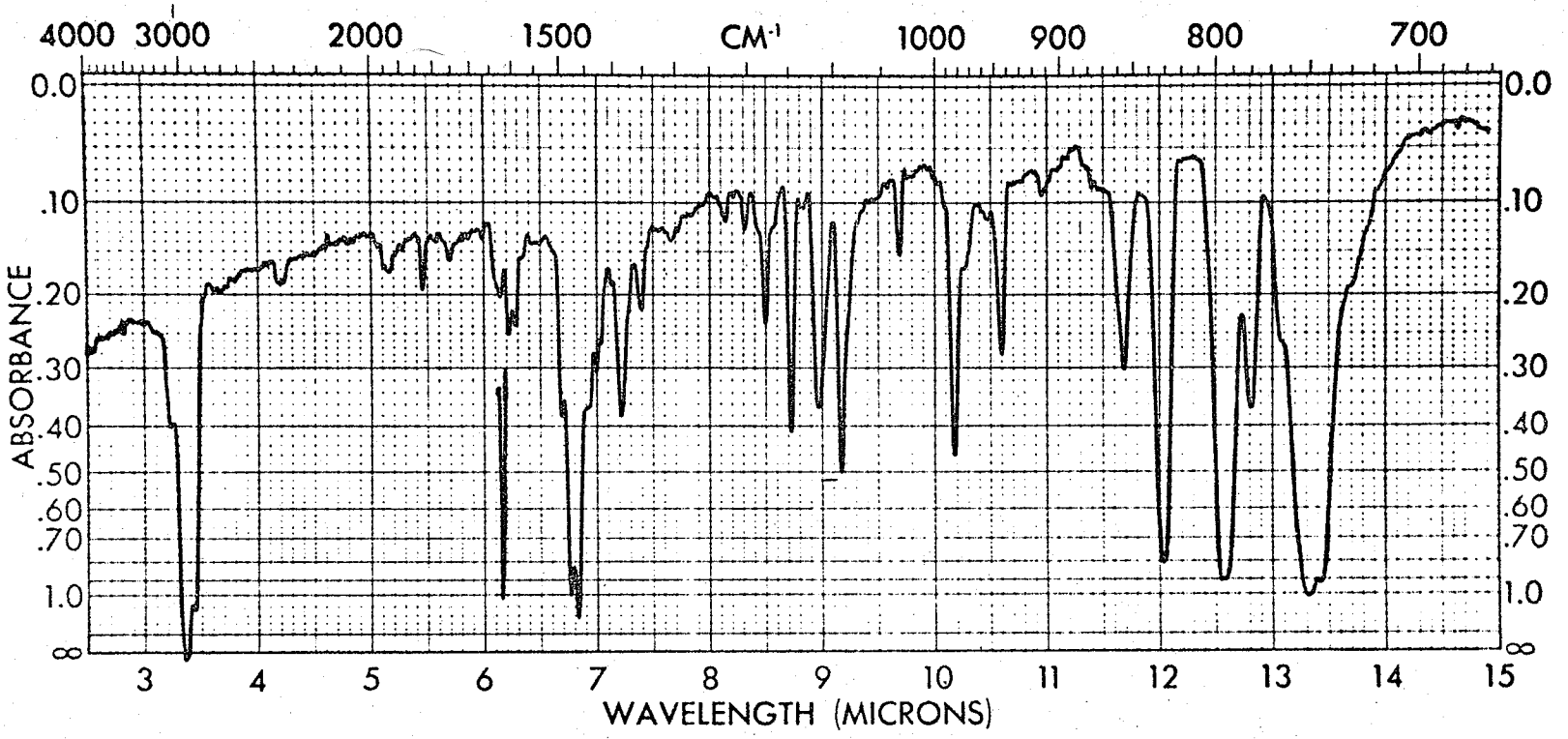
I. R. Spectrum of 1,4,8,9-Tetrabromofluoranthene (LXXIV).

Phase-Nujol Mull.



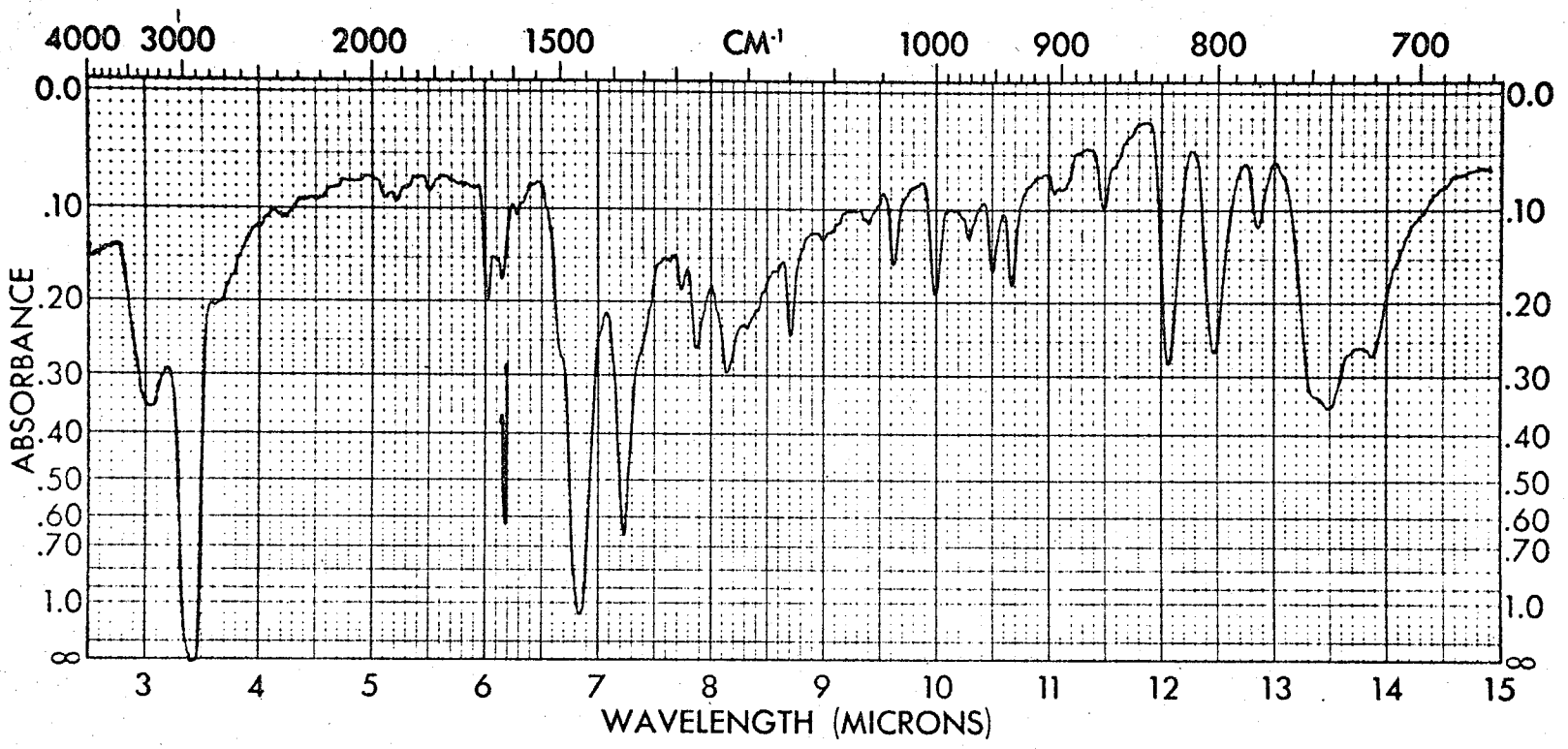
I. R. Spectrum of 1-Bromoacetamidofluoranthene (LXXVI).

Phase-Nujol Mull.



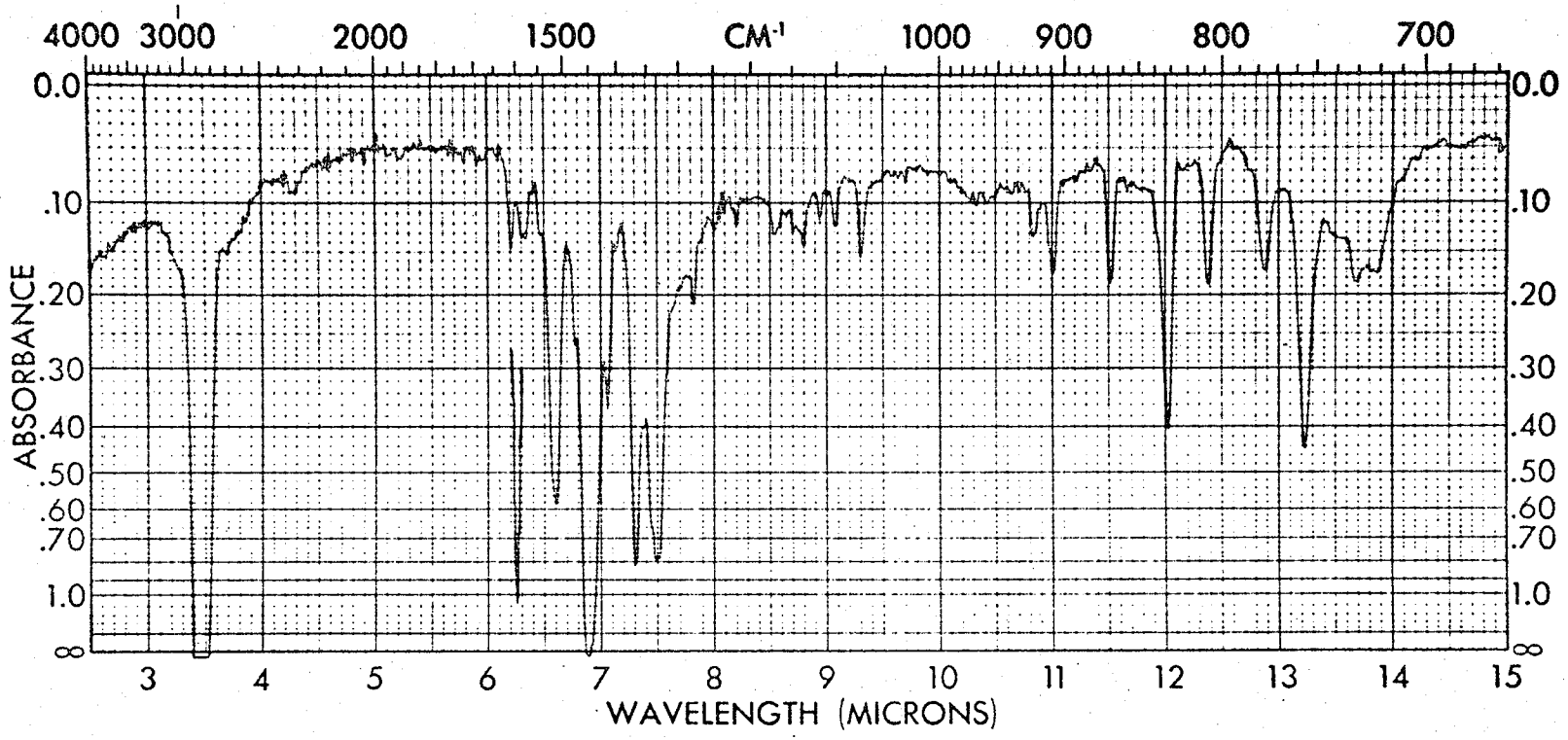
I. R. Spectrum of 1-Bromofluoranthene (LXXVII).

Phase-Nujol Mull.



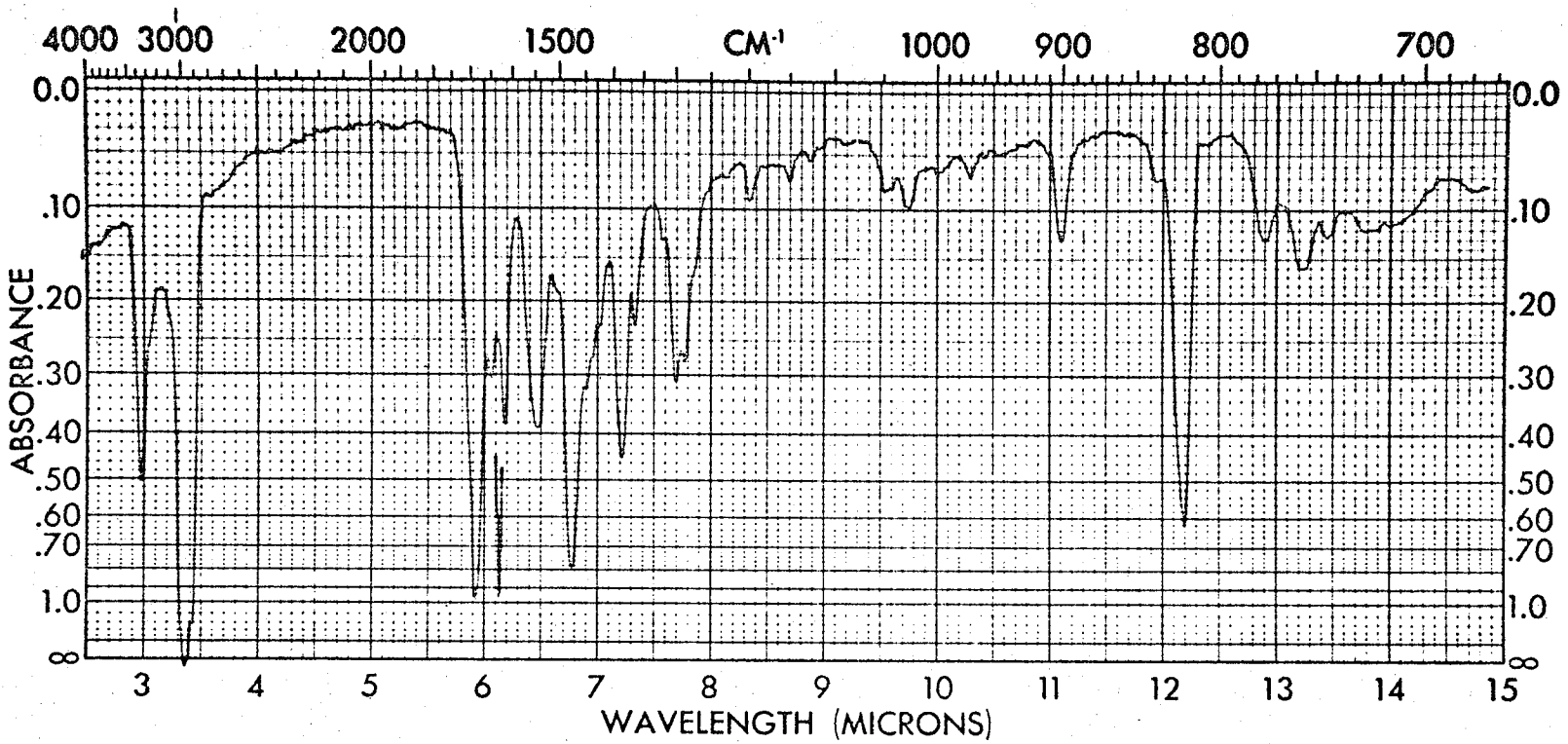
I. R. Spectrum of 1-Hydroxyfluoranthene (LXXVIII).

Phase-Nujol Mull.



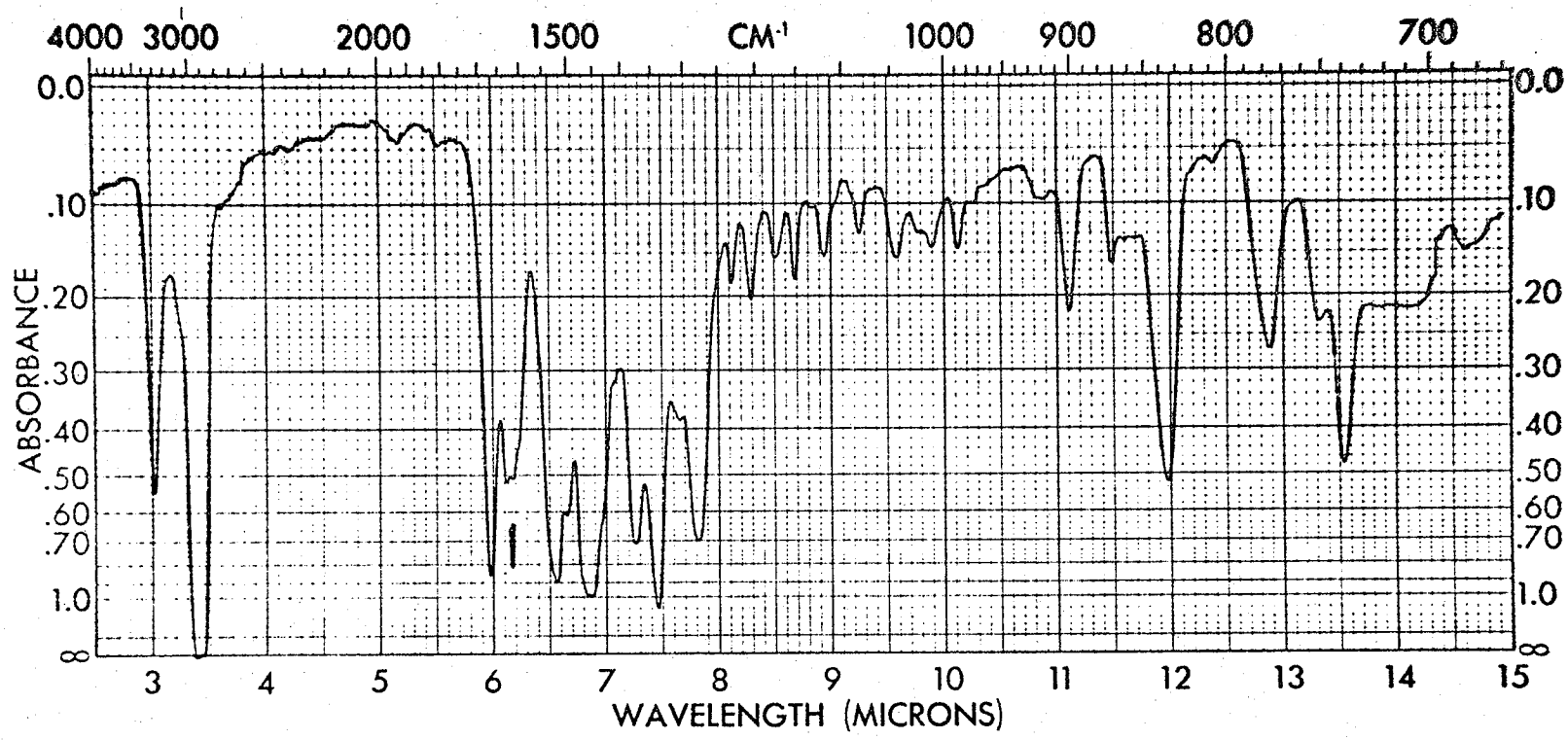
I. R. Spectrum of 1,(?)-Dinitrofluoranthene (LXXIX).

Phase-Nujol Mull.



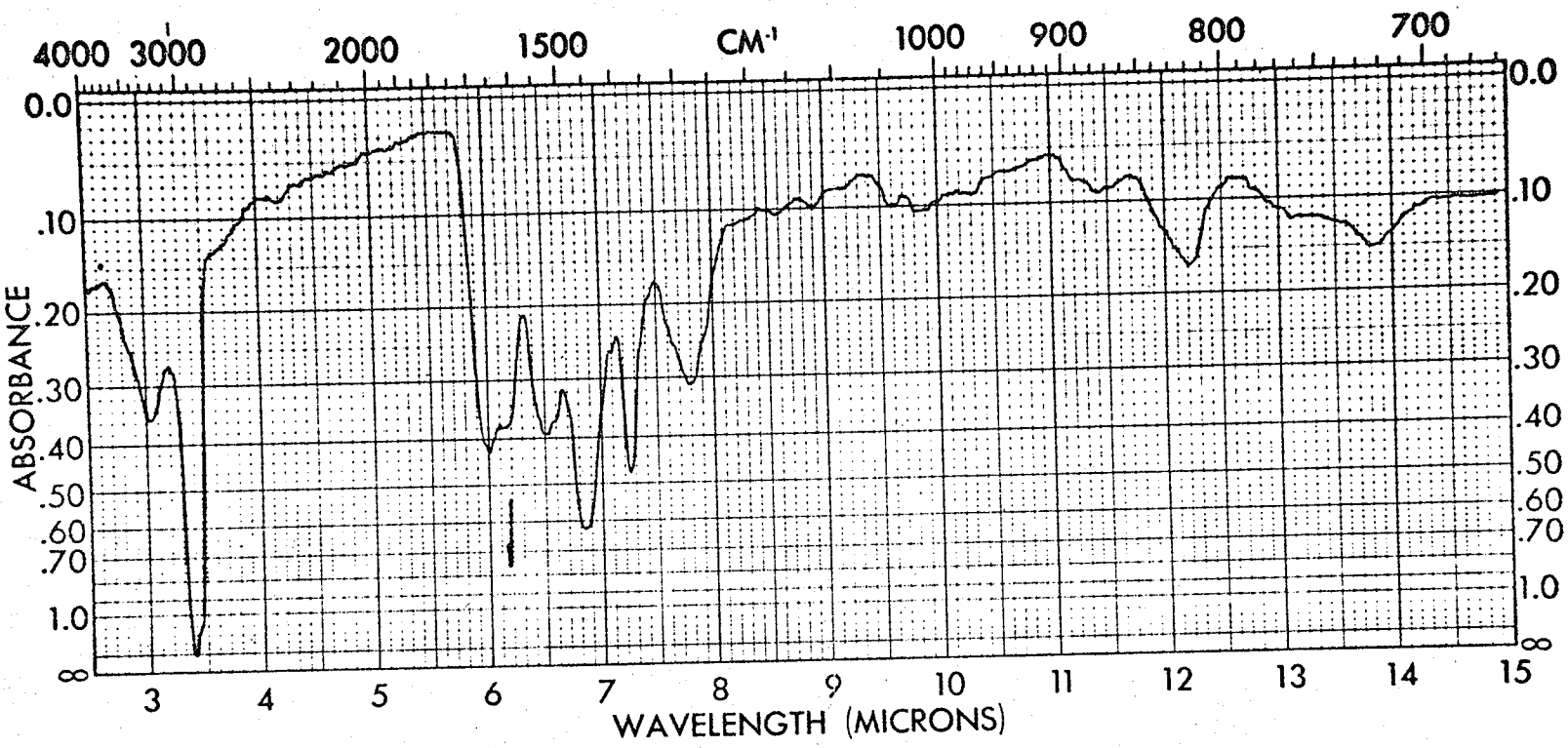
I. R. Spectrum of 1,(?)-Diacetamidofluoranthene (LXXXI).

Phase-Nujol Mull.



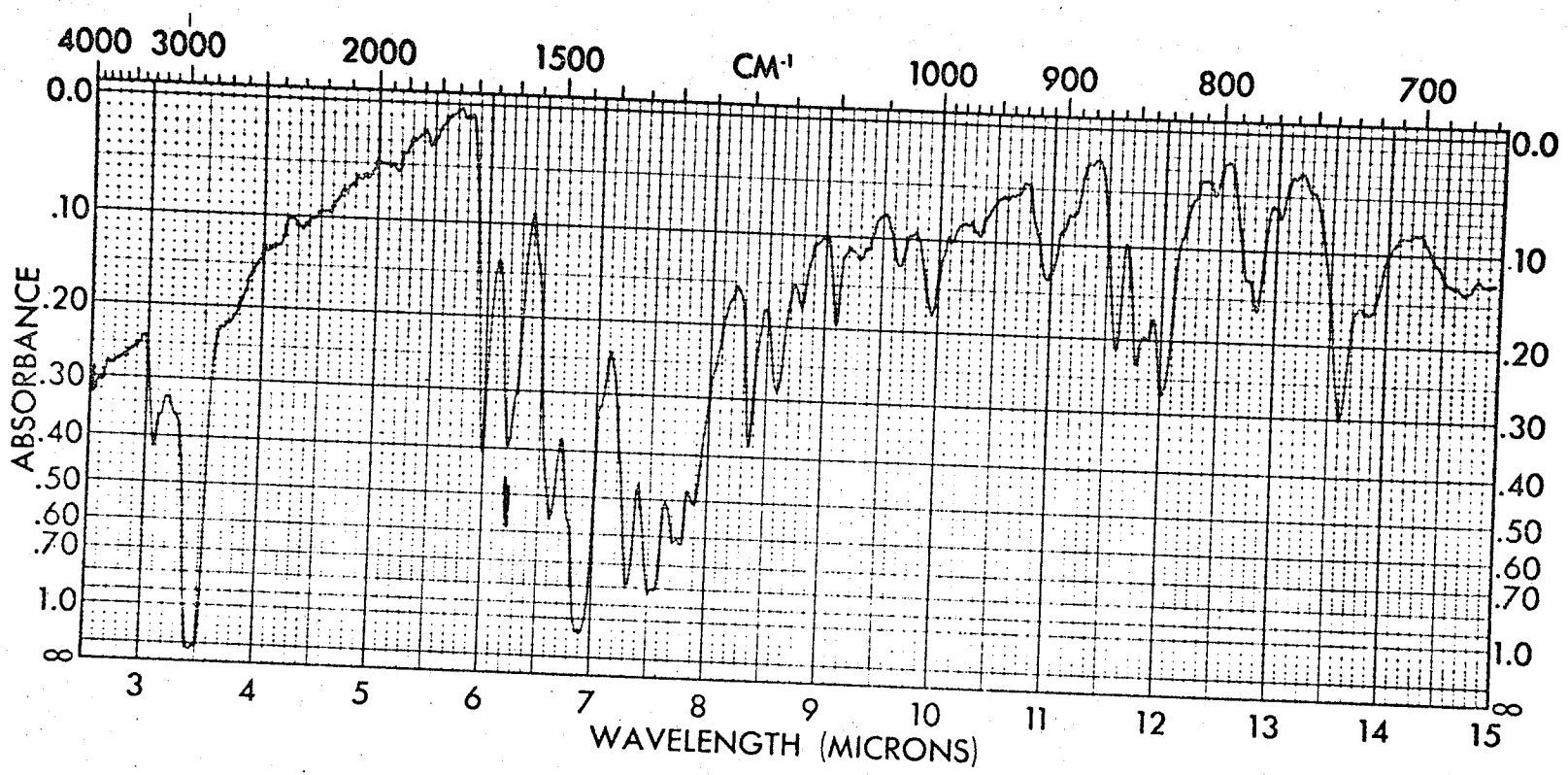
I. R. Spectrum of 1-Acetamido-Mononitrofluoranthene (LXXXIII).

Phase-Nujol Mull.



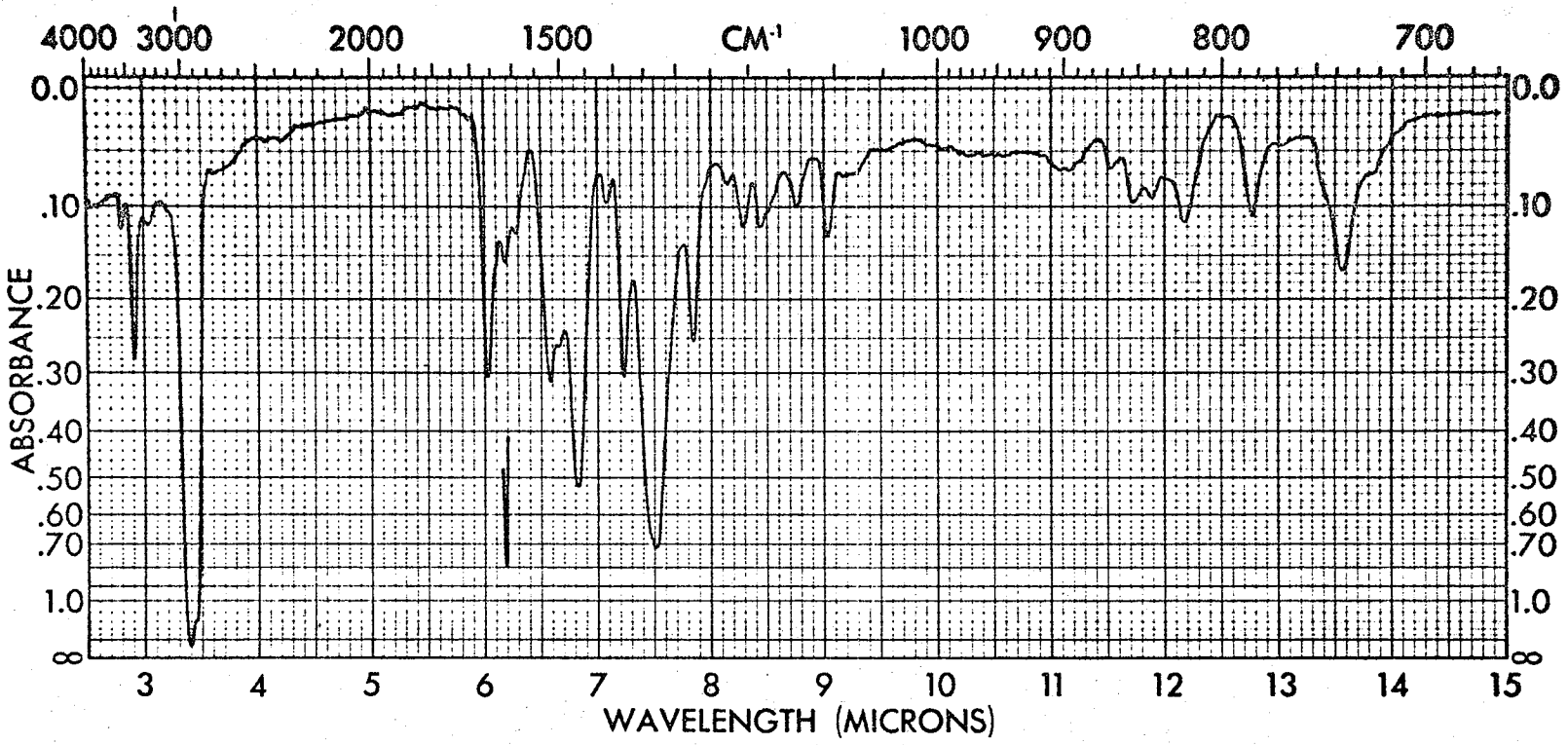
I. R. Spectrum of 1-Acetamido-Monoaminofluoranthene (LXXXV).

Phase-Nujol Mull.



I. R. Spectrum of 1-Acetamido-Dinitrofluoranthene (LXXXII).

Phase-Nujol Mull.



I. R. Spectrum of 1-Amino-(??)-Dinitrofluoranthene Hydrochloride (LXXXIV).

Phase-Nujol Mull.

PART B

SYNTHESIS OF SOME 3,6-DISUBSTITUTED FLUORENONES

INTRODUCTION

Fluorenone is closely related to fluoranthene and the synthesis of substituted fluorenones is often the only means of proving the orientation of substituents in the fluoranthene molecule. Oxidation of substituted fluoranthenes with dichromate or chromic acid solutions, invariably give substituted or unsubstituted fluorenone carboxylic acids depending on the ring broken. As was mentioned in part A of this thesis (page 19) Charlesworth and Mathiaparanam (1) developed a very efficient synthesis for unsymmetrical 3,6-disubstituted fluorenones using m-acetotoluidide and p-nitrobenzoyl chloride as starting materials (see page 154). Their work was necessitated by the desire to prove the identity of 3-bromo-6-nitrofluorenone which was the oxidation and decarboxylation product of 2-nitro-9-bromofluoranthene synthesized by Charlesworth and Dolenko (2).

It was discovered that very few unsymmetrical 3,6-disubstituted fluorenones were reported in the literature, so it appeared that application of diazonium reactions to 4-amino-2-methyl-4'-nitrobenzophenone (an intermediate in the reaction scheme; page 154) to produce the analogous chloro-, fluoro- and iodo- compounds should be possible. Cyclization to form the corresponding 3-halo-6-nitrofluorenones would be both worthwhile and interesting. Furthermore it would provide good practice for the anticipated synthesis of similar disubstituted fluorenones which might have been required in connection with elucidation of structure on the bromination and nitration of 1-substituted fluoranthenes. Indeed, they could be used not only to establish identity of the oxidized and de-

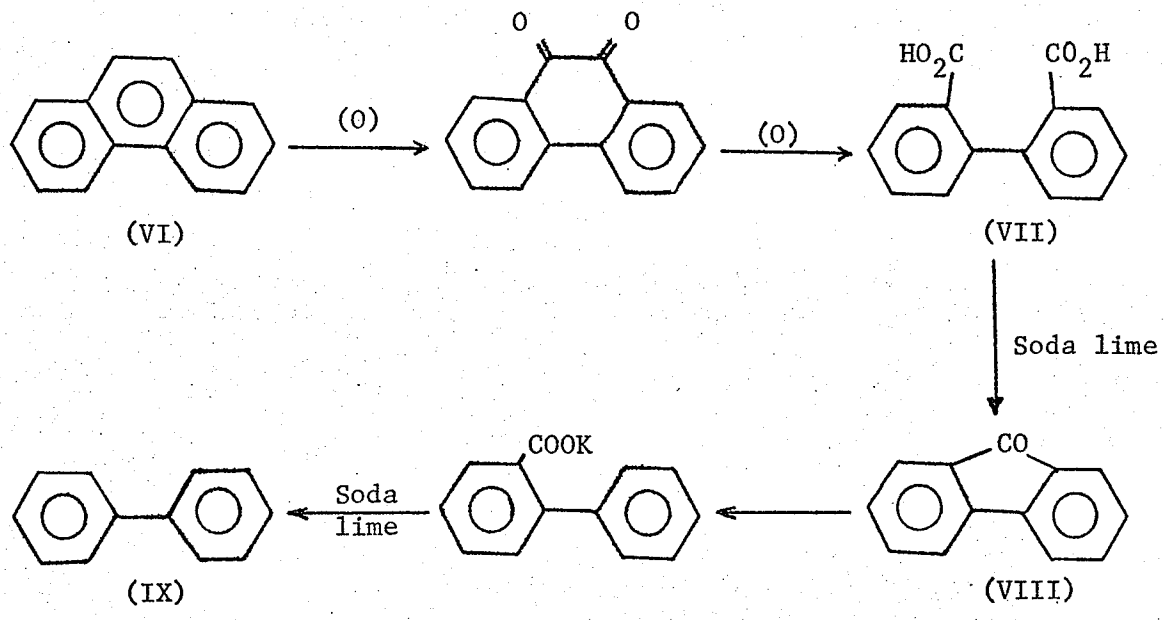
carboxylated fluoranthene compounds, but also as starting materials for synthesizing substituted fluoranthenes. These series of reactions were undertaken when bromination of 1-acetamidofluoranthene (see part A page 48) was proving to be quite difficult and there was even doubt as to its successful completion.

LITERATURE SURVEY

While working on the pyrogenetic hydrocarbons in 1867, Berthelot (3) isolated a new substance from the fraction of crude anthracene oil boiling between 300 and 310°. On recrystallization from ethanol a white fluorescent solid melting at 113° was obtained. Because of the fluorescence Berthelot named it "Fluorene". However, in 1883 Hodgkinson and Mathews (4) showed that the fluorescence was due to the presence of some impurity which was removed by recrystallization or sublimation.

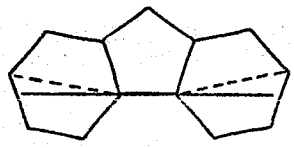
Fluorene occurs in coal tar, and is obtained commercially from that source. It forms a sodio derivative, $(C_6H_4)_2CHNa$, on heating with sodium or better with sodamide at 120-150° (5a). By means of this compound it can be separated from other hydrocarbons in coal tar fractions (6).

The discovery of phenanthrene (VI) in 1872 by Fittig and Ostermayer (7) and independently by Graebe (8) played a major role in the elucidation of the structure of fluorene. Fittig and Ostermayer (9) carried out the following degradation, leading to the known diphenyl (IX).



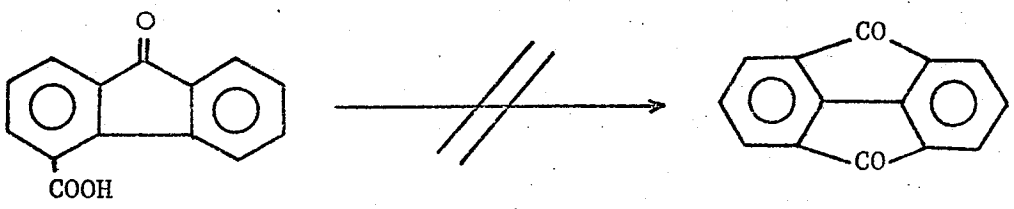
The ketone (VIII) produced from the then unknown diphenic acid (VII) was rightly interpreted as diphenylene ketone. Fittig (10) distilled the diphenylene ketone with zinc dust and found that it was reduced to a white substance melting at 113-114°. This he called diphenylene methane. Barbier (11) observed that the compound obtained by the oxidation of fluorene was identical with the diphenylene ketone of Fittig and Ostermayer.

In 1878, Fittig and Schmitz (12) reported that the diphenylene methane previously obtained by Fittig from the diphenylene ketone was identical with fluorene obtained by Berthelot and Barbier. Hence the structural formula of fluorene could be represented as:

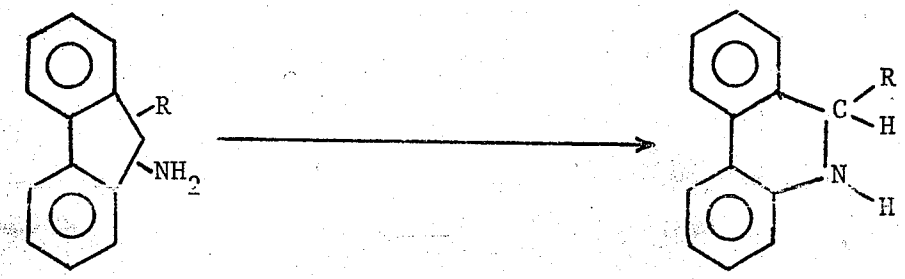


(X)

Evidence seems to indicate that the benzene rings are bent away from the coaxial diphenyl bond with a distortion of the valence angles from the benzene rings by 12°, to give X a planar structure as pictured by Pinck and Hilbert (17), where the five membered ring is nearly a regular pentagon. This formula is probable from dipole measurements (13),(14) and X-ray studies (15) and is further supported by the failure of fluorenone-4-carboxylic acid to close a fourth ring (16), the distance being too great to be bridged.



Such a planar configuration as X would be in a state of strain and has been used (17) to account for the ready enlargement of the five membered ring in the Stieglitz rearrangement of the amines of the type XI to yield phenanthridines.

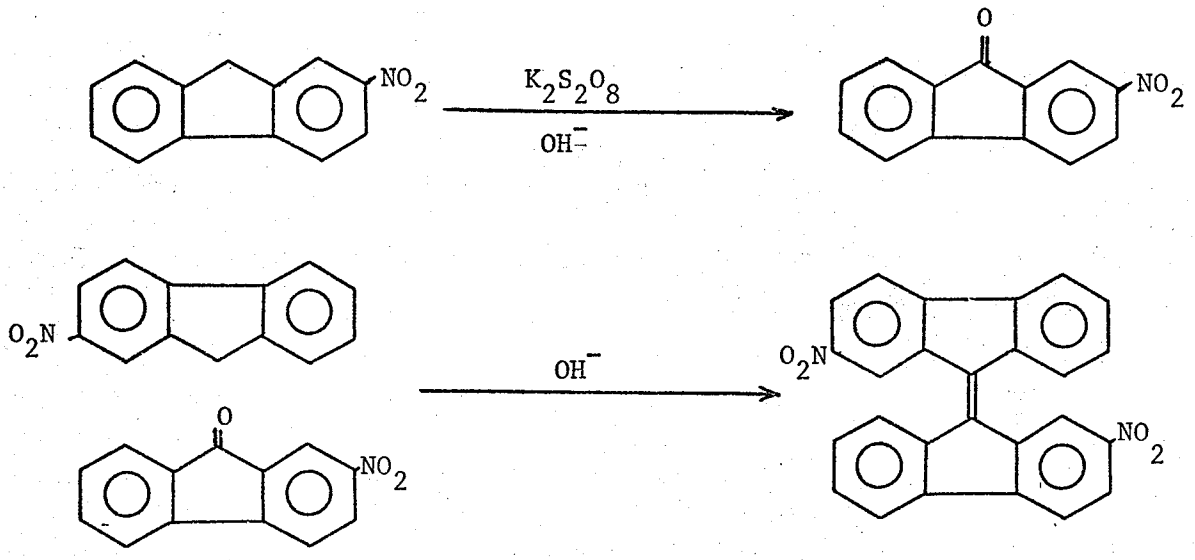


(XI)

Oxidation of Fluorene

Fluorenone is the main oxidation product of fluorene and has been obtained with a variety of oxidizing agents. With sodium dichromate in acetic acid Huntress et al.(59) obtained fluorenone in good yields. This method is suitable for large scale laboratory preparations. Courtot (60) also obtained almost quantitative yield of fluorenone using potassium permanganate as the oxidizing agent at room temperature. This author found that 2,7-dibromofluorene can be oxidized to 2,7-dibromofluorenone with chromic anhydride in acetic acid (see No. 15 page 71) in good yield and would expect the unsubstituted fluorene to be oxidized to fluorenone as easily.

Gutman, Butle and Fenton (61) studied the oxidation of fluorene, 2-acetamidofluorene and 2-nitrofluorene by alkaline potassium persulfate solutions. They found that fluorene and 2-acetamidofluorene were resistant to oxidation whereas 2-nitrofluorene was attacked at the methylene carbon to yield 2-nitrofluorenone and 2,2'-dinitro-9,9'-difluorylidine.



Since of the three fluorene derivatives investigated only 2-nitrofluorene, which has a strongly electron attracting substituent on the nucleus was attacked, it appears that successful oxidation of fluorene compounds by persulfate depends upon the formation of an anion.

In 1965, Ogata et al.(18) in their investigation of peracetic oxidations of polynuclear aromatic compounds, found that fluorene on oxidation with peracetic acid gave a dihydroxy fluorenone. The positions of the two hydroxyl groups are still uncertain.

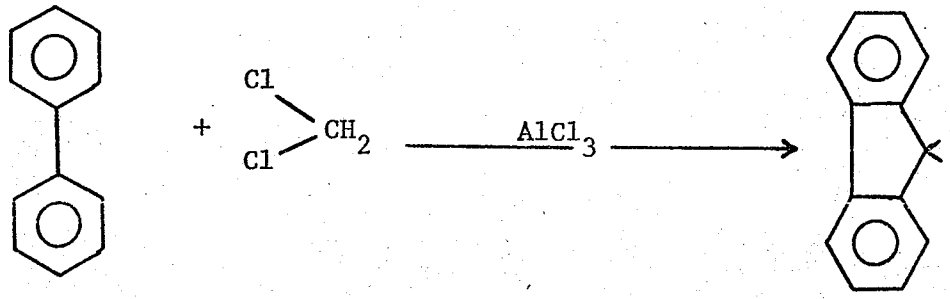
It is interesting to note that fluorenone itself can be further oxidized to fluorenone peroxide with a possible structure of $(C_6H_4)_2C{=}\overset{+}{O}{-}\bar{O}$. When acetic anhydride and sulfuric acid are present, the lactone of 2-hydroxydiphenyl-2'-carboxylic acid is also obtained (5b).

Synthesis of Fluorenones

1) Oxidation of Fluorenes

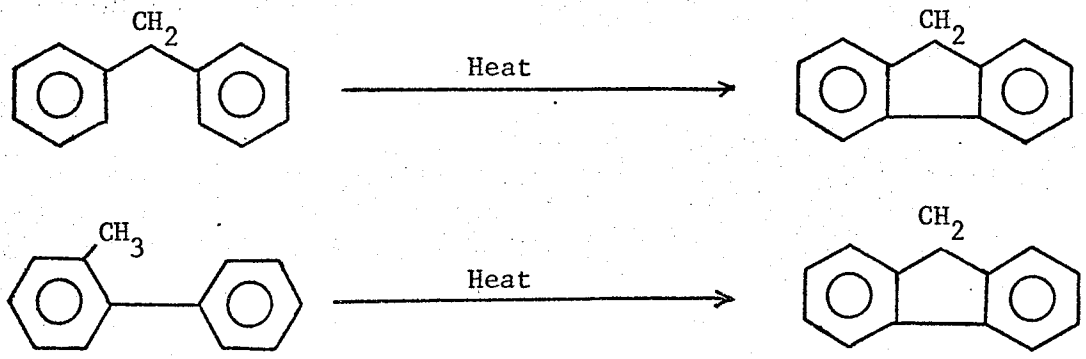
Fluorenones may be obtained by the oxidation of fluorenes by methods described in the previous section. Thus the methods of formation of fluorenes could be extended as a synthetic route to fluorenones, by including the oxidation step. Hence, the formation of fluorenes is considered first.

Adam (19) in 1886, showed that diphenyl and methylene dichloride when subjected to Friedel-Crafts conditions yielded fluorene. The reaction indicated the close relationship of diphenyl to fluorene. The



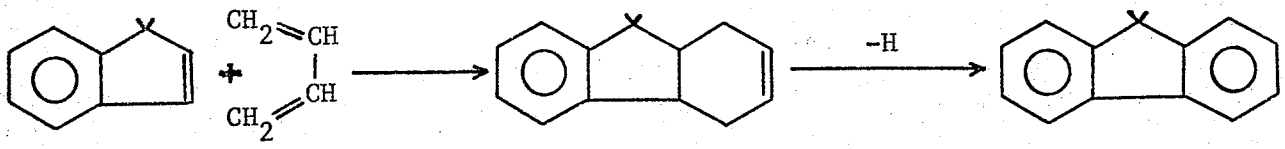
synthesis of new diphenyl derivatives has led to the successful preparation of fluorenone and fluorene derivatives with substitutents in the 3, 4 and 6 positions (20).

Fluorenes are also obtained by cyclodehydrogenation, usually by heating to a high temperature in the presence of a catalyst, of diphenyl methane and of ortho methyl diphenyls (20)(21)(22).



Utilizing this idea Longo (23) et al. were able to synthesize 1-methyl-fluorene and 1,6-dimethylfluorene from the corresponding diphenyls.

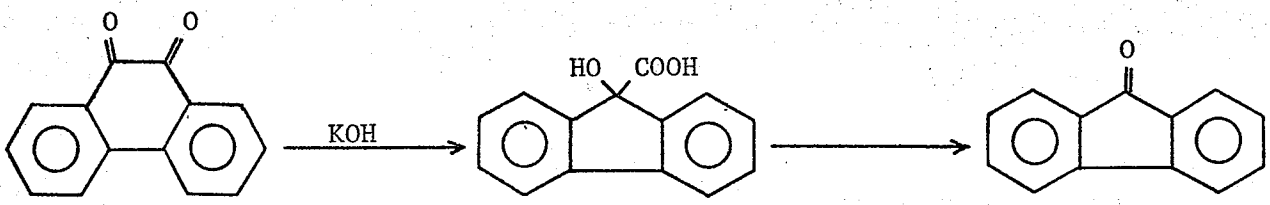
Another synthesis of fluorenes involves a Diels-Alder reaction with addition of 1,3-butadiene to indene to give a tetrahydrofluorene (24) which on dehydrogenation gives fluorene.



Harradence et al. (25) prepared a few fluorene derivatives by applying the Mannich reaction to ∝-indane derivatives.

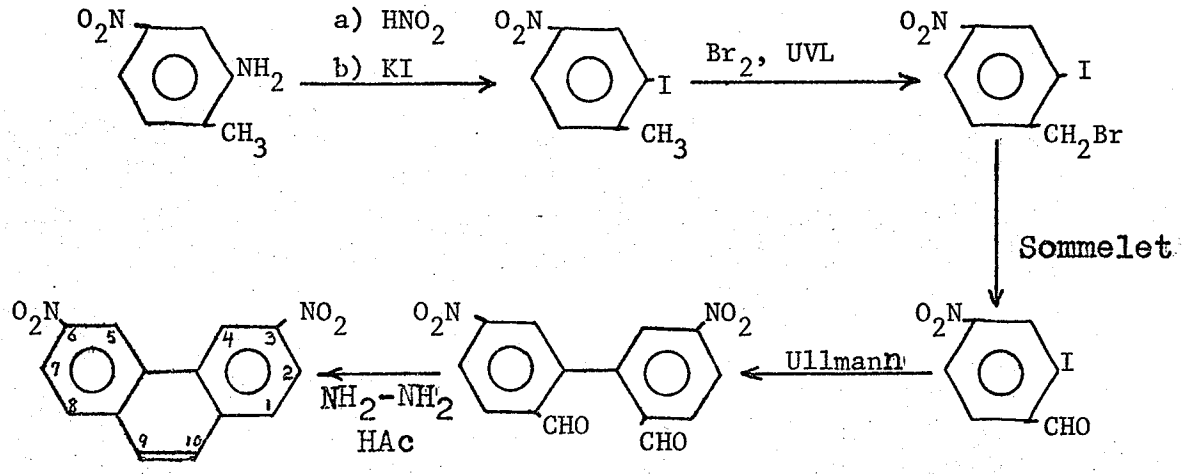
2) From Phenanthraquinones

One of the most reliable methods of preparing substituted fluorenones is by conversion of phenanthraquinone derivatives. Phenanthraquinone bearing structural similarity to open chain ∝-diketones undergoes benzilic acid rearrangement giving diphenylene glycollic acid. This being an ∝-hydroxy acid, oxidized readily to fluorenone.



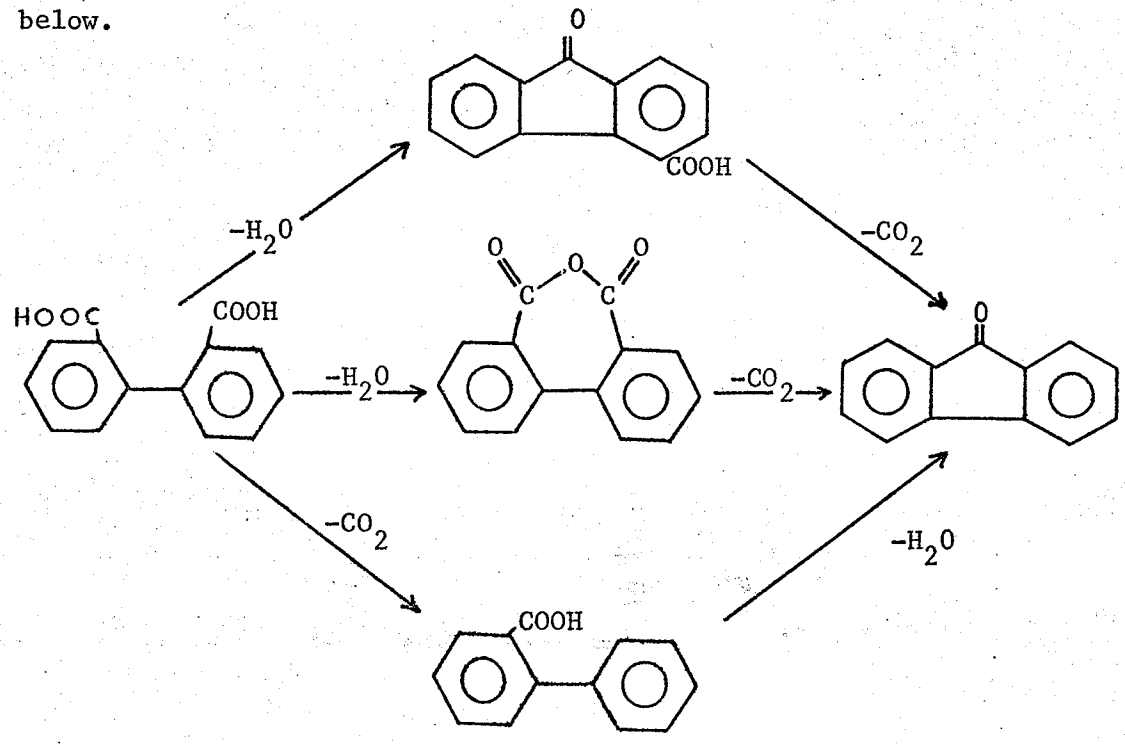
The passage from phenanthraquinone directly to fluorenone without the above intermediate has been accomplished using alkaline permanganate (26). This method of fluorenone synthesis was once limited by the fact that many of the desired phenanthraquinones were not known. In 1958, Bacon et al.(27)

discovered a new route to phenanthrenes from substituted diphenyl-2,2'-dialdehydes, by reductive cyclization using hydrazine. They extended the applicability of this reductive cyclization to the synthesis of 3,6-dinitrophenanthrene in the following manner starting from 2-amino-4-nitro-toluene.

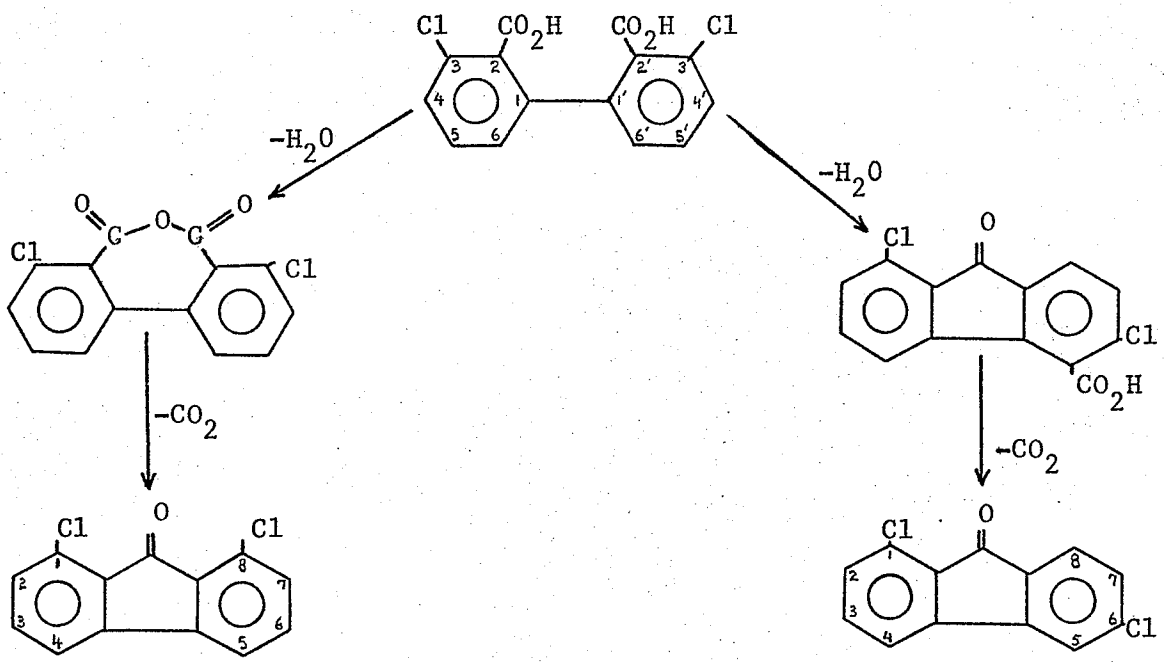


3) From Diphenic Acids

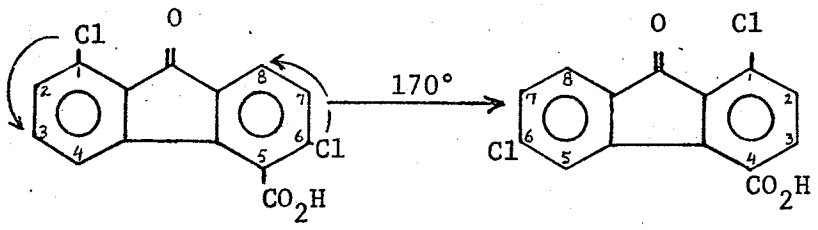
Huntress et al.(28) obtained fluorenone by heating diphenic acid at 360°. The transformation may occur in three ways. This is illustrated below.



Huntress et al.(29) succeeded in preparing a number of dichlorofluorenones from various dichlorodiphenic acids and their anhydrides by pyrolysis. For example 3,6-dichlorofluorenone was obtained from 5,5'-dichlorodiphenic anhydride, and 1,8-dichlorofluorenone was obtained from 3,3'-dichlorodiphenic anhydride. However, when 3,3'-dichlorodiphenic acid was heated, the product was 1,6-dichlorofluorenone-5-carboxylic acid, from which 1,6-dichlorofluorenone could be obtained by further heating. The last two syntheses are illustrated below.



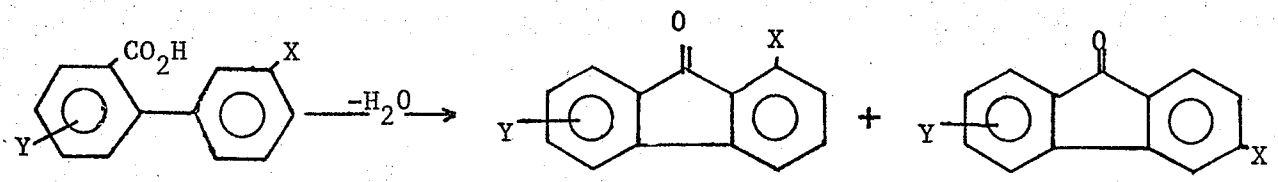
Huntress et al.(30) further investigated the action of concentrated sulfuric acid on 3,3'-dichlorodiphenic acid. They found that at 125°, 1,6-dichlorofluorenone-5-carboxylic acid formed whereas at 170°, 1,6-dichlorofluorenone-4-carboxylic acid formed. Furthermore, the latter acid can be obtained from the former at 170°. A migration of halogens has been proposed.



The decarboxylation of 1,6-dichlorofluorenone-4-carboxylic acid in sulfuric acid gave 3,6-dichlorofluorenone. Further experiments showed that both 1,8-dichlorofluorenone and 1,6-dichlorofluorenone rearranged to 3,6-dichlorofluorenone on heating in sulfuric acid at 185-200°. These results emphasize the danger in the use of high temperatures in the synthesis of fluorenones.

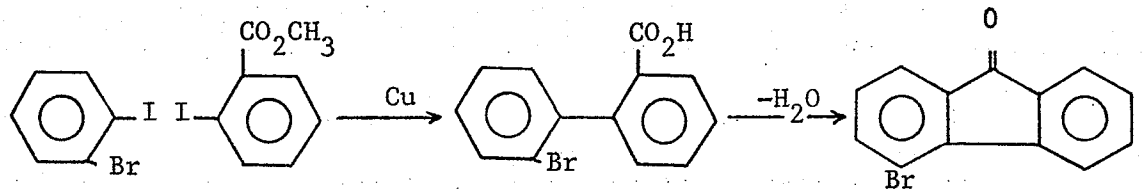
4) From Ortho Carboxy Diphenyl Derivatives

The dehydration of ortho carboxy diphenyl derivates constitutes another method of fluorenone synthesis. The ring closure is usually effected with concentrated sulfuric acid. A distinct disadvantage is encountered in this method if the substituent in the second ring is in the meta position as on ring closure two compounds are possible. However, no complications are involved if the substituents are in the first ring or in the ortho and

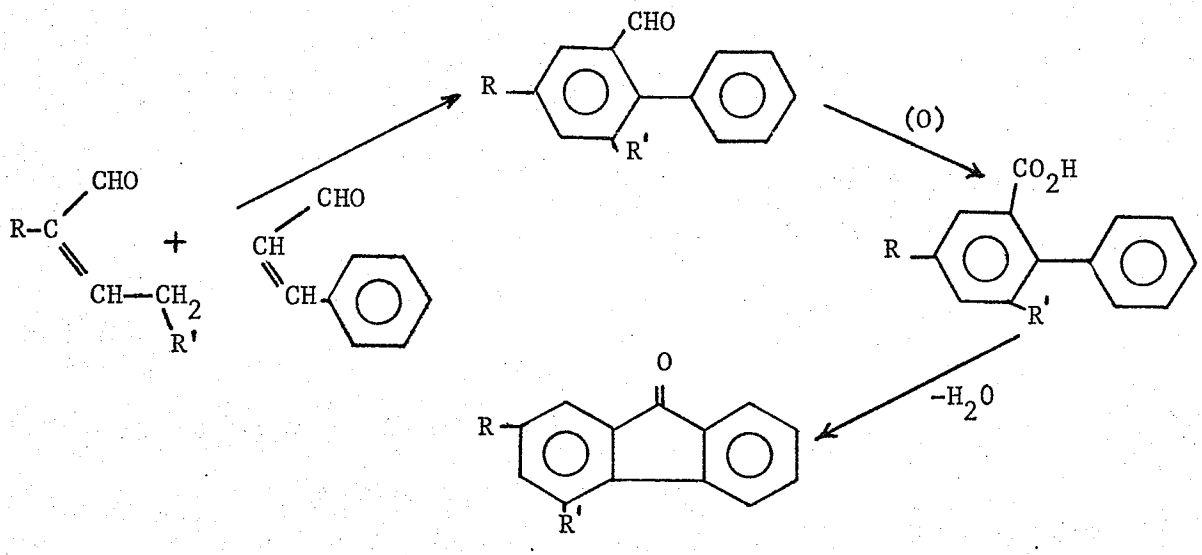


para positions of the second ring.

Miller and Bachman (31), synthesized 4-bromofluorenone from 2-bromo-2'-carboxydiphenyl in quantitative yields using concentrated sulfuric acid.

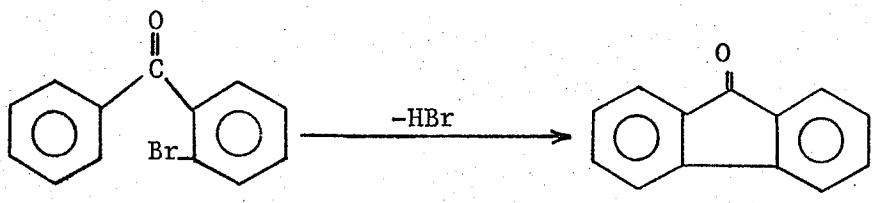


Recently Wiemann et al.(32)(33), showed that compounds of the general formula R'CH_2CH = C.R.CHO condensed with cinnamaldehyde at 400° in the presence of magnesium oxide to yield 2,4-substituted diphenyl aldehyde with traces of cyclohexadiene. The diphenyl aldehydes were oxidized to acids, which on cyclization gave fluorenones. They prepared several 2,4-disubstituted fluorenones with different R and R'.



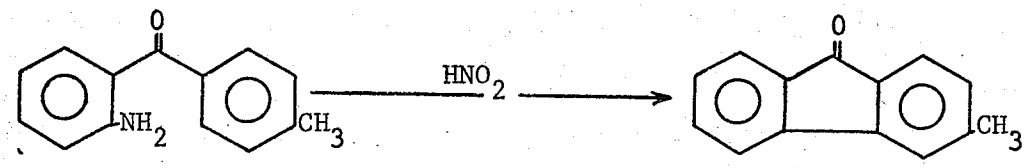
5) From 2-Substituted Benzophenones

Fluorenone may also be synthesized from ortho halogen benzophenone derivatives. As Miller et al.(31) have pointed out, this method



possesses disadvantages in that yields are small, the intermediates are difficult to prepare, and rearrangement is possible because of the high temperature required to effect elimination of halogen acid. A few years later, however, (34) fluorenones were obtained in fair yield by heating diaryl ketones with an ortho chlorine with metallic iron in a rotating bomb.

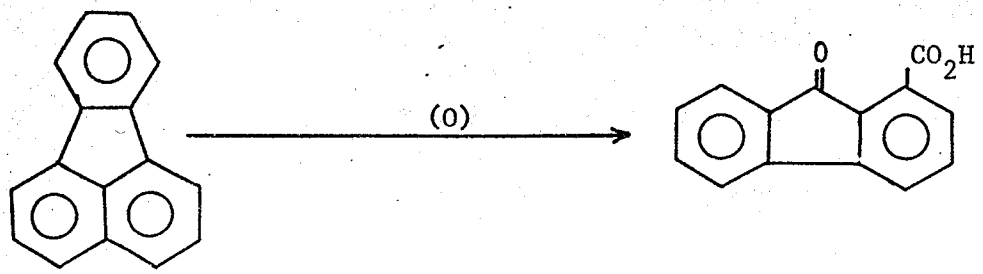
A similar method to the one above consists of the successive diazotization and internal coupling of derivatives of ortho amino benzophenone. Ullmann et al. (35) prepared 3-methylfluorenone by the Pschorr cyclization of 2-(p-methylbenzoyl) aniline. This method has found wide

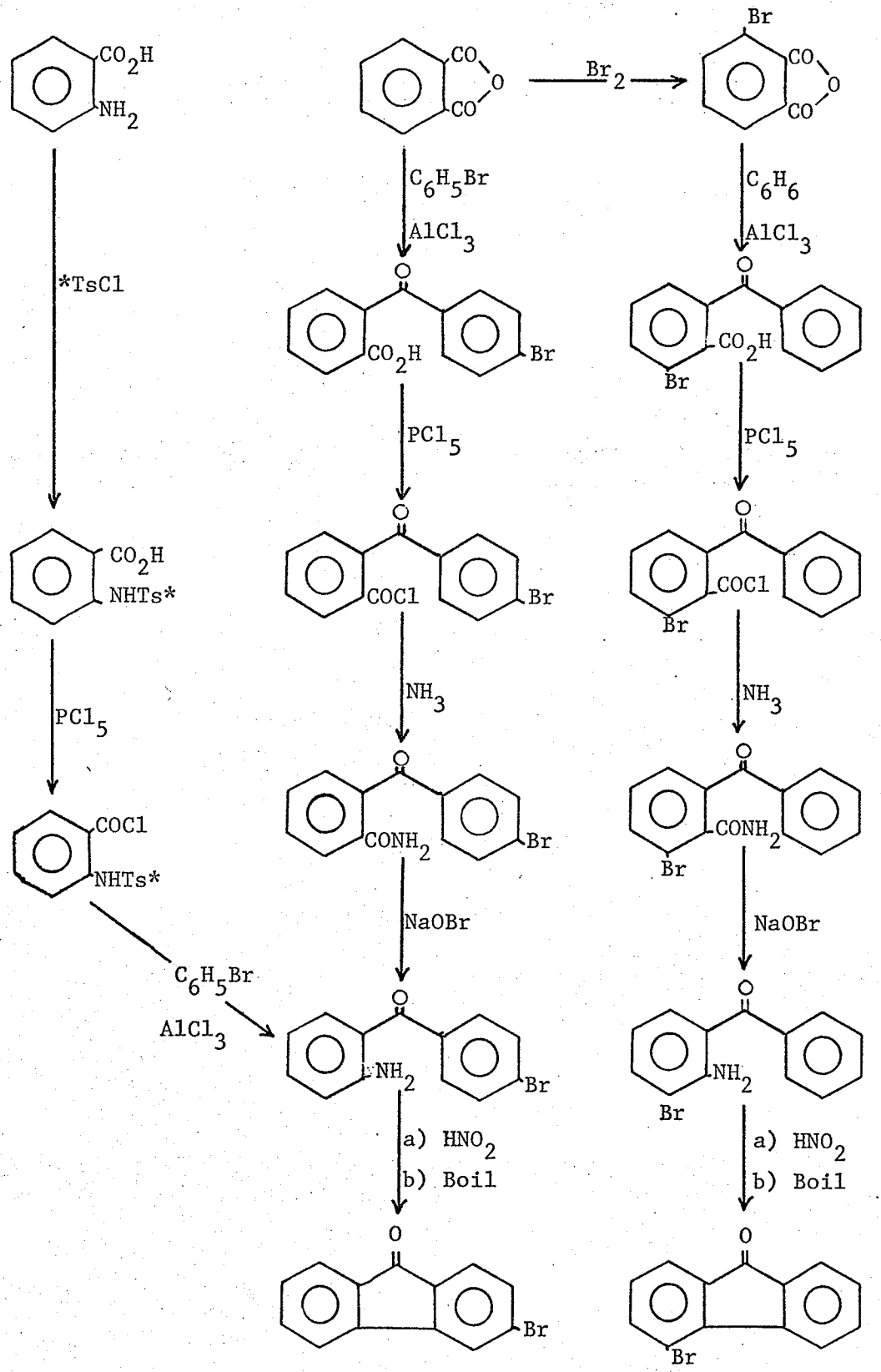


application for the synthesis of substituted fluorenones. For example Miller et al.(31) used the method for the synthesis of 3- and 4-bromofluorenones starting with commercially available chemicals. This work is shown on the following page.

6) From Fluoranthenes

The oxidation of fluoranthene with potassium chromate, chromic anhydride or potassium permanganate yields 1-fluorenonecarboxylic acid as one of the principal products (see Part A page 6). Oxidation of substituted



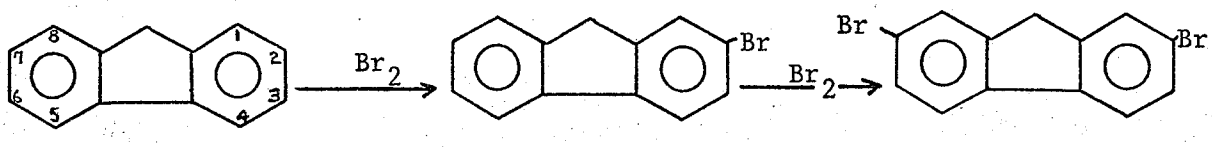


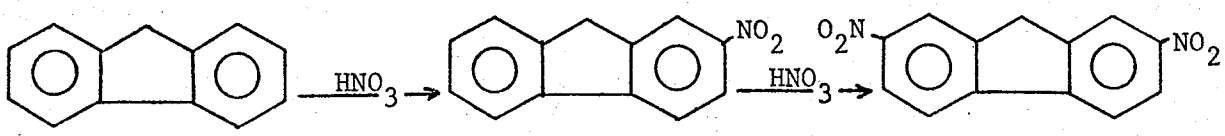
*Ts: p-$CH_3 . C_6H_4 . SO_2$-

fluoranthenes with dichromate or chromic acid solutions, invariably give substituted or unsubstituted fluorenone carboxylic acids depending on the ring broken (see Part A page 9). Decarboxylation gives the corresponding fluorenones. When the oxidation works, this is a convenient way to prepare substituted fluorenones from fluoranthenes. Quite often, however, the yields are quite low. For example, Campbell et al.(36) oxidized 3-nitro-9-bromofluoranthene and got 28% yield of 6-bromo-2-nitrofluorenone-1-carboxylic acid. After decarboxylation, however, only a 4.5% yield was achieved. Sometimes several products might result from the oxidation. For example, Campbell et al.(37) oxidized 3,8,9-tribromofluoranthene and isolated three products; 6,7-dibromofluorenone-1-carboxylic acid, 2,6,7-tribromofluorenone-1-carboxylic acid and 4,5-dibromophthalic acid (see Part A page 11). Occasionally the oxidation yields no fluorenone carboxylic acids. Lithown (38) was unable to oxidize 3,9-dinitrofluoranthene. This present author experienced the same difficulty with a 1,(?)-dinitrofluoranthene (see Part A page 59).

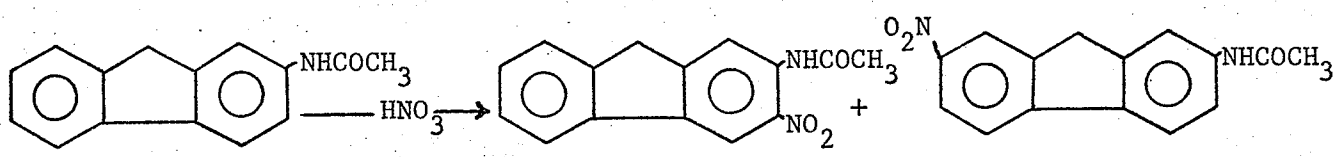
7) Direct Substitution

The most active site for electrophilic substitution in fluorene is position 2. In most reactions a further substituent enters at position 7(5C). The following examples illustrate this (5C)(39).

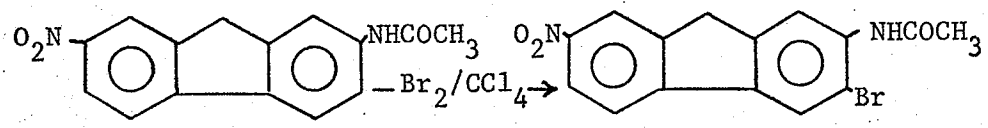


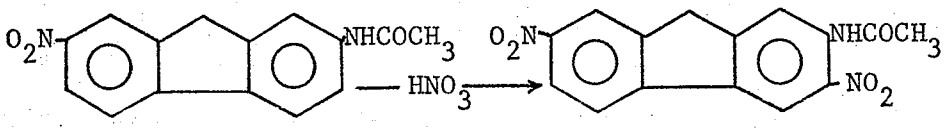


When a highly activating substituent is present, further substitution can occur in the same ring (5C)(36)(40). This is illustrated with nitration and bromination below.

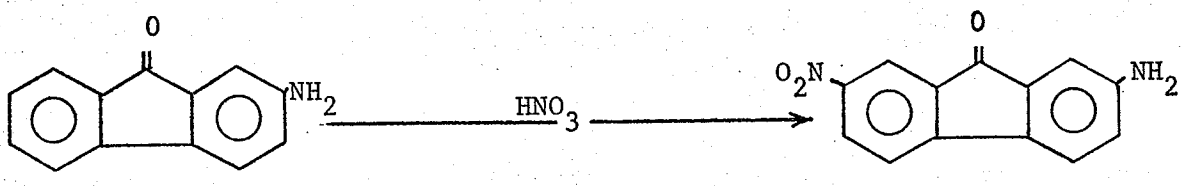


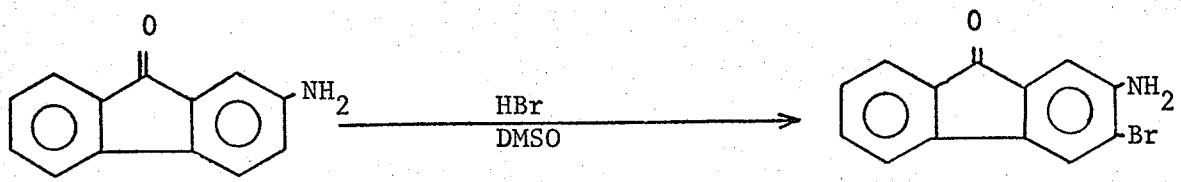
main isomer



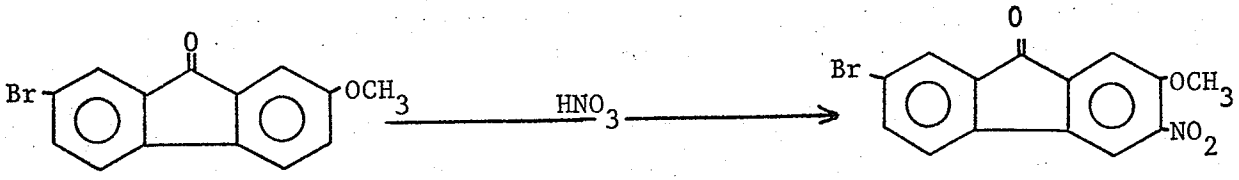


Nitration of 2-aminofluorenone gives the 7-nitro derivative almost exclusively (5C). However, bromination of 2-aminofluorenone gives mainly the 3-bromo derivative (41).





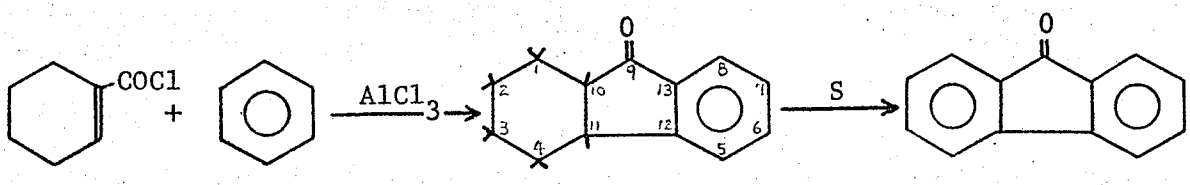
Apparently if the 7-position is blocked, nitration of an activating group will occur in the same ring (40).

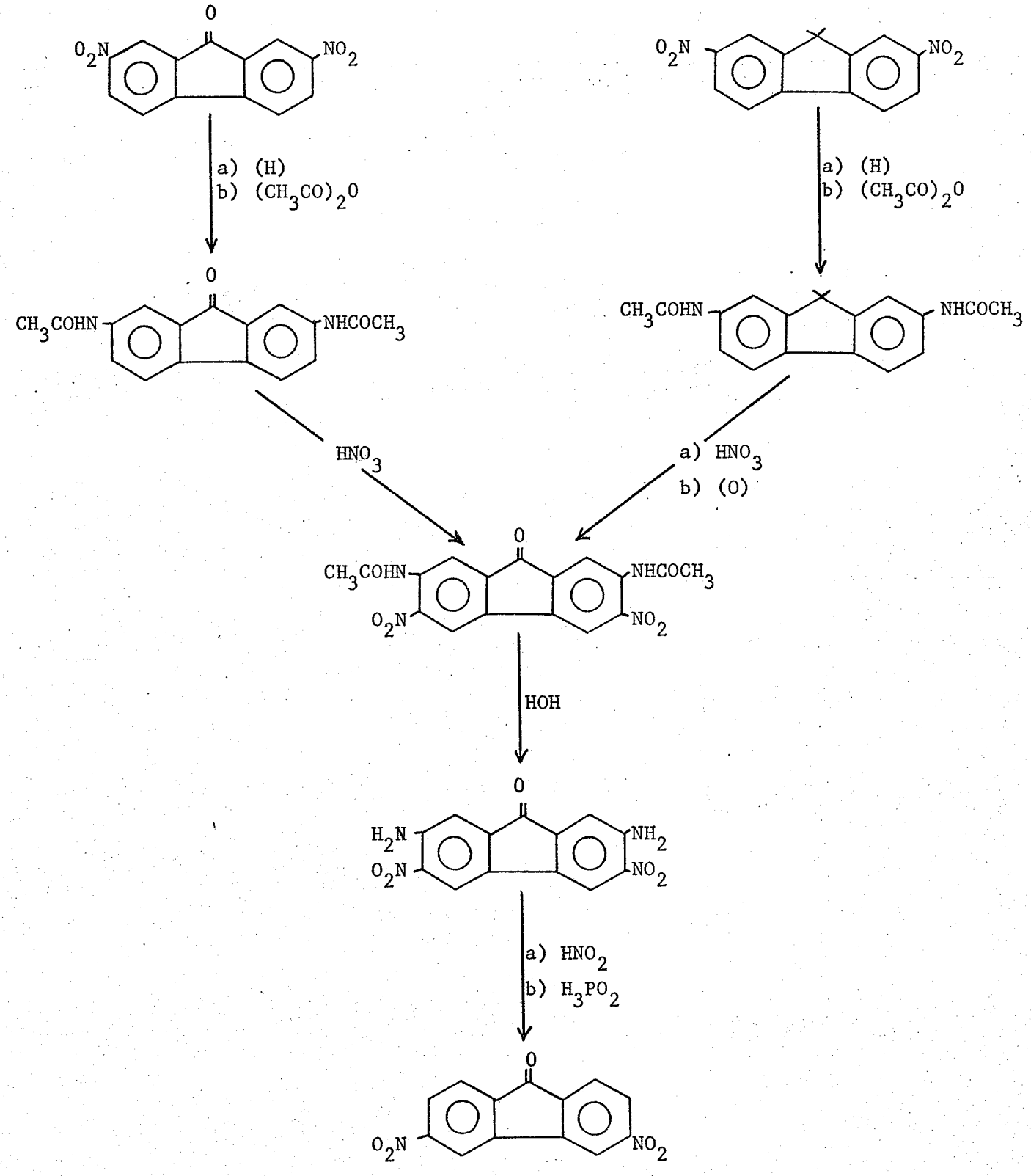


Barker et al.(42) synthesized some 3,6-disubstituted fluorenones starting from 2,7-diacetamidofluorene and 2,7-diacetamidofluorenone. Both these compounds behaved in a similar manner in many respects. The dinitration of 2,7-diacetamidofluorenone gave only one compound , namely 2,7-diacetamido-3, 6-dinitrofluorenone. This compound was converted to the dinitrofluorenone by hydrolysing the acetamido groups followed by deamination. This work is illustrated on the following page. The orientation of the nitro groups was confirmed by converting the above dinitrofluorenone to the dibromofluorenone which was shown to be identical with 3,6-dibromofluorenone obtained from 3,6-dibromophenanthraquinone.

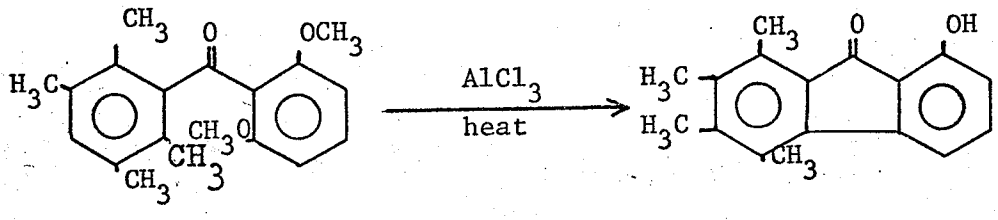
8) From Miscellaneous Compounds

Colonge et al.(43) reported that condensation of cyclohexene-1-carbonyl chloride with benzene, in the presence of aluminum chloride gave 1,2,3,4,10,11-hexahydrofluorenone. Dehydrogenation with sulfur gave fluorenone. They also prepared several methyl substituted fluorenones by condensing cyclohexene-1-carbonyl chloride with toluene, p-xylene and m-xylene.

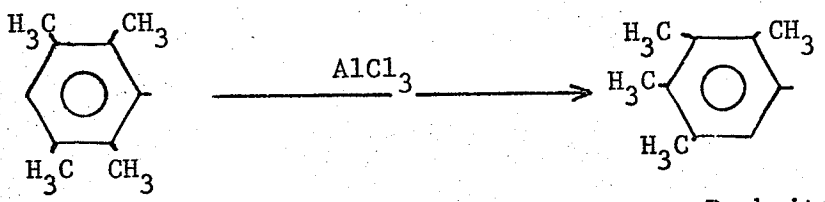



O
O_2N
NO_2
a) (H)
b) $(CH_3CO)_2O$
CH_3COHN
$NHCOCH_3$
HNO_3
a) HNO_3
b) (O)
HOH
H_2N
NH_2
a) HNO_2
b) H_3PO_2

In 1962, Fuson et al.(44) reported that when the dimethyl ether of 2-duroyl resorcinol was demethylated with hydrobromic acid or aluminum chloride, the phenol may undergo further reaction. With hydrobromic acid, the cleavage products were resorcinol and duroic acid. Production of phenol had been accomplished with aluminum chloride, but long heating also produced 1,2,3,4-tetramethyl-8-hydroxyfluorenone. The isomerization



of the duryl radical to the corresponding prehnityl group had been observed earlier (44).



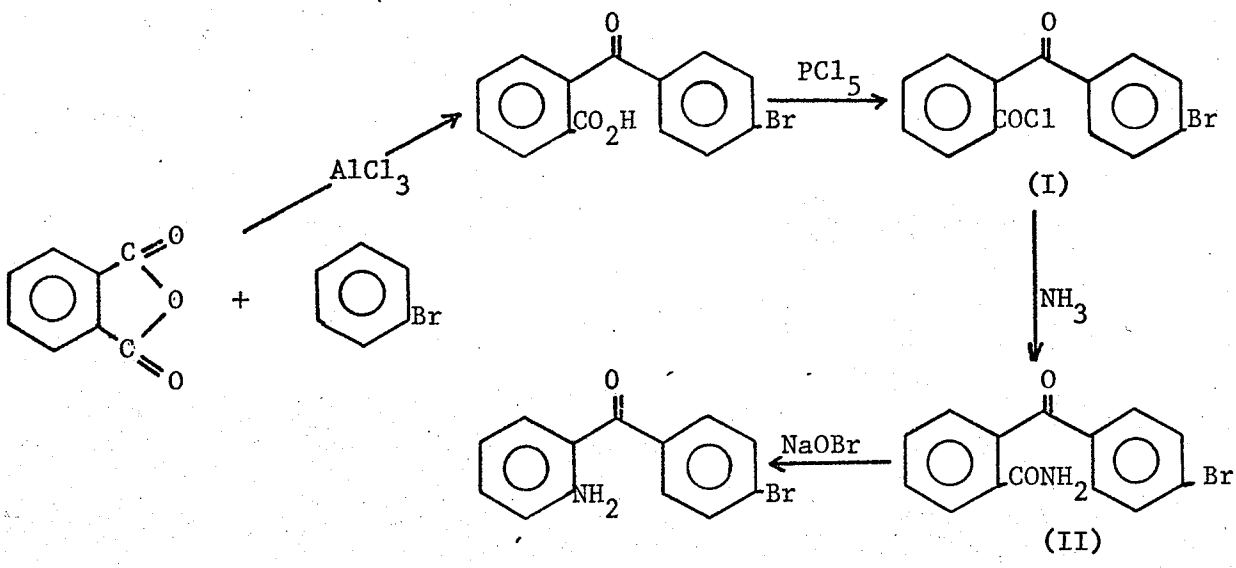
Duryl group Prehnityl group

The structure of 1,2,3,4-tetramethyl-8-hydroxyfluorenone was established by an independent synthesis of its methyl ether (44).

9) Method of Charlesworth and Mathiaparanam (1)

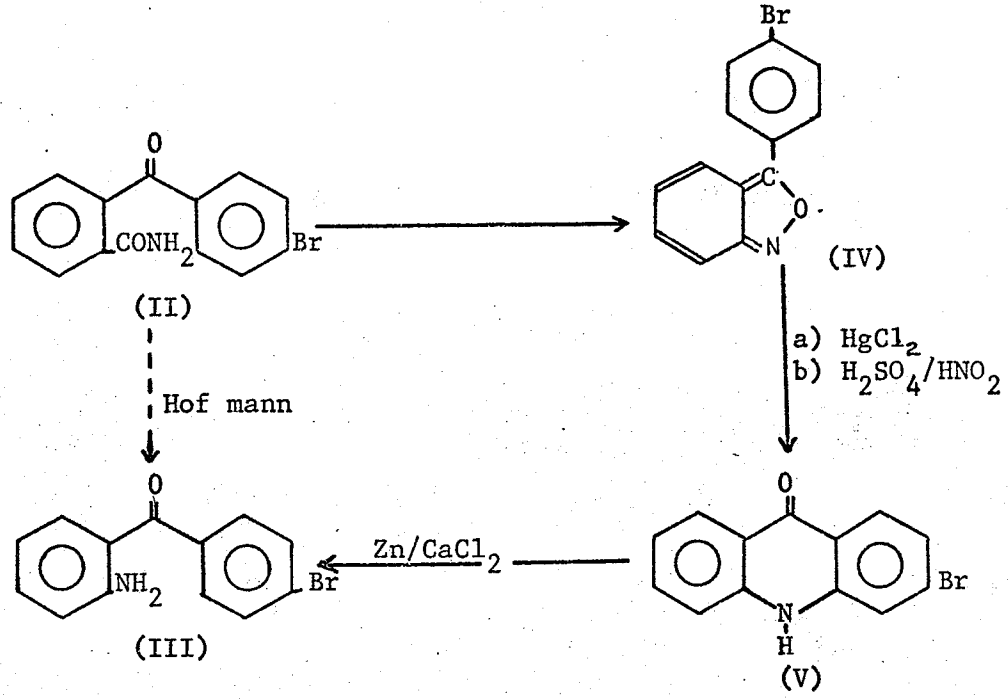
In 1935, Miller and Bachman (31) reported the synthesis of 3-bromofluorenone by a Pschorr cyclization of 2-(4-bromobenzoyl)-aniline. He reported that the above amine could be synthesized in two ways. In the first, he used phthalic anhydride and bromobenzene as the starting

materials. He then followed the sequence shown below.

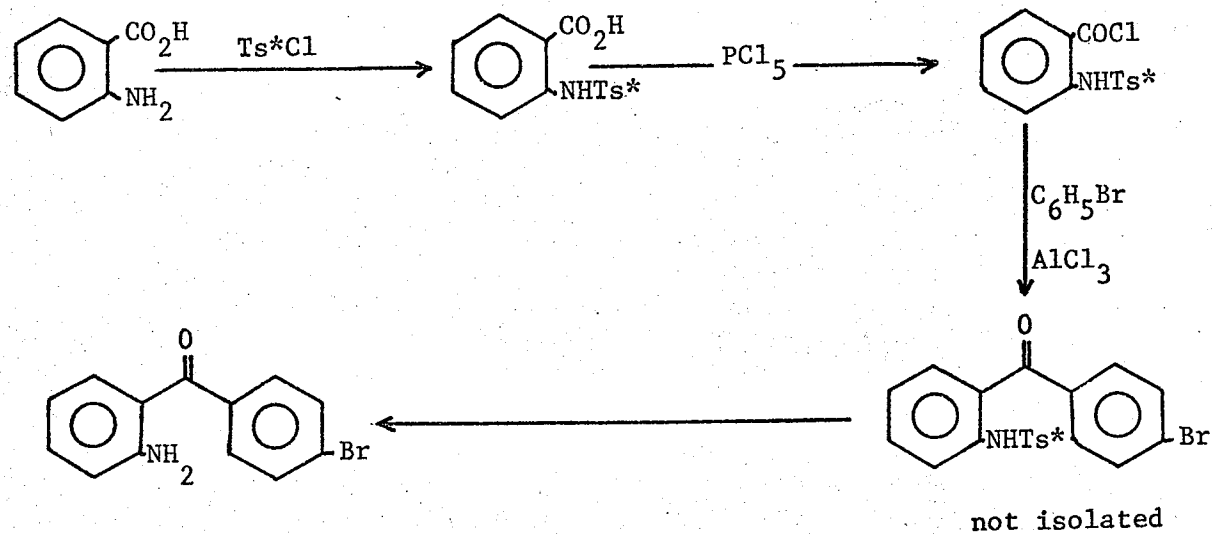


In 1965, Campbell et al.(45) repeated the above synthesis and found some inconsistencies. Miller and Bachman stated that the acid chloride I and amide II melted at 162-163° and 183° respectively. However, Campbell et al. found that the products with the same melting points were impure starting material and the ammonium salt. The acid chloride they found to be an oil and the amide melts at 213-214° (45). They noted that Miller and Bachman must have prepared some amide, since by the Hofmann reaction they obtained an amine III with the correct melting point. Campbell et al. also observed that Miller and Bachman used twice the theoretical quantity of bromine required for the Hofmann reaction. Under these circumstances Campbell et al. found that the product was not the amine III, but 3-(4-bromophenyl)-anthranil (IV) together with a small amount of a dibromo-anthranil probably 5-bromo-3(4-bromophenyl) anthranil. The structure of the anthranil was confirmed by the formation of a mercuric chloride compound, conversion to 3-bromoacridone (V) by the action of sulfuric acid and sodium nitrite (47) and reduction with zinc and calcium chloride

solution to the amine III.

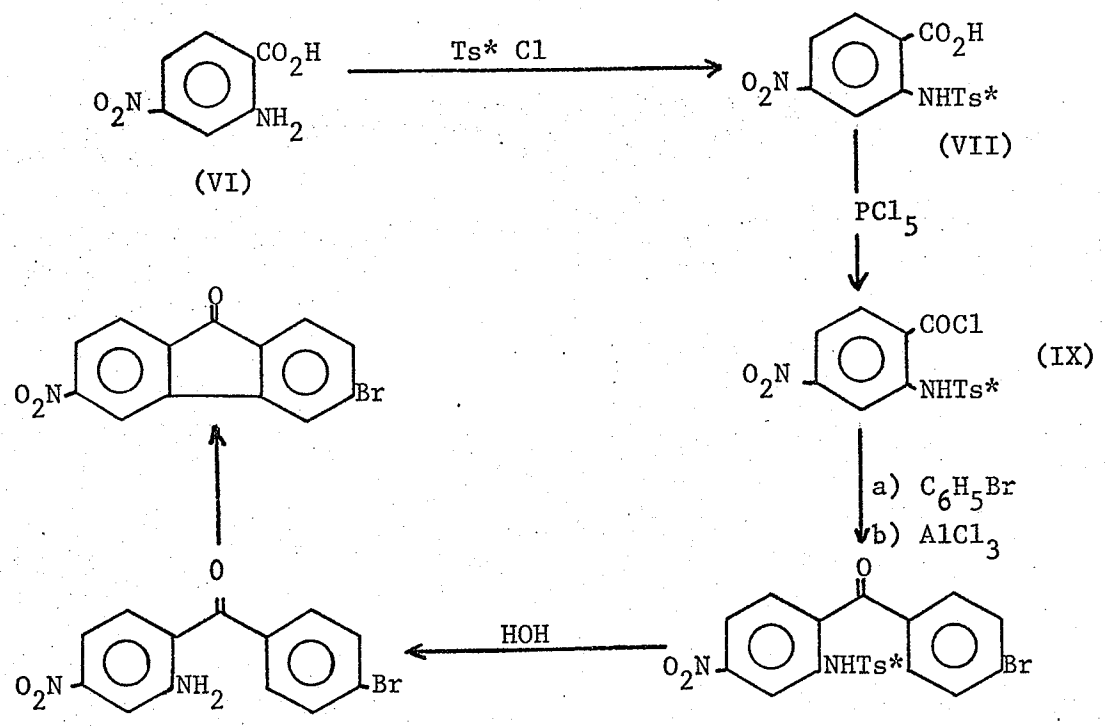


Miller and Bachman (31) also synthesized 2-(4-bromobenzoyl)-aniline(III) starting with anthranilic acid and following the scheme shown below.



Ts* - $CH_3.C_6H_4.SO_2$-

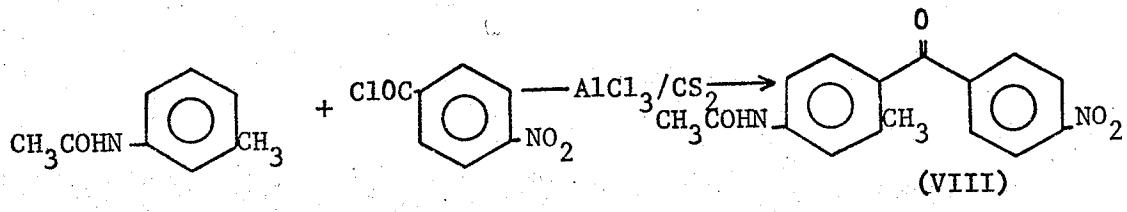
Mathiaparanam (48) attempted to synthesize 3-bromo-6-nitrofluorenone according to this latter scheme as shown by the sequence of reactions below.



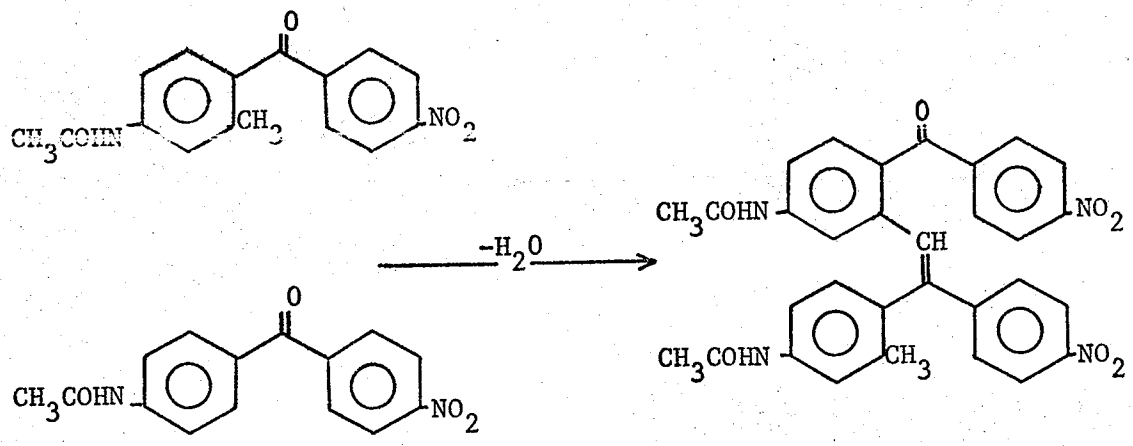
4-Nitroanthranilic acid (VI) was prepared according to Prysiasniuk (49), and was then tosylated to give VII. The tosyl derivative was then converted to the acid chloride IX which was subjected to Friedel-Crafts conditions in bromobenzene. Subsequent hydrolysis of the tosyl group failed and forced the author to seek another scheme of synthesis.

Ts* - $CH_3.C_6H_4.SO_2$-

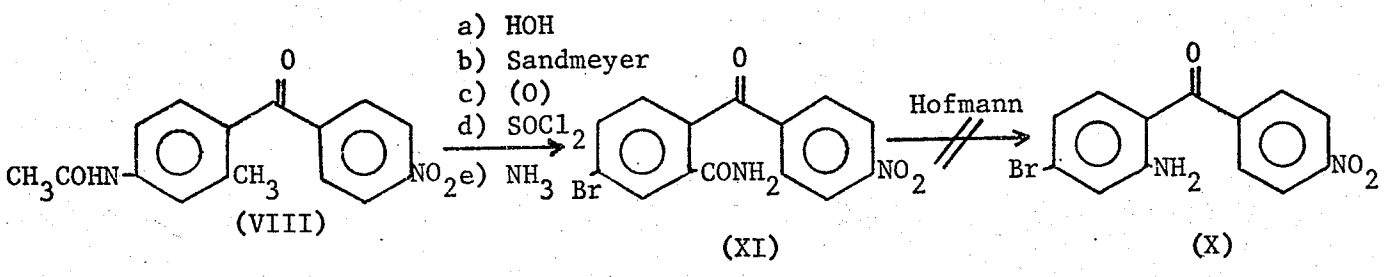
Mathiaparanam then decided to begin by synthesizing 4-acetamido-2-methyl-4'-nitrobenzophenone (VIII) from m-acetotoluidide and p-nitrobenzoyl chloride according to Mehta et al.(50). Excess aluminum chloride was used to form a complex with the carbonyl group of the benzophenone and



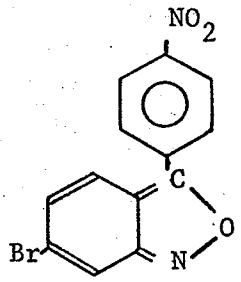
thus prevent any intermolecular condensation to form a "dypnone" type of product as shown below. The acetamido ketone VIII was converted to



5-bromo-2-(4-nitrobenzoyl)-benzamide (XI) by the usual reactions. The Hof mann reaction on this amide failed to give the expected amine X. Instead a yellow acidic compound of m.p. 232-233° was obtained.

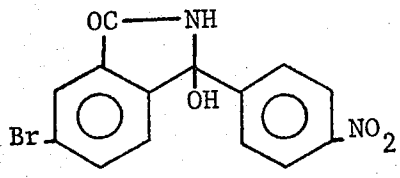


It is unlikely that this acidic compound would be the anthranil XII shown below. Bhatt (51) in 1964, suggested a pseudo amide structure for 2-



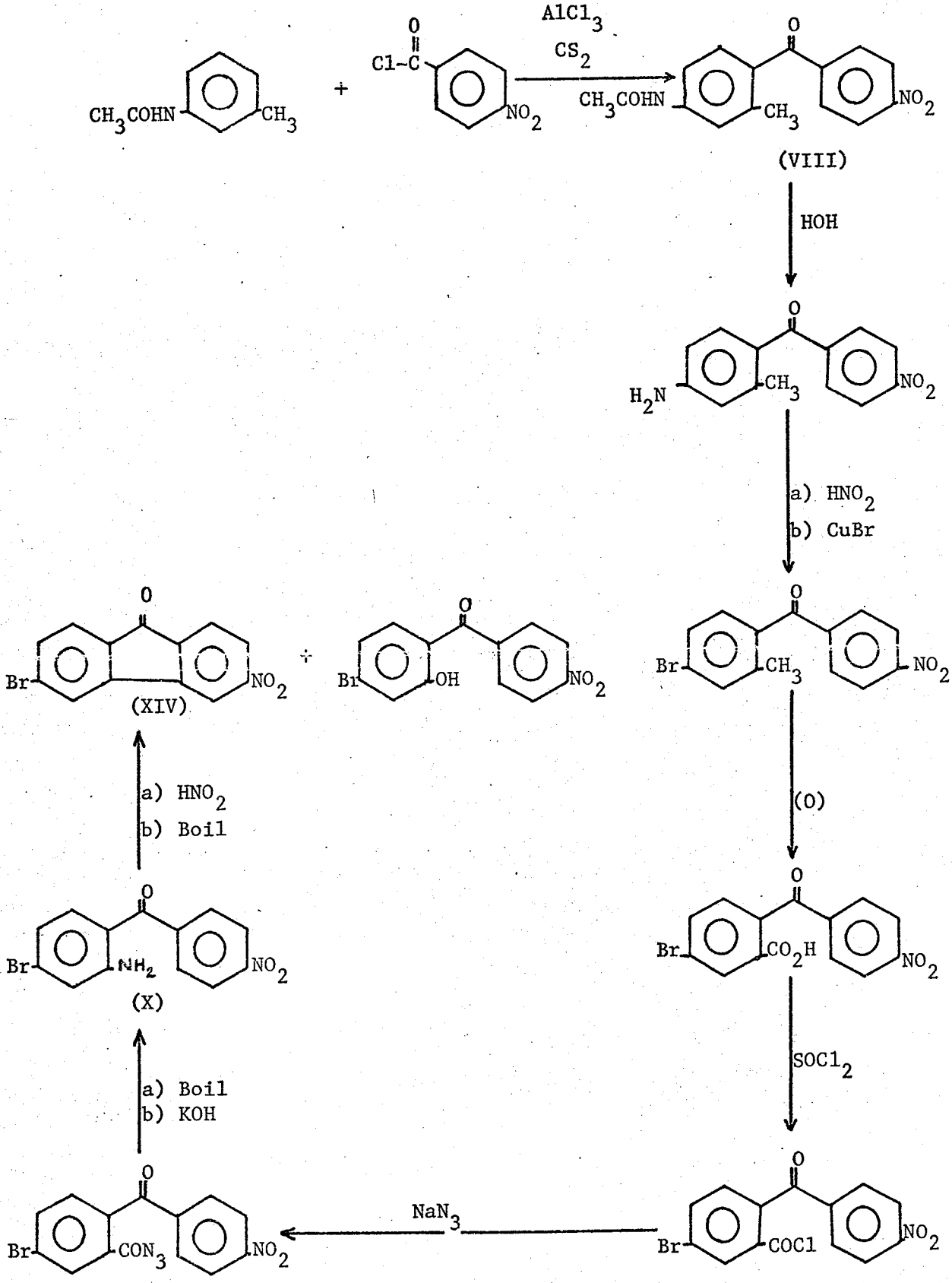
(XII)

(p-bromobenzoyl)-benzamide based on infra red spectral studies. On this basis, Charlesworth and Mathiaparanam (1) considered XIII as the corresponding pseudo amide structure of their acidic compound and suggested this as a possible reason



(XIII)

for failure of the Hofmann reaction. They therefore decided to prepare the amine X by the Curtius method. Their complete reaction scheme appears on the following page. Cyclization of 5-bromo-2-(p-nitrobenzoyl)-aniline by the Pschorr method not only gave the desired product 3-bromo-6-nitrofluorenone (XIV) but also 2-hydroxy-4-bromo-4'-nitrobenzophenone (XV).

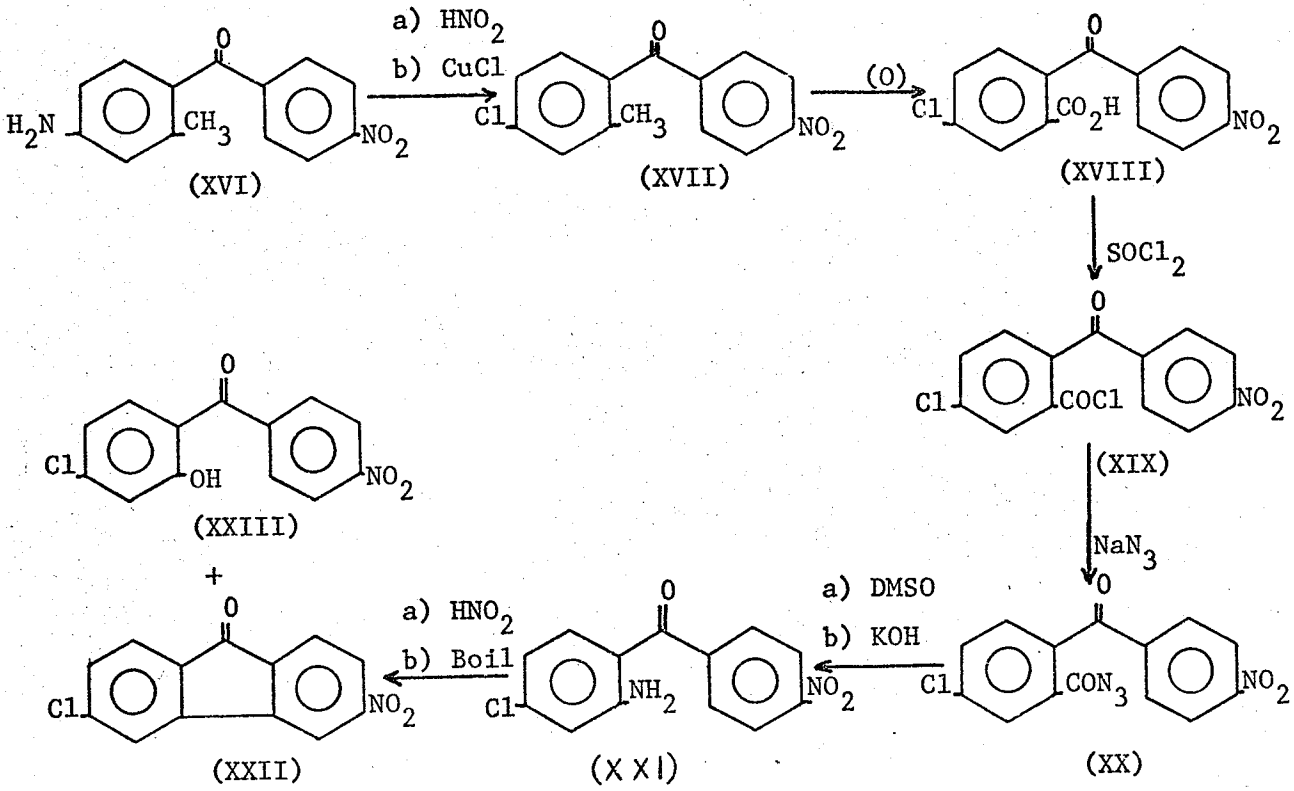

AlCl3
CS2
(VIII)
HOH
a) HNO2
b) CuBr
(O)
SOCl2
NaN3
a) Boil
b) KOH
a) HNO2
b) Boil
(XIV)

DISCUSSION OF RESULTS

As stated in the introduction it was decided to employ this method (see previous page) for the synthesis of 3-chloro-, 3-fluoro- and 3-iodofluorenone.

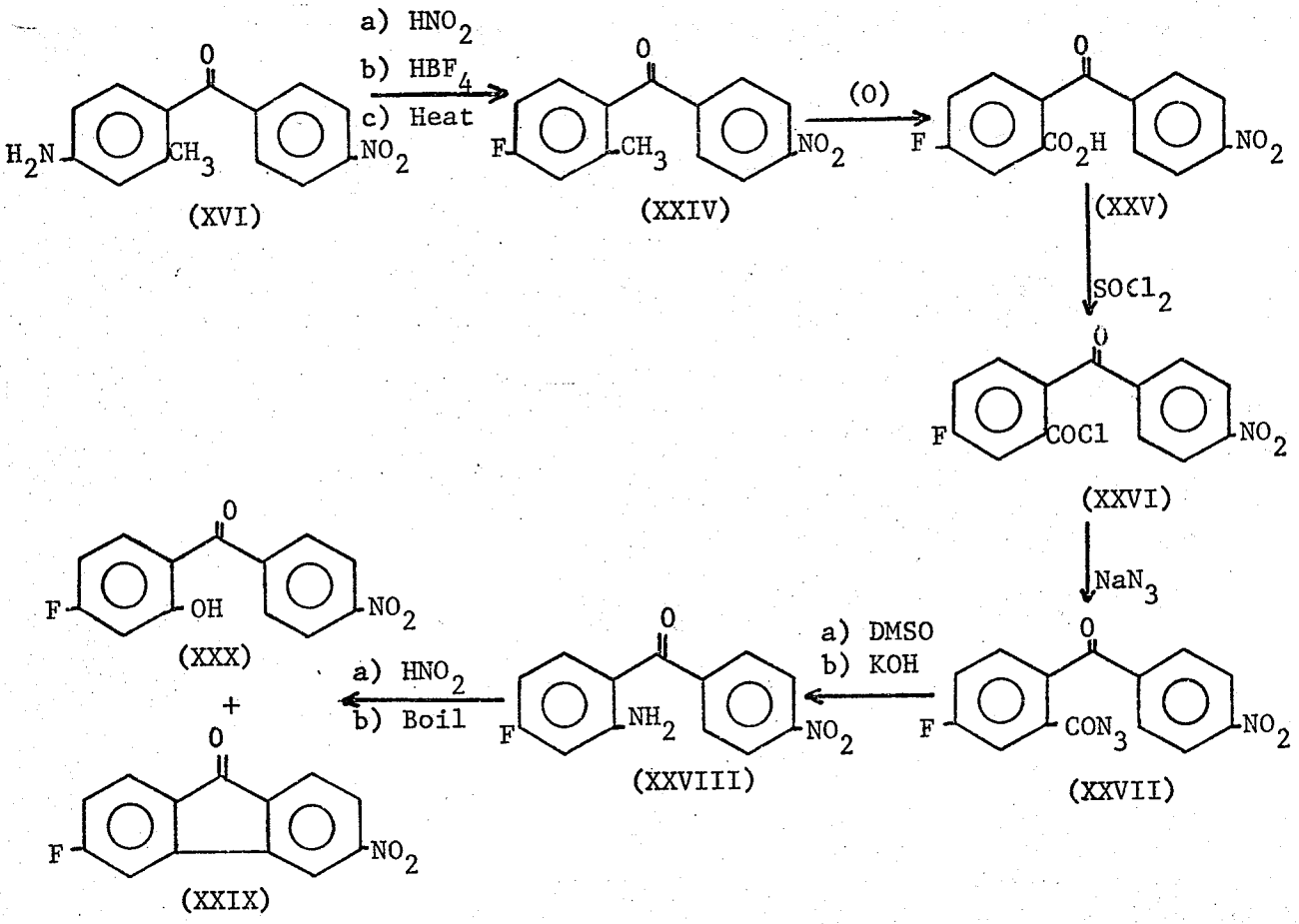
Synthesis of 3-Chloro-6-Nitrofluorenone (XXII)

The starting compound for this synthesis was essentially 4-amino-2-methyl-4'-nitrobenzophenone (XVI). The synthesis is almost identical to that of Charlesworth et al.(1). Cuprous chloride instead of cuprous bromide was used in the Sandmeyer reaction. The Curtius rearrangement did not work well with benzene, toluene or dimethylformamide as solvent. However, it worked quite well in dimethylsulfoxide. Seven new compounds were thus synthesized with the last two being 3-chloro-6-nitrofluorenone (XXII) and 4-chloro-2-hydroxy-4'-nitrobenzophenone (XXIII). The reaction scheme is shown below.



Synthesis of 3-Fluoro-6-Nitrofluorenone (XXIX)

The starting compound for this synthesis was 4-amino-2-methyl-4'-nitrobenzophenone (XVI). This was subjected to a Schiemann reaction with nitrous acid and fluoboric acid. After that the sequence of reactions follows the pattern of Charlesworth et al.(1) except that dimethyl sulfoxide instead of benzene was used as the solvent for the Curtius rearrangement. The final products were 3-fluoro-6-nitrofluorenone (XXIX) and 4-fluoro-2-hydroxy-4'-nitrobenzophenone (XXX). Seven new compounds were synthesized. The reaction scheme is shown below.

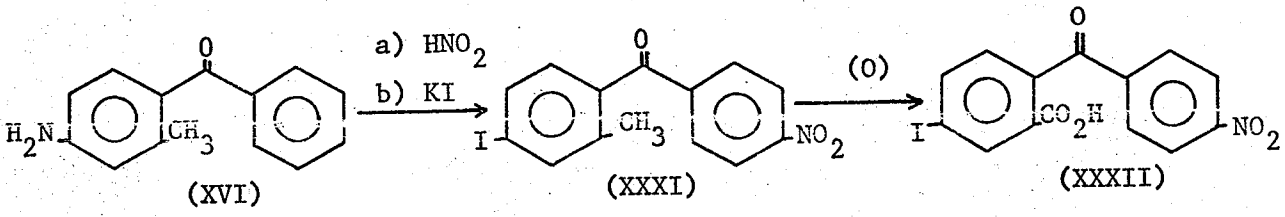


Attempted Synthesis of 3-Iodo-6-Nitrofluorenone

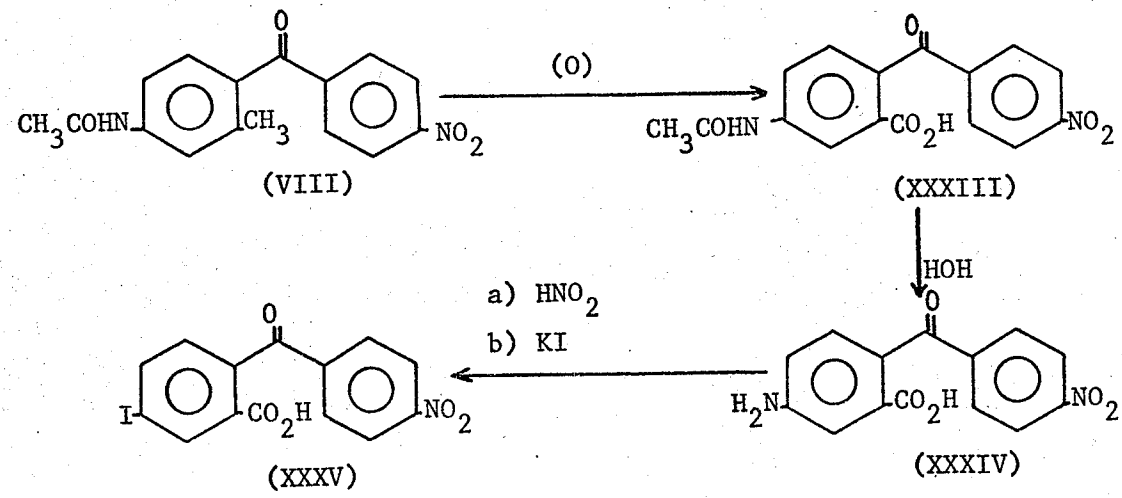
The initial plan was to make 4-iodo-2-methyl-4'-nitrobenzophenone and follow the reaction sequence of Charlesworth et al.(1). 4-Amino-2-methyl-4'-nitrobenzophenone (XVI) was diazotised and treated with potassium

iodide to form 4-iodo-2-methyl-4'-nitrobenzophenone (XXXI). Oxidation of XXXI to the acid XXXII with a variety of oxidizing agents caused a loss of iodine in the molecule. With subsequent steps to 3-iodo-6-nitrofluorenone, even more iodine was lost.

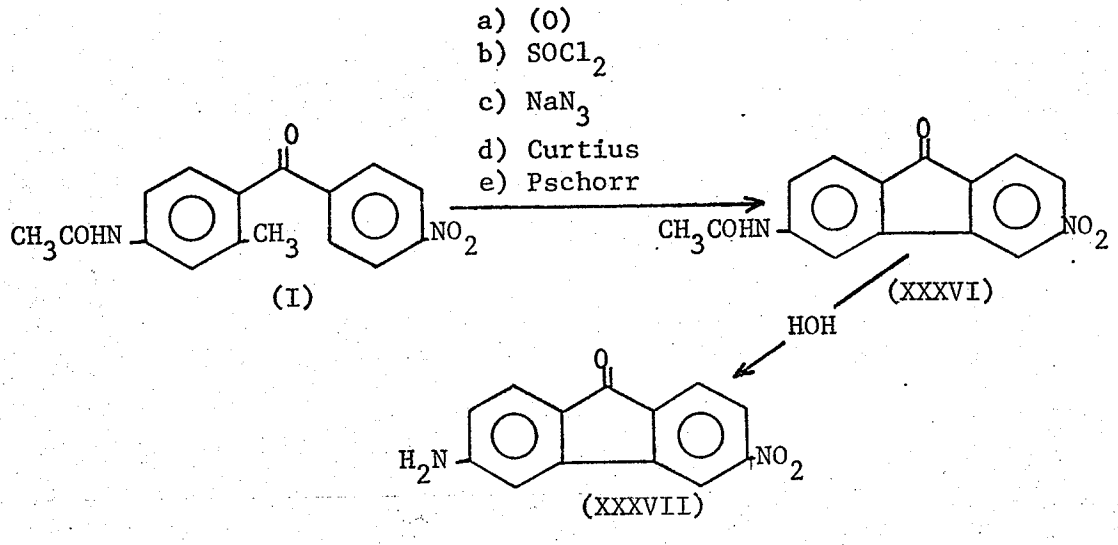
Hahn et al.(58) in an attempt to synthesize 2-(4-iodobenzoyl)-benzoic acid by a Friedel-Crafts reaction with phthalic anhydride and iodobenzene found that large quantities of iodine were lost in the preparation. They separated the iodo-substituted acid from the unsubstituted acid by preparation of the iodochloride derivative using chlorine gas in chloroform. This procedure might separate the iodonitro acid (XXXII) from the acid from which iodine was lost.



An attempt was then made to substitute iodine after the oxidation of the methyl group as shown below. However, the introduction of iodine by diazotisation and potassium iodide



on the amino acid XXXIV to give 5-iodo-2-(p-nitrobenzoyl) benzoic acid (XXXV) was unsuccessful. An attempt was then made at synthesizing 3-acetamido-6-nitrofluorenone (XXXVI) with the object of hydrolysing it to 3-amino-6-nitrofluorenone (XXXVII). If this could be achieved then any 3-halo-6-nitrofluorenone could be made by diazotization of the amine XXXVI followed by the appropriate reaction. Analysis of the compound XXXVI

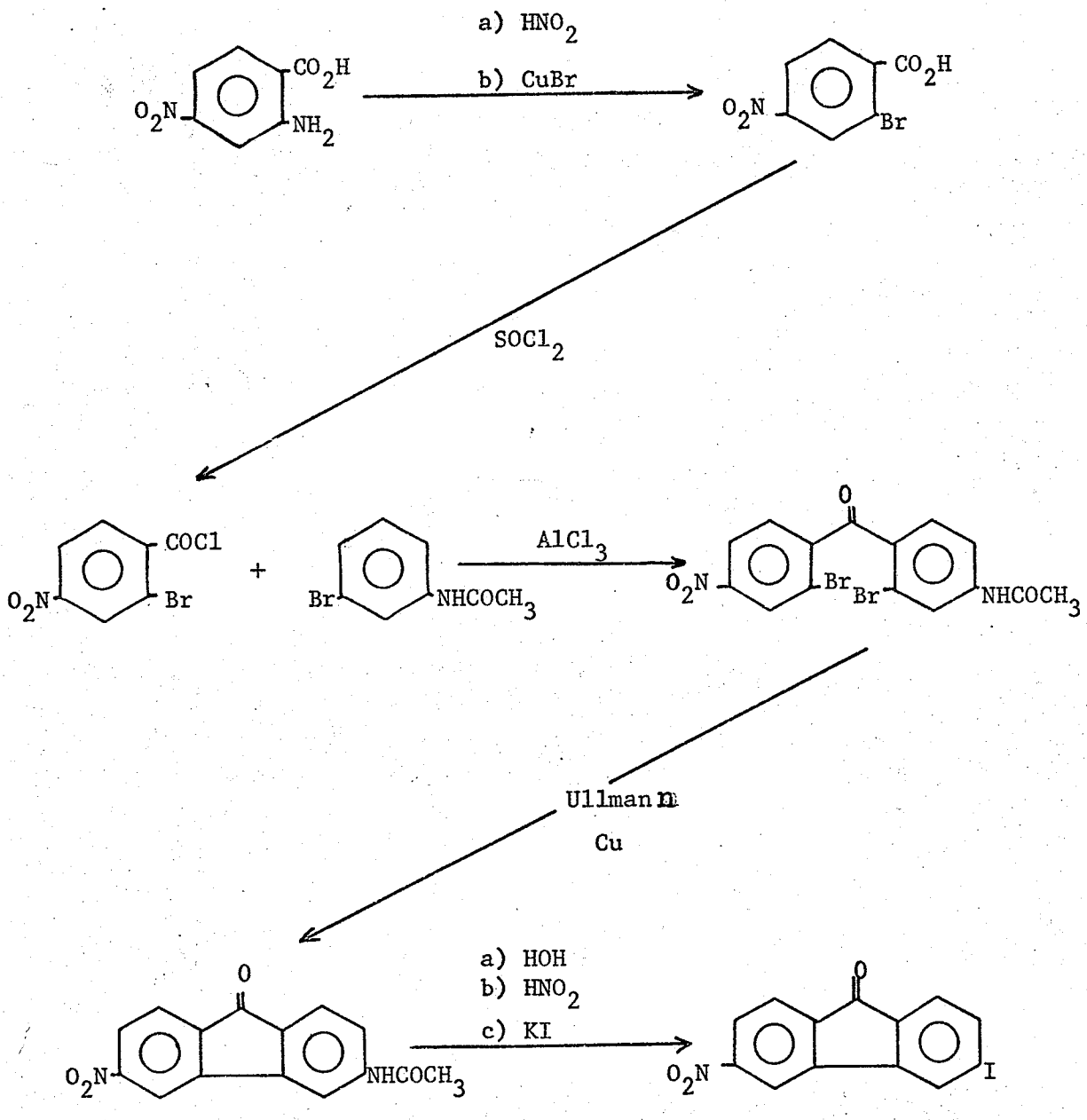


however, showed loss of nitrogen somewhere along the sequence. At this point the reactions in Part A of this thesis were much more interesting and it was decided to leave the synthesis of 3-iodo-6-nitrofluorenone to future work.

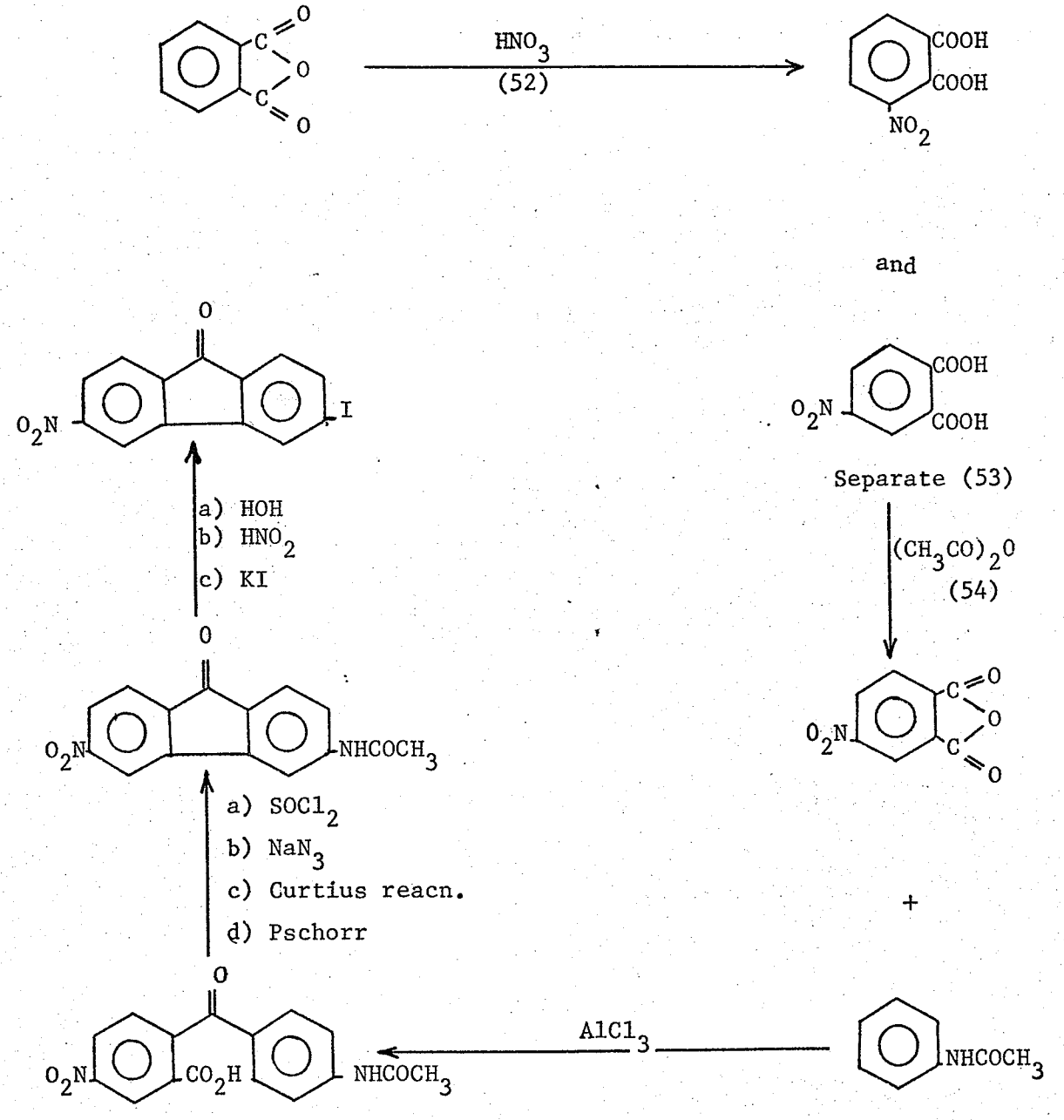
Proposed Synthesis of 3-Iodo-6-Nitrofluorenone

The following schemes might prove fruitful in the synthesis of the desired compound. 4-Nitroanthranilic acid is available commercially.

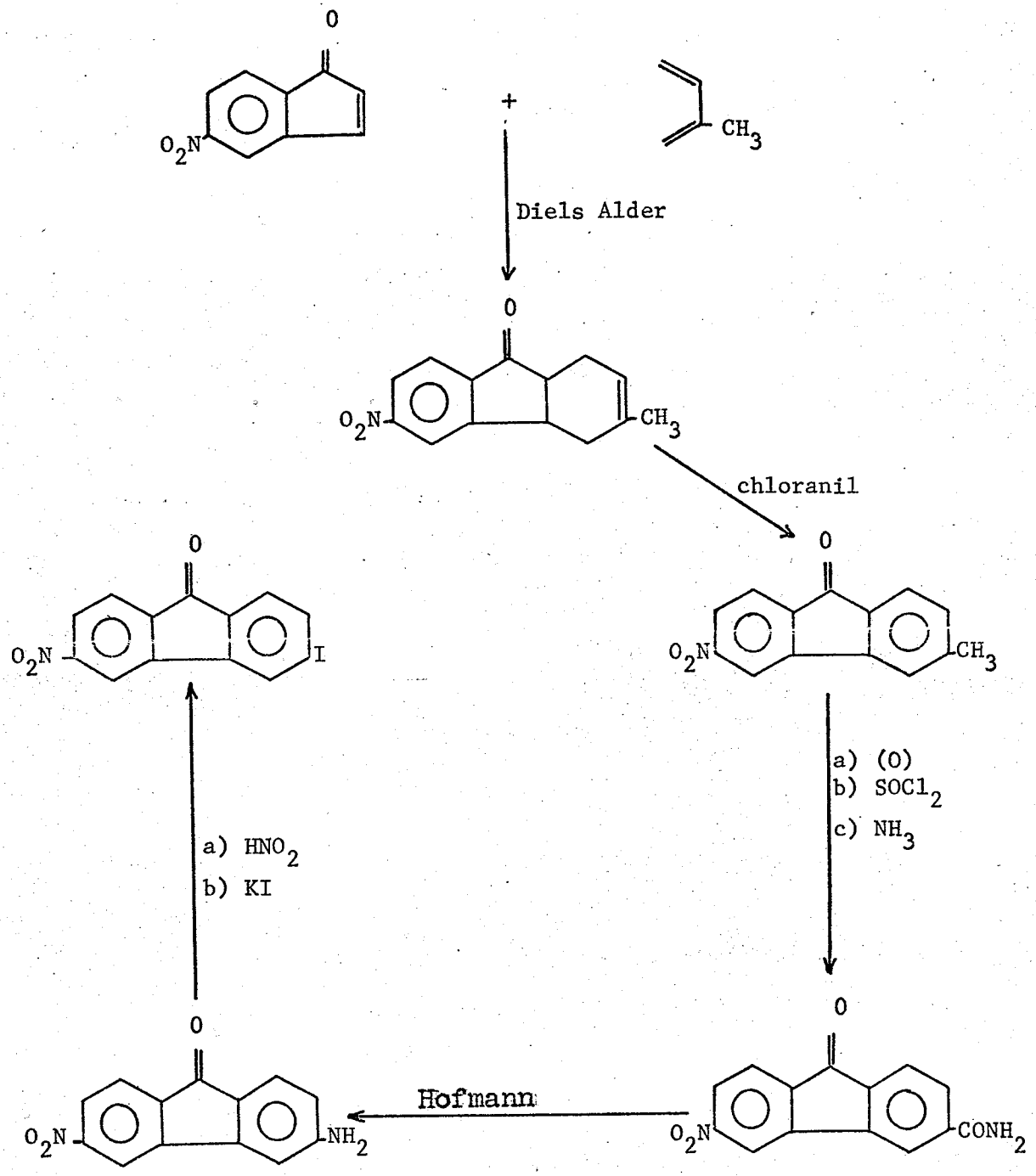
1)



2)


HNO3
(52)
COOH
COOH
NO2
and
O2N
COOH
COOH
Separate (53)
(CH3CO)2O
(54)
a) HOH
b) HNO2
c) KI
I
NHCOCH3
a) SOCl2
b) NaN3
c) Curtius reacn.
d) Pschorr
CO2H
AlCl3

3)



EXPERIMENTAL

1) Synthesis of 4-Amino-2-Methyl-4'-Nitrobenzophenone (XIII)

The method used was similar to that of Mehta et al. (50) and Charlesworth et al.(1). In a two liter three necked flask, equipped with a Herschberg stirrer, a reflux condenser with a calcium chloride tube and a dropping funnel were placed anhydrous aluminum chloride (75 g.) and dry carbon disulfide (50 ml.). The suspension was cooled in ice and a solution of p-nitrobenzoyl chloride (25 g.) in carbon disulfide (100 ml.) was added slowly with stirring. After the addition was complete, stirring was continued for another 15 minutes. At the end of this time, a solution of m-acetotoluidide (25 g.) in carbon disulfide (100 ml.) was carefully added with cooling. The mixture was allowed to stand for an hour and then refluxed on a water bath for 4 hours. It was cooled in ice, then ice cold concentrated hydrochloric acid (200 ml.) was added carefully to liberate the ketone. Most of the carbon disulfide was distilled off using a water bath, and the residual solution was filtered to isolate the ketone. The ketone was recrystallized from ethanol and water. The acetamido ketone was then hydrolysed with concentrated hydrochloric acid (100 ml.) on a water bath for 6 hours. The solution was cooled and made alkaline by the addition of sodium hydroxide (10%). The amino ketone was filtered and recrystallized from benzene. The 4-amino-2-methyl-4'-nitrobenzophenone was obtained as red elongated prisms (20.3 g.) of m.p. 164-166°. This compound was identical to that synthesized by Charlesworth et al. (1). The infra red spectrum is shown on page 181.

Analysis:

Found: N, 10.6

Calculated for $C_{14}H_{12}O_3N_2$: N, 10.9

2) Synthesis of 4-Chloro-2-Methyl-4'-Nitrobenzophenone (XIV)

4-Amino-2-methyl-4'-nitrobenzophene (XIII) (16 g.) was dissolved in hot concentrated hydrochloric acid (80 ml.) and the solution was cooled to 0° by adding ice to it. A solution of sodium nitrite (6 g.) in water (30 ml.) was cooled to 0° and added slowly to the white suspension of the amine hydrochloride with vigorous stirring. The color of the suspension turned from white to brownish-yellow as the diazonium salt was formed. Once the addition was complete, the diazonium salt solution was allowed to stand 15 minutes at 0° and was added to a boiling solution of cuprous chloride (92 g.) in concentrated hydrochloric acid (200 ml.) at such a rate that the boiling was not stopped. The solution was boiled for 30 minutes whereupon a purple solid precipitated. The solid was filtered off, dried and dissolved in benzene. The benzene solution was washed successively with sodium sulfite solution (5%), sodium hydroxide solution (10%) and water. The benzene was evaporated off, and the crude product recrystallized from aqueous acetone as brownish-white crystals (13 g.) of m.p. 98.5-101°. The infra red spectrum is shown on page 182.

Analysis:

Found: N, 13,05; Cl, 4.93
Calculated for $C_{14}H_{10}O_3NCl$: N, 12.90; Cl, 5.10

3) Synthesis of 5-Chloro-2-(p-Nitrobenzoyl)-Benzoic Acid (XV)

4-Chloro-2-Methyl-4'-Nitrobenzophenone (XIV) (8.5 g.) was dissolved in glacial acetic acid (25 ml.) with heating. A solution of chromium trioxide (6.6 g.) in a mixture of water (15 ml.) glacial acetic acid (25 ml.) and concentrated sulfuric acid (8 ml.) was added slowly from a dropping funnel at such a rate that the temperature of the reaction mixture remained

just below the boiling point. The mixture was refluxed for 3 hours and then poured into excess water. The precipitate was filtered and washed with water. The solid was then dissolved in hot potassium hydroxide solution (10%) and filtered through a sintered glass funnel. Acidification gave a white precipitate of m.p. 190-196°. Recrystallization from glacial acetic acid (charcoal) gave 5-chloro-2-(p-nitrobenzoyl)-benzoic acid as yellowish-white crystals (5.2 g.) of m.p. 194-196°. The infra red spectrum is shown on page 183.

Analysis:

Found: N, 4.54; Cl, 13.1

Calculated for $C_{14}H_8O_5NCl$: N, 4.6; Cl, 11.6

4) Synthesis of 5-Chloro-2-(p-Nitrobenzoyl)-Benzoyl Chloride (XVI)

5-Chloro-2-(p-nitrobenzoyl)-benzoic acid (XV)(5 g.) was placed in a flask fitted with a reflux condenser and a calcium chloride tube. Benzene (40 ml.) was added and the reaction mixture was made into a suspension by stirring. Thionyl chloride (10 ml.) was added to the suspension and the reaction mixture refluxed for one hour. Benzene and thionyl chloride were removed by vacuum distillation and the residue washed with anhydrous ether and dried in a desiccator. The 5-chloro-2-(p-nitrobenzoyl)-benzoyl chloride was obtained as a light brown amorphous powder (2.8 g.) of m.p. 144-146.5°. The infra red spectrum is shown on page 184.

Analysis:

Found: N, 4.20; Cl, 21.36

Calculated for $C_{14}H_7O_4NCl_2$: N, 4.32; Cl, 21.82

5) Activation of Sodium Azide

The procedure used was that described by Smith (56) in Organic Reactions. Commercially available sodium azide (20 g.) was moistened with

hydrazine hydrate (85%, 0.5-1.0 ml.) and ground in a mortar until homogeneous. After standing for twelve hours the material was dissolved in the minimum amount of hot water in a beaker. Excess acetone was added to the cooled solution and the mixture was allowed to stand for one hour. The precipitated sodium azide was collected, washed with acetone and dried (13 g.). Sodium azide thus activated begins to lose its activity after a day, but the activity can be regenerated at any time by dissolving the azide in water and reprecipitating it with acetone.

6) Synthesis of 5-Chloro-2-(p-Nitrobenzoyl)-Benzoic Acid Azide (XVII)

Activated sodium azide (4 g.) was dissolved in water (11 ml.) and added to a chilled solution of 5-chloro-2-(p-nitrobenzoyl)-benzoyl chloride (7.6 g.) in acetone (100 ml.). The reaction mixture was stirred for 3 hours and the precipitate filtered off and dried in a vacuum desiccator. Recrystallization from absolute ether gave 5-chloro-2-(p-nitrobenzoyl)-benzoic acid azide as a white powder (1.8 g.) of m.p. 112-115°. The infra red spectrum is shown on page 185.

Analysis:

Found: N, 16.81; Cl, 10.47

Calculated for $C_{14}H_7O_4N_4Cl$: N, 16.90; Cl, 10.71

7) Synthesis of 5-Chloro-2-(p-Nitrobenzoyl)-Aniline (XVIII) via a Curtius Reaction

a) 5-Chloro-2-(p-nitrobenzoyl)-benzoic acid azide (1.3 g.) in benzene (25 ml.) was boiled for 2 hours and cooled. Potassium hydroxide solution (50%, 15 ml.) was added and the mixture warmed, whereupon a white solid separated. This proved to be 5-chloro-2-(p-nitrobenzoyl)-benzoic acid of m.p. 195°. Thus the above reaction merely hydrolyzed the azide to the acid.

More acid azide was heated in benzene and an attempt to isolate the isocyanate proved fruitless. Conversion of the acid azide to the amine via a Curtius reaction in xylene and in N,N-dimethylformamide also met with failure.

b) 5-Chloro-2-(p-nitrobenzoyl)-benzoic acid azide (2 g.) was dissolved in dimethyl sulfoxide (50 ml.) and stirred at 100° for 5 hours. Addition of water (300 ml.) to the cooled solution caused a precipitate to form. This was filtered, dried and taken up in benzene (40 ml.). Potassium hydroxide solution (50%, 25 ml.) was added and the mixture warmed on the steam bath. The benzene was distilled off under vacuum and a yellow precipitate formed. After filtering and drying, the solid was treated with hot concentrated hydrochloric acid and the solution filtered through a sintered glass funnel. The filtrate after cooling, was made alkaline by adding sodium hydroxide solution (10%). Recrystallization of the precipitated amine from ethanol (charcoal) gave 5-chloro-2-(p-nitrobenzoyl)-aniline as brilliant yellow crystals (0.8 g.) of m.p. 203-205°. The infra red spectrum is shown on page 186.

Analysis:

Found: N, 10.18; Cl, 13.17

Calculated for $C_{13}H_9O_3N_2Cl$: N, 10.13; Cl, 12.84

8) Synthesis of 3-Chloro-6-Nitrofluorenone (XIX) and 2-Hydroxy-4-Chloro-4'-Nitrobenzophenone (XX)

5-Chloro-2-(p-nitrobenzoyl)-aniline (XVIII)(0.8 g.) was dissolved in concentrated sulfuric acid (2 ml.), and a few drops of water added to the solution. The amine sulfate which separated as a yellowish white suspension was cooled to 0° in an ice bath. An ice cold solution of sodium nitrite (0.2 g.) in water (2 ml.) was added slowly to the cooled suspension.

The solution was allowed to stand for 30 minutes after which it was placed on the steam bath for 1 hour. The precipitate which formed was filtered, washed with sodium hydroxide solution (10%) and then with water. The dried 3-chloro-6-nitrofluorenone recrystallized from nitrobenzene as gold platelets (0.2 g.) of m.p. 329-331°. The infra red spectrum is shown on page 187.

Analysis:

Found: N, 5.03; Cl, 13.17
Calculated for $C_{16}H_6O_3NCl$: N, 5.40; Cl, 13.64

The sodium hydroxide washings from above on acidification with concentrated hydrochloric acid gave 2-hydroxy-4-chloro-4'-nitrobenzophenone. Recrystallization from aqueous ethanol gave light yellow needles (0.25 g.) of m.p. 148-149°. The infra red spectrum is shown on page 188.

Analysis:

Found: N, 5.21; Cl, 13.59
Calculated for $C_{13}H_8O_4NCl$: N, 5.05; Cl, 12.85

9) Synthesis of 4-Fluoro-2-Methyl-4'-Nitrobenzophenone (XXI) via a Schiemann Reaction

A solution of fluoboric acid (HBF_4)(8 ml.) and water (10 ml.) was added to 4-amino-2-methyl-4'-nitrobenzophenone (XIII)(1.5 g.) dissolved in tetrahydrofuran (20 ml.), and the reaction mixture cooled in ice and water with stirring. A cold solution (0-5°) of sodium nitrite (1 g.) in water (5 ml.) was then added dropwise. The reaction mixture was stirred for 30 minutes during which time a white precipitate of diazonium fluoborate formed. The salt was filtered and washed successively with cold fluoboric acid solution (5%), methanol and anhydrous ether.

The diazonium fluoborate salt was decomposed by refluxing in xylene (40 ml.) for 2 hours. This was done in the fume hood because pungent fumes of boron trifluoride were given off. The solution was evaporated

to dryness under a bell jar overnight. The residue was twice recrystallized from ethanol (charcoal) to give 4-fluoro-2-methyl-4'-nitrobenzophenone as pearlish platelets (0.9 g.) of m.p. 101-102°. The infra red spectrum is shown on page 189.

Analysis:

Found: N, 5.38; F, 7.15
Calculated for $C_{14}H_{10}O_3NF$: N, 5.48; F, 7.44

10) Synthesis of 5-Fluoro-2-(p-Nitrobenzoyl)-Benzoic Acid (XXII)

4-Fluoro-2-methyl-4'-nitrobenzophenone (XXI)(2.5 g.) was dissolved in glacial acetic acid (20 ml.) with heating. A solution of chromium trioxide (1.8 g.) in a mixture of water (10 ml.) glacial acid (12 ml.) and concentrated sulfuric acid (2 ml.) was added dropwise. The solution was refluxed for 4 hours, cooled and added to an ice-water mixture. The white precipitate which formed was filtered and washed with water. The solid was then dissolved in hot potassium hydroxide solution (10%) and filtered through a sintered glass funnel. Acidification gave a light brown precipitate of m.p. 175-180°. This was recrystallized first from ethanol (charcoal) and then benzene to give 5-fluoro-2-(p-nitrobenzoyl)-benzoic acid as white crystals (1.2 g.) of m.p. 187-189°. The infra red spectrum is shown on page 190.

Analysis:

Found: N, 4.72; F, 6.39
Calculated for $C_{14}H_8O_5NF$: N, 4.84; F, 6.56

11) Synthesis of 5-Fluoro-2-(p-Nitrobenzoyl)-Benzoyl Chloride (XXIII)

The experimental procedure used here was similar to that used for the synthesis of 5-chloro-2-(p-nitrobenzoyl)-benzoyl chloride (XVI) (No. 4 on page 164). 5-Fluoro-2-(p-nitrobenzoyl)-benzoic acid (XXII)

(5 g.) yielded 5-fluoro-2-(p-nitrobenzoyl)-benzoyl chloride as slightly pink crystals (2.3 g.) of m.p. 154-156°. The infra red spectrum is shown on page 191.

Analysis:

Found: N, 4.41
Calculated for $C_{14}H_7O_4NFCl$: N, 4.56

12) Synthesis of 5-Fluoro-2-(p-Nitrobenzoyl)-Benzoic Acid Azide (XXIV)

Activated sodium azide (see No. 5 page 164)(1.2 g.) was dissolved in water (4 ml.) and added to a chilled solution of 5-fluoro-2-(p-nitrobenzoyl)-benzoyl chloride (2.1 g.) in acetone (30 ml.). The reaction mixture was stirred for 2 hours. Water (30 ml.) was added to dissolve any excess sodium azide and precipitate the organic azide. An oil formed which crystallized on cooling and stirring. Recrystallization from absolute ether gave 5-fluoro-2-(p-nitrobenzoyl)-benzoic acid azide as a white powder (0.8 g.) of m.p. 120-122°. The infra red spectrum is shown on page 192.

Analysis:

Found: N, 17.82; F, 6.36
Calculated for $C_{14}H_7O_4N_4F$: N, 17.82; F, 6.05

13) Synthesis of 5-Fluoro-2-(p-Nitrobenzoyl)-Aniline (XXV) via a Curtius Reaction

5-Fluoro-2-(p-nitrobenzoyl)-benzoic acid azide (1 g.) was dissolved in dimethyl sulfoxide (30 ml.) and stirred at 100° for 5 hours. Addition of water (200 ml.) to the cooled solution caused a precipitate to form. This was filtered, dried and taken up in benzene (30 ml.). Potassium hydroxide solution (50%, 25 ml.) was added and the mixture warmed on the steam bath. The benzene was distilled off under vacuum and a yellow pre-

cipitate formed. After filtering and drying, the solid was treated with hot concentrated hydrochloric acid and the solution filtered through a sintered glass funnel. The filtrate after cooling, was made alkaline by adding sodium hydroxide solution (10%). 5-Fluoro-2-(p-nitrobenzoyl)-aniline precipitated out of solution as golden yellow platelets (0.4 g.) of m.p. 205-206°. The infra red spectrum is shown on page 193.

Analysis:

Found: N, 9.91; F, 6.36
Calculated for $C_{13}H_9O_3N_2F$: N, 10.77; F, 7.31

14) Synthesis of 3-Fluoro-6-Nitrofluorenone (XXVI) and 2-Hydroxy-4-Fluoro-4'-Nitrobenzophenone (XXVII)

5-Fluoro-2-(p-nitrobenzoyl)-aniline (XXV)(0.6 g.) was dissolved in concentrated sulfuric acid (2 ml.), and a few drops of water added to the solution. The amine sulfate suspension was cooled to 0°, and a cold solution (0-5°) of sodium nitrite (0.2 g.) in water (2 ml.) was added dropwise with stirring. A brown solution formed and this was stirred in an ice-water bath for 1 hour. The reaction mixture was then heated on the steam bath for 2 hours. The yellow precipitate which formed was filtered, washed with sodium hydroxide solution (10%) and then with water. The dried 3-fluoro-6-nitrofluorenone was recrystallized from nitrobenzene as bright yellow platelets (0.2 g.) of m.p. 281-283°. The infra red spectrum is shown on page 194.

Analysis:

Found: N, 5.70; F, 8.11
Calculated for $C_{13}H_6O_3NF$: N, 5.74; F, 7.86

The sodium hydroxide washings from above on acidification with concentrated hydrochloric acid gave 2-hydroxy-4-fluoro-4'-nitrobenzophenone. Recrystallization twice from aqueous ethanol gave yellow needles (0.18 g.)

of m.p. 107-110°. The infra red spectrum is shown on page 195.

Analysis:

Found: N, 6.26; F, 7.40
Calculated for $C_{13}H_8O_4NF$: N, 5.37; F, 7.28

15) Synthesis of 4-Iodo-2-Methyl-4'-Nitrobenzophenone (XXXI)

4-Amino-2-methyl-4'-nitrobenzophenone (XIII)(10 g.) was dissolved in hot concentrated hydrochloric acid (70 ml.) and the solution was cooled to 0° in an ice-salt bath. A solution of sodium nitrite (5 g.) in water (25 ml.) was cooled to 0° and added slowly to the white suspension of the amine hydrochloride with vigorous stirring. The color of the suspension turned from white to brownish-yellow as the diazonium salt was formed. After standing at 0-5° for about 15 minutes, the diazonium solution was added dropwise to an ice cold solution of potassium iodide (25 g.) in water. A reaction takes place immediately and some iodine vapor was given off. The reaction mixture was stirred at 0-5° for 2 hours and then slowly heated to about 80° in a water bath. Some iodine sublimed on the cooler portions of the flask and in the condenser. On cooling, a cake formed at the bottom of the flask. It was separated, washed with water and dissolved in benzene. The benzene extract was washed successively with sodium sulfite solution (5%), sodium hydroxide solution (10%) and water. The benzene was evaporated off and the residue recrystallized from aqueous acetone to give 4-iodo-2-methyl-4'-nitrobenzophenone as light red crystals (7 g.) of m.p. 106-108°. The analysis at this stage was not satisfactory so the compound was recrystallized twice from benzene (charcoal) to give light red crystals (5.5 g.) of m.p. 108-110°. The infra red spectrum is shown on page 196 .

Analysis:

Found: N, 3.75; I, 33.81
Calculated for $C_{14}H_{10}O_3NI$: N, 3.80; I, 34.54

16) Attempted Oxidation of 4-Iodo-2-Methyl-4'-Nitrobenzophenone (XXXI) to 5-Iodo-2-(p-Nitrobenzoyl)-Benzoic Acid (XXXII)

4-Iodo-2-methyl-4'-nitrobenzophene (8 g.) was dissolved in glacial acetic acid (25 ml.) with heating. A solution of chromium trioxide (6 g.) in a mixture of water (15 ml.) glacial acetic acid (25 ml.) and concentrated sulfuric acid (8 ml.) was added slowly from a dropping funnel at such a rate that the temperature of the reaction mixture remained just below the boiling point. Iodine was evolved and sublimed on the cooler portions of the reaction flask. The mixture was refluxed for 3 hours and then poured into excess water. The precipitate was filtered and washed with water. The solid was then dissolved in hot potassium hydroxide solution (10%) and filtered through a sintered glass funnel. Acidification gave a white precipitate (2.5 g.) of m.p. 301-303°. As was expected analysis indicated loss of iodine. Permanganate and dichromate oxidations yielded the same results.

Analysis:

Found: N, 3.62; I, 19.40
Calculated for $C_{14}H_8O_5NI$: N, 3.53; I, 31.99

17) Synthesis of 5-Acetamido-2-(p-Nitrobenzoyl)-Benzoic Acid (XXXIII)

4-Acetamido-2-methyl-4'-nitrobenzophenone was prepared according to the procedure used for the synthesis of 4-amino-2-methyl-4'-nitrobenzophenone (No. 1 page 162) but without the hydrolysis step. The procedure used for the oxidation is similar to that used by Leggate and Dunn (57) for the oxidation of 2-methyl-4-methoxyacetanilide to N-acetyl-5-methoxyanthranilic acid. 4-Acetamido-2-methyl-4'-nitrobenzophenone (10 g.) in acetone (500 ml.) was treated with potassium permanganate (27 g.) and magnesium sulfate during 3 days at room temperature. Sodium sulfite was then added to destroy excess permanganate and the reaction mixture was

filtered. The filtrate was evaporated to 100 ml., diluted with water, and extracted with chloroform to remove unreacted starting material. Acidification with concentrated hydrochloric acid yielded 5-acetamido-2-(p-nitrobenzoyl)-benzoic acid as white crystals (4.5 g.) of m.p. 231-233°. The infra red spectrum is shown on page 197.

Analysis:

Found: N, 8.18

Calculated for $C_{16}H_{12}O_6N_2$: N, 8.54

SUMMARY

1) The synthesis of 3-chloro-6-nitrofluorenone (XXII) has been accomplished.

2) While achieving this synthesis the following new compounds have also been prepared:

i 4-Chloro-2-methyl-4'-nitrobenzophenone (XVII)

ii 5-Chloro-2-(p-nitrobenzoyl)-benzoic acid (XVIII)

iii 5-Chloro-2-(p-nitrobenzoyl)-benzoyl chloride (XIX)

iv 5-Chloro-2-(p-nitrobenzoyl)-benzoic acid azide (XX)

v 5-Chloro-2-(p-nitrobenzoyl)-aniline (XXI)

vi 2-Hydroxy-4-chloro-4'-nitrobenzophenone (XXIII)

3) The synthesis of 3-fluoro-6-nitrofluorenone (XXIX) has been accomplished.

4) While achieving this synthesis the following new compounds have also been prepared:

i 4-Fluoro-2-methyl-4'-nitrobenzophenone (XXIV)

ii 5-Fluoro-2-(p-nitrobenzoyl)-benzoic acid (XXV)

iii 5-Fluoro-2-(p-nitrobenzoyl)-benzoyl chloride (XXVI)

iv 5-Fluoro-2-(p-nitrobenzoyl)-benzoic acid azide (XXVII)

v 5-Fluoro-2-(p-nitrobenzoyl)-aniline (XXVIII)

vi 2-Hydroxy-4-fluoro-4'-nitrobenzophenone (XXX)

5) The synthesis of 4-iodo-2-methyl-4'-nitrobenzophenone (XXXI) and 5-acetamido-2-(p-nitrobenzoyl)-benzoic acid (XXXIII) have also been accomplished.

6) The synthesis of 3-iodo-6-nitrofluorenone was not accomplished using the reaction scheme of Charlesworth and Mathiaparanam because of loss of iodine in the oxidation step.

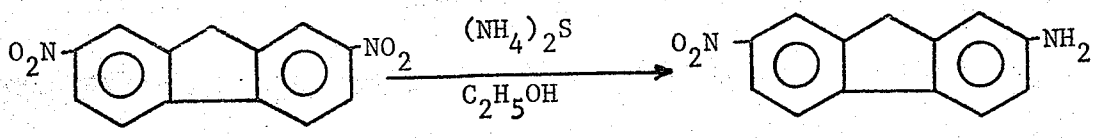
7) Several alternate methods have been proposed for the synthesis of 3-iodo-6-nitrofluorenone.

RECOMMENDATIONS FOR FUTURE WORK

1) 3-Cyano-6-nitrofluorenone could be prepared by Charlesworth and Mathiaparanam's scheme or by some variation in the reaction sequence.

2) By reduction of the nitro group in 3-halo-6-nitrofluorenone, a variety of other 3,6-disubstituted unsymmetrical fluorenones could be synthesized.

3) Barker et al.(42) synthesized 3,6-dinitrofluorenone by nitration of 2,7-diacetamidofluorenone followed by subsequent hydrolysis and deamination (see page 146). In 1968, Andrew, Campbell et al. (55) achieved the following reduction. The same could be tried with 3,6-



dinitrofluorenone. By diazonium reactions on the subsequent nitroamine a variety of 3,6-disubstituted unsymmetrical fluorenones including 3-iodo-6-nitrofluorenone could be synthesized.

4) Separation of 5-iodo-(p-nitrobenzoyl)-benzoic acid from the non-iodo substituted acid might be done according to the method of Hahn et al. (58) as discussed on page 157. If this can be achieved, synthesis of 3-iodo-6-nitrofluorenone following Charlesworth and Mathiaparanam's scheme might be possible. Alternatively the separation of the iodo

from the non-iodo compound could be left to the last stage of the above scheme.

5) The preparation of 3-iodo-6-nitrofluorenone might be achieved by one of the syntheses outlined on pages 159-161.

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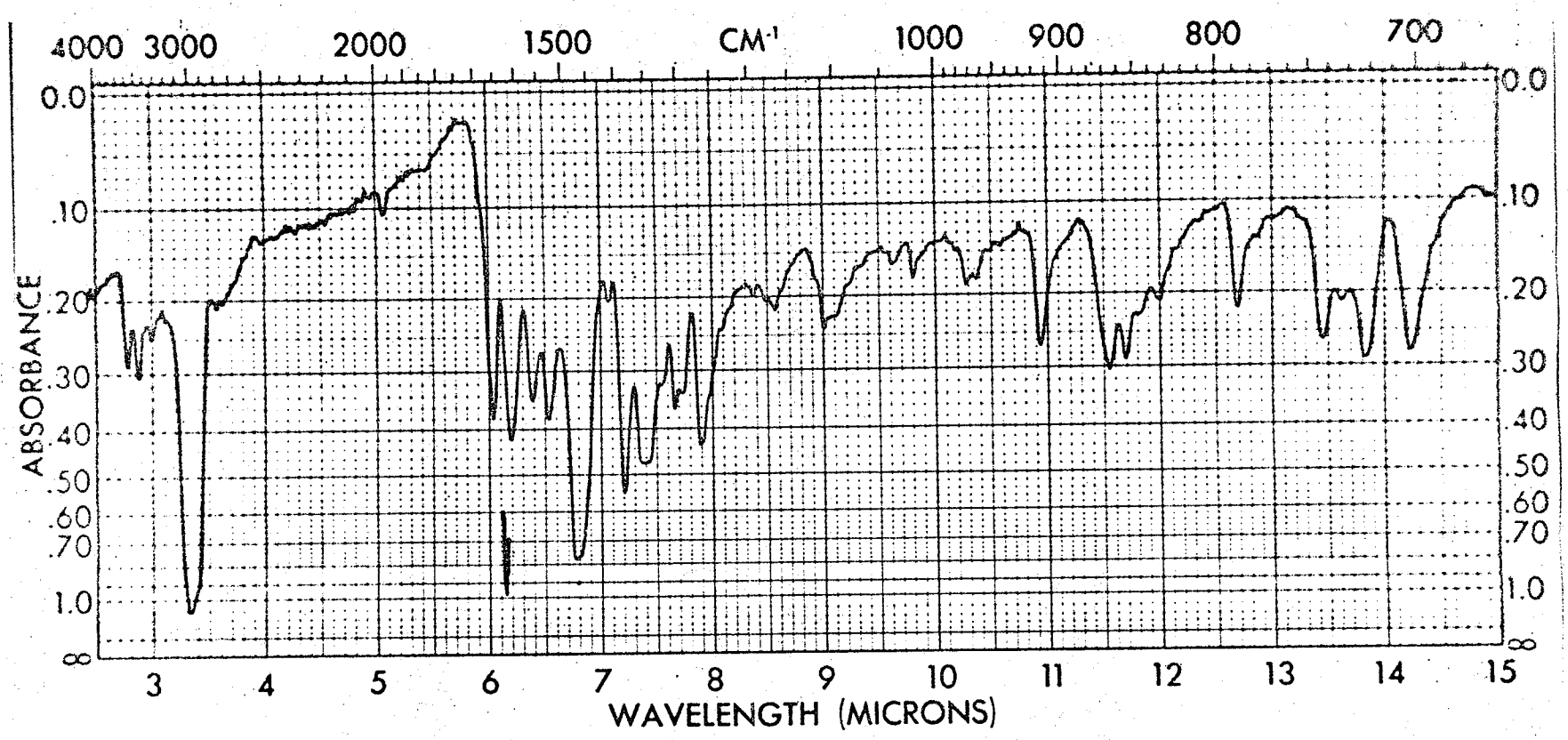
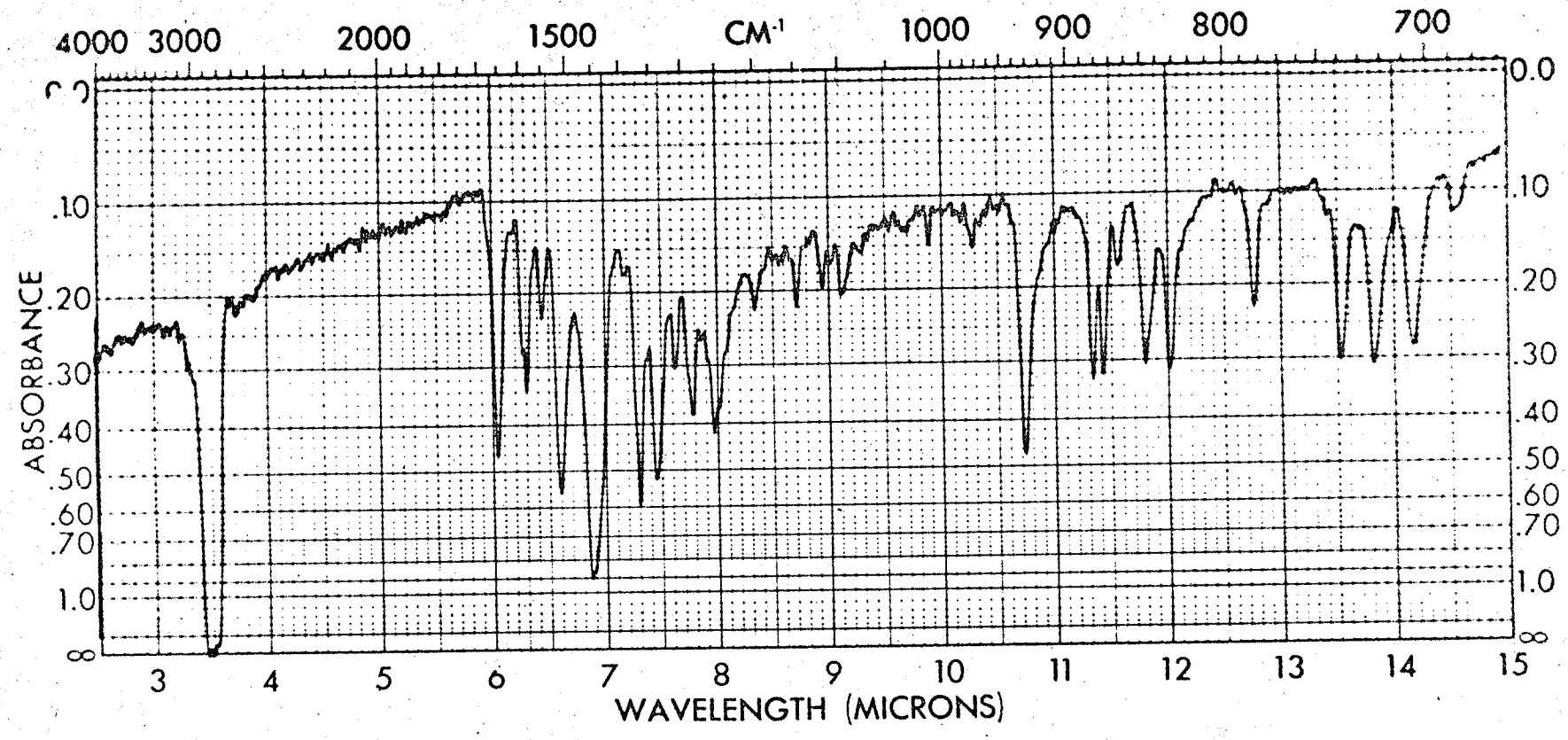
INFRA RED SPECTRA



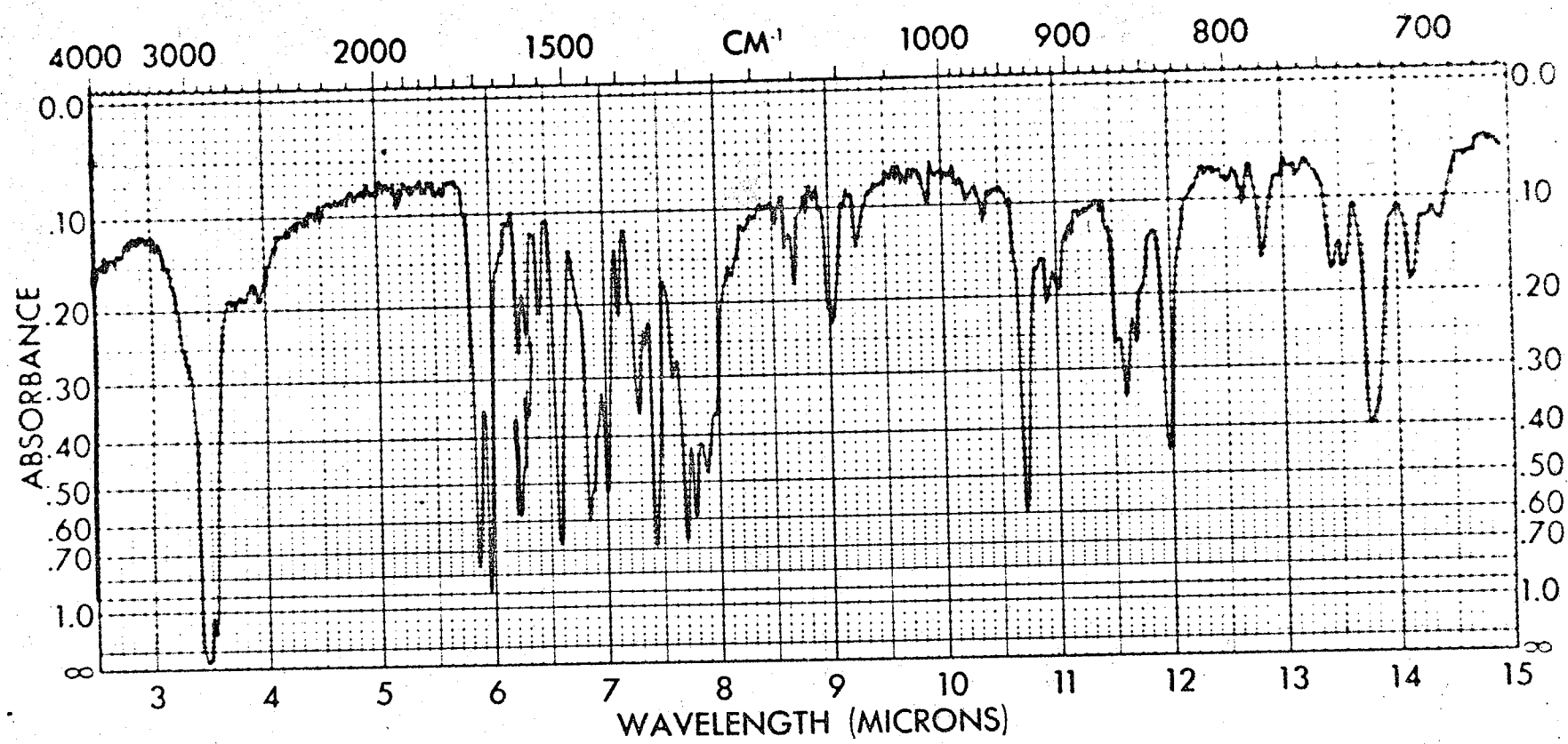
I. R. Spectrum of 4-Amino-2-Methyl-4'-Nitrobenzophenone (XIII).

Phase-Nujol Mull.



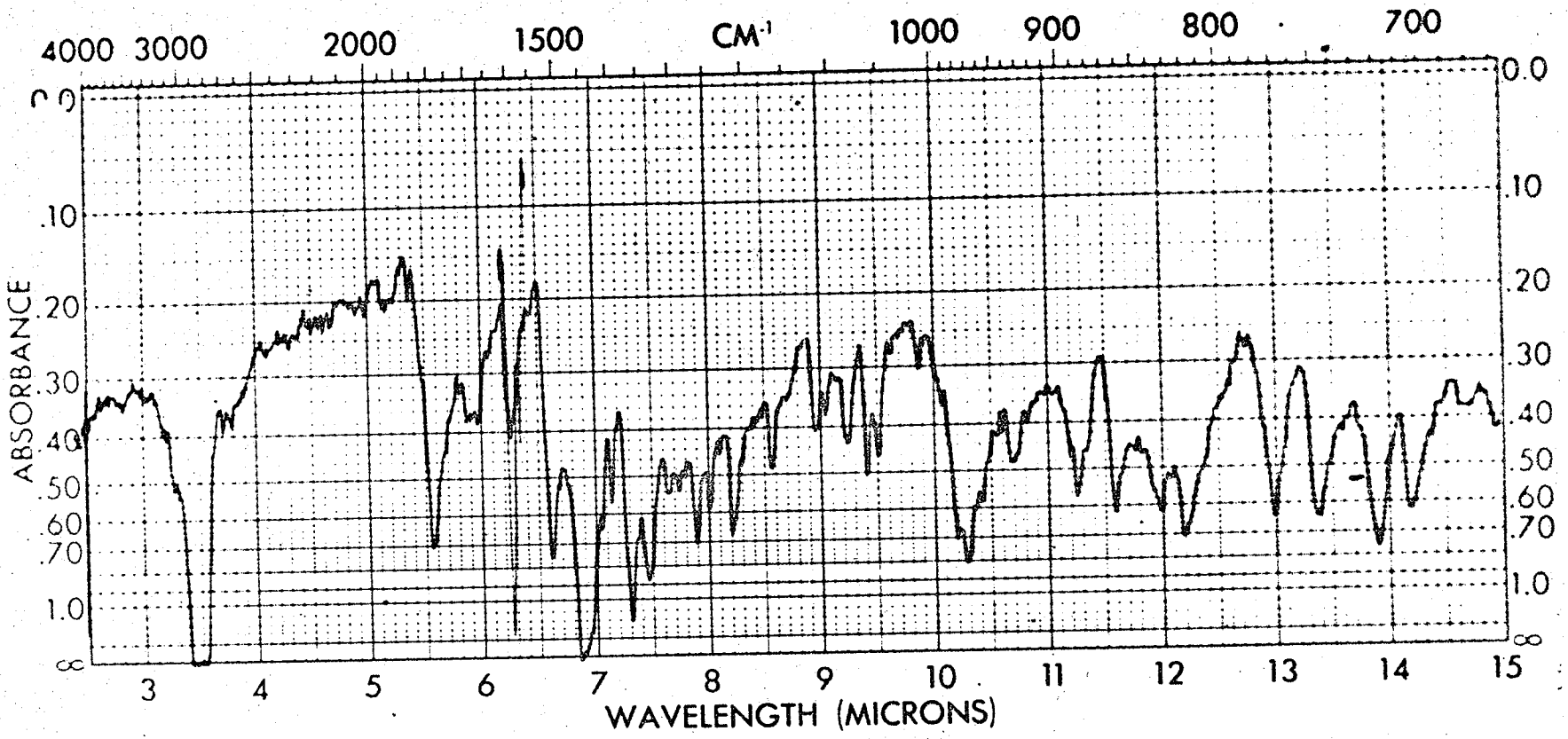
I. R. Spectrum of 4-Chloro-2-Methyl-4'-Nitrobenzophenone (XIV).

Phase-Nujol Mull.



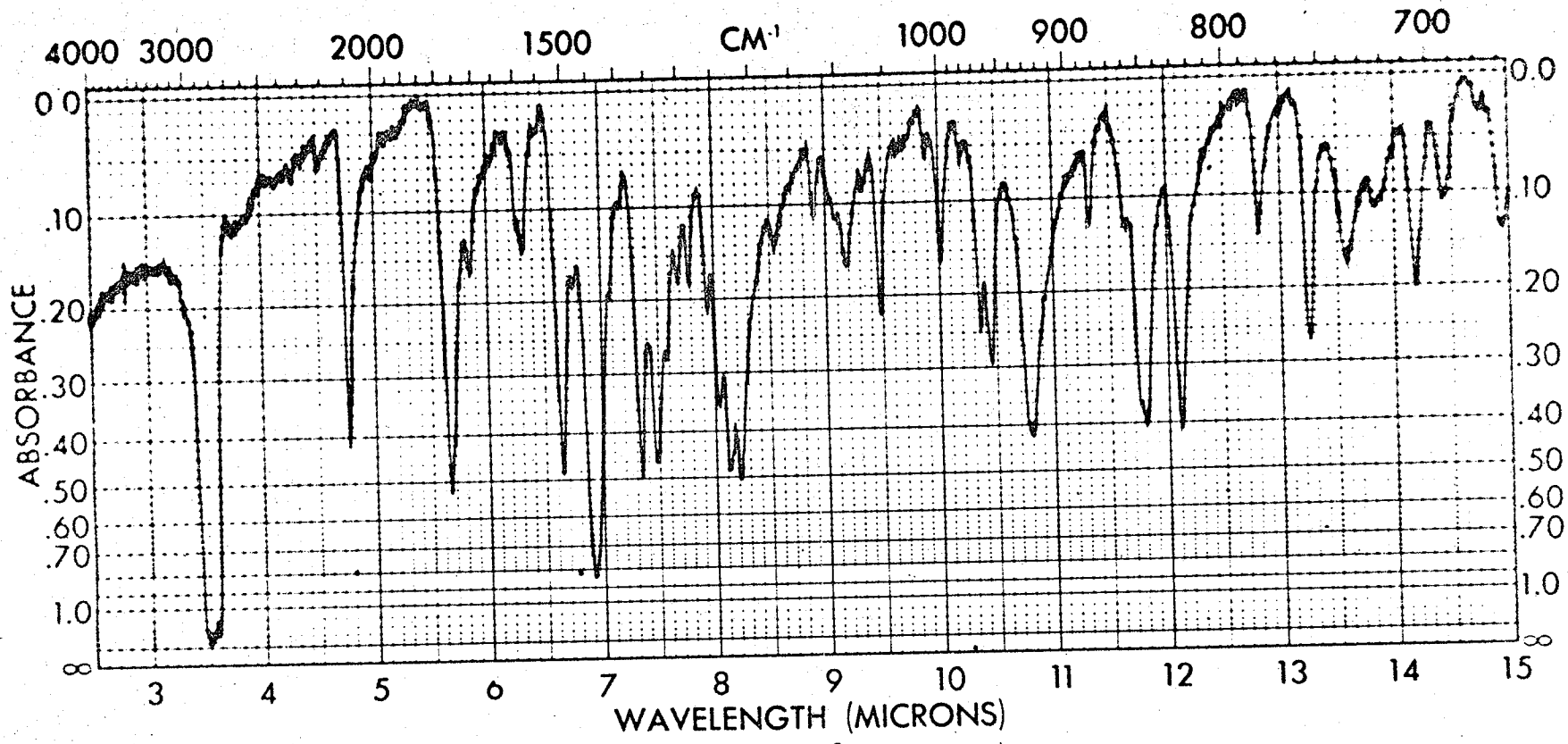
I. R. Spectrum of 5-Chloro-2-(p-Nitrobenzoyl)-Benzoic Acid (XV).

Phase-Nujol Mull.



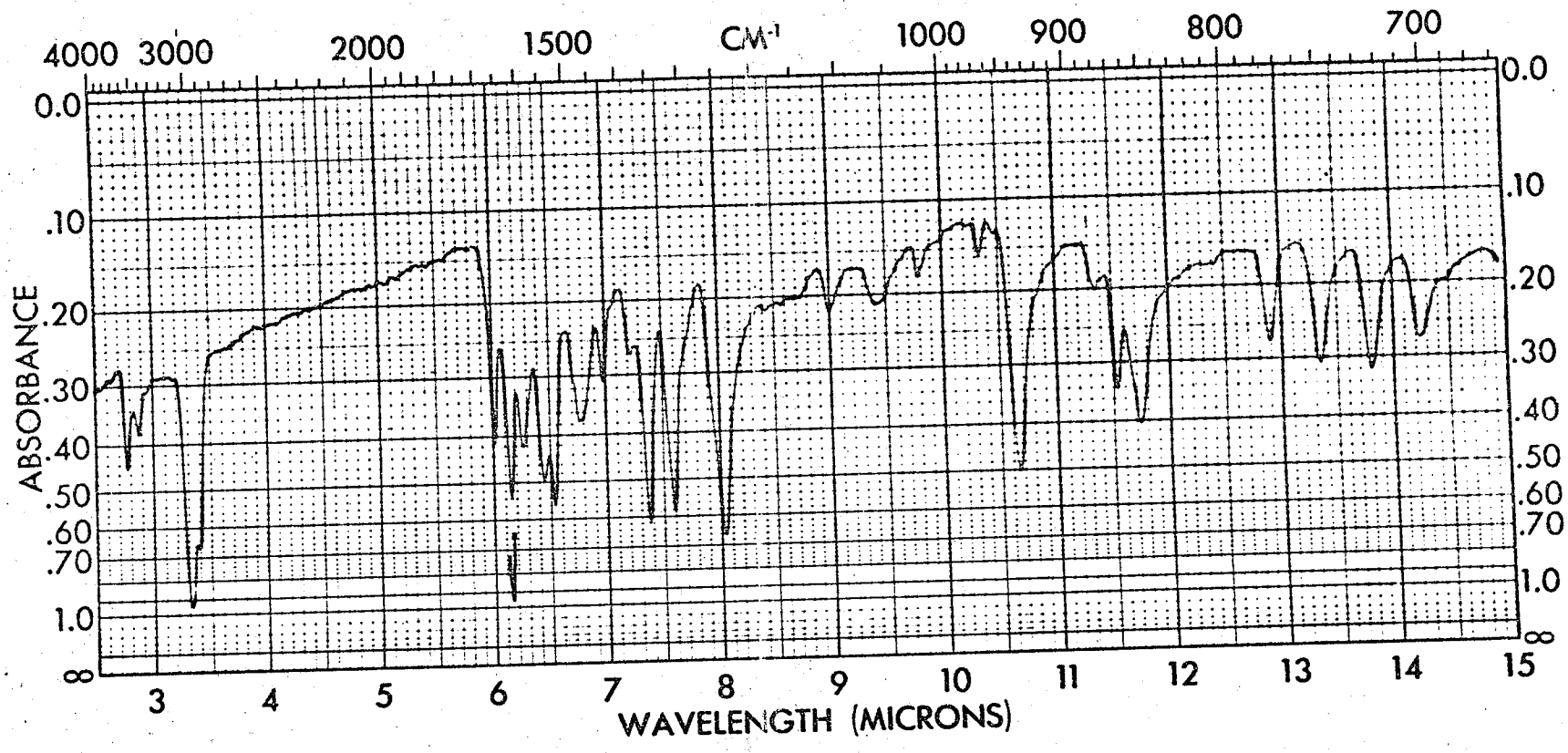
I. R. Spectrum of 5-Chloro-2-(p-Nitrobenzoyl)-Benzoyl Chloride (XVI).

Phase-Nujol Mull.



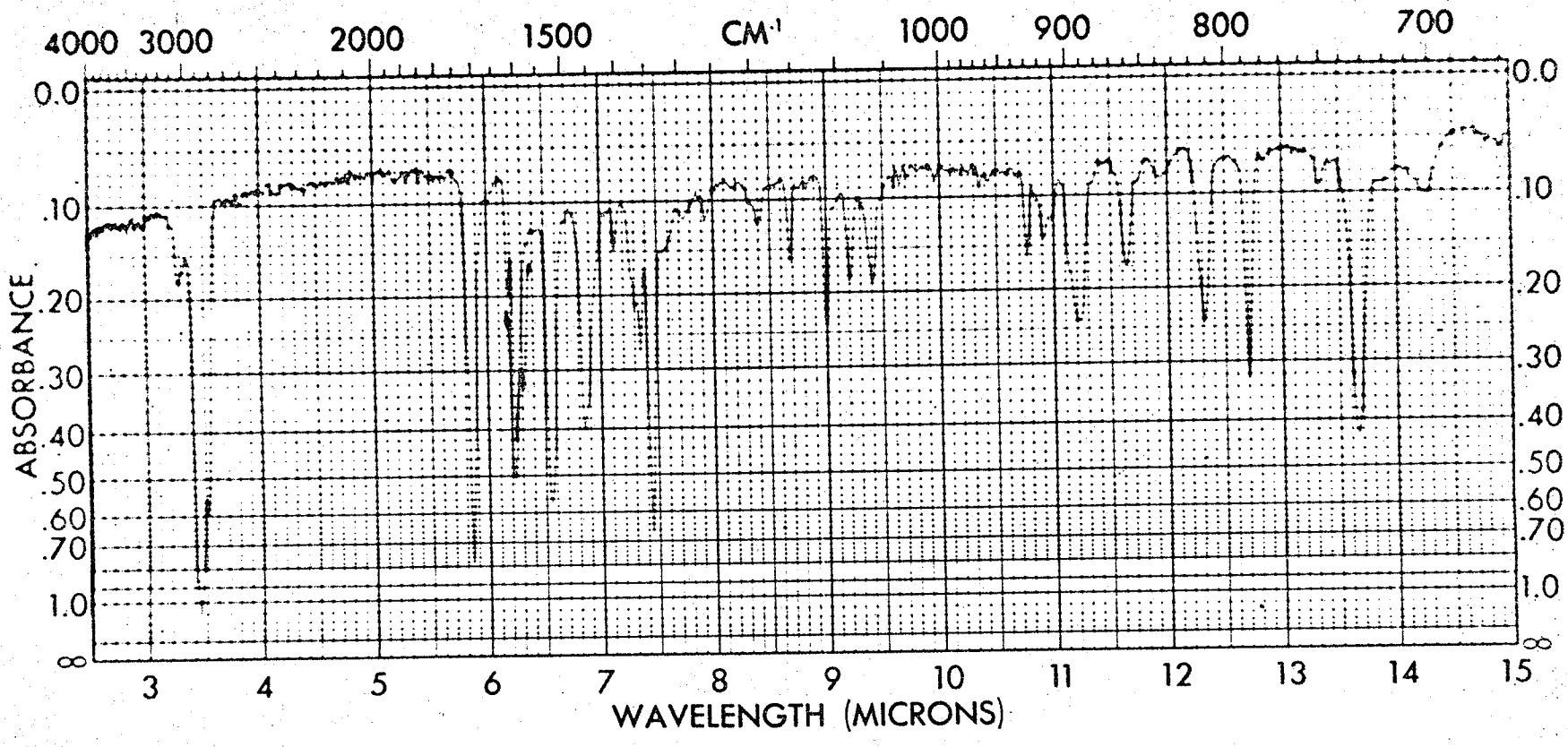
I. R. Spectrum of 5-Chloro-2-(p-Nitrobenzoyl)-Benzoic Acid Azide (XVII).

Phase-Nujol Mull.



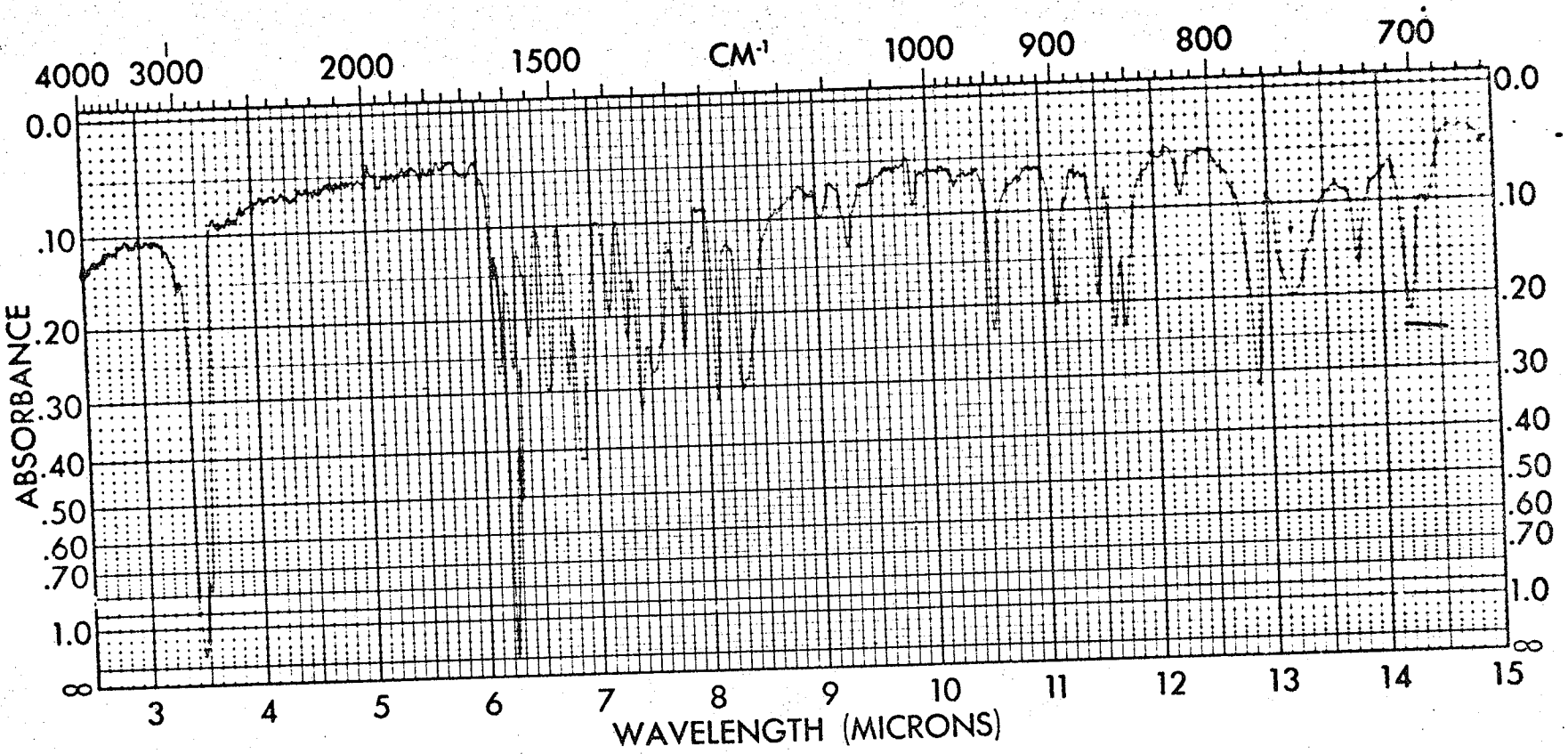
I.R. Spectrum of 5-Chloro-2-(p-Nitrobenzoyl)-Aniline (XVIII).

Phase-Nujol Mull.



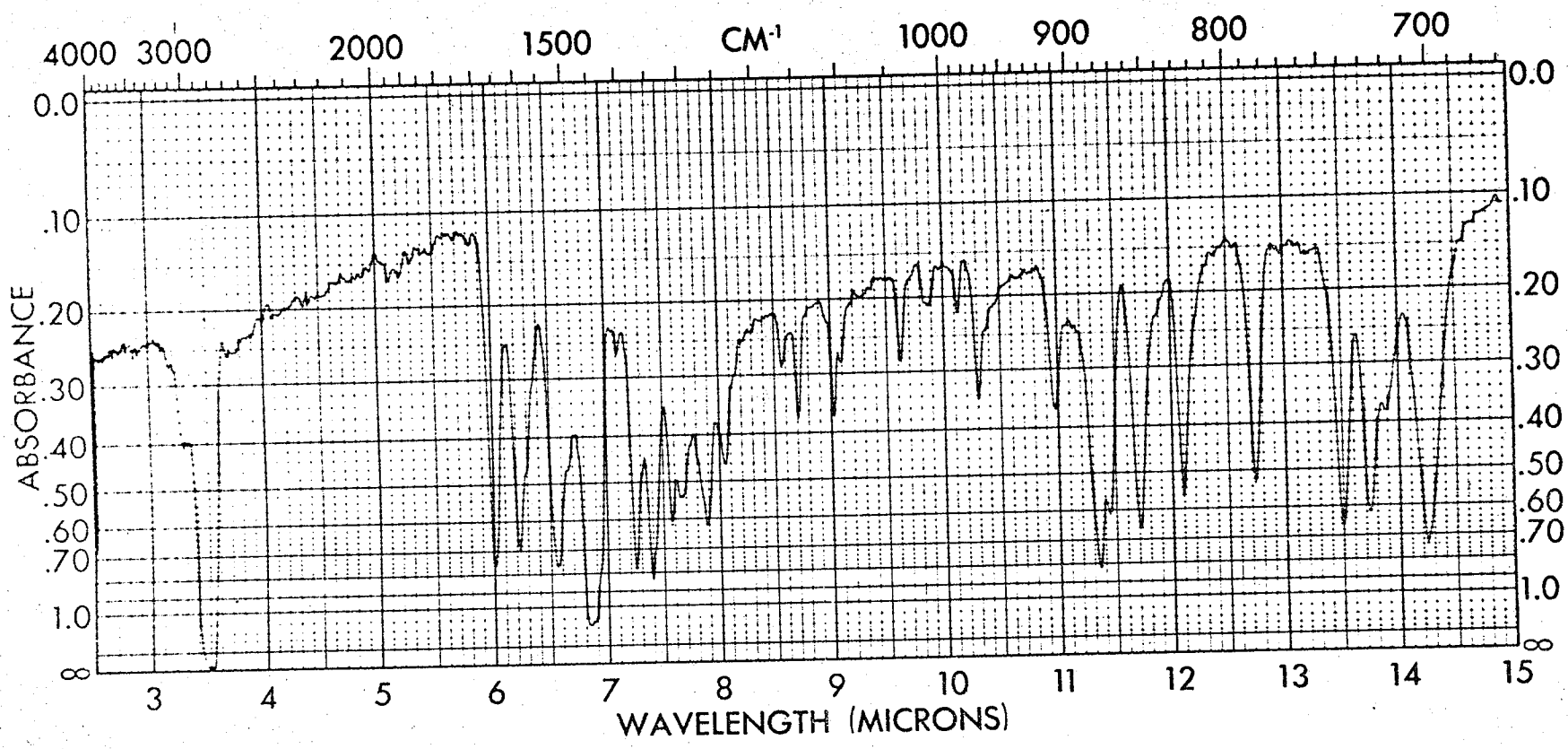
I. R. Spectrum of 3-Chloro-6-Nitrofluorenone (XIX).

Phase-Nujol Mull.



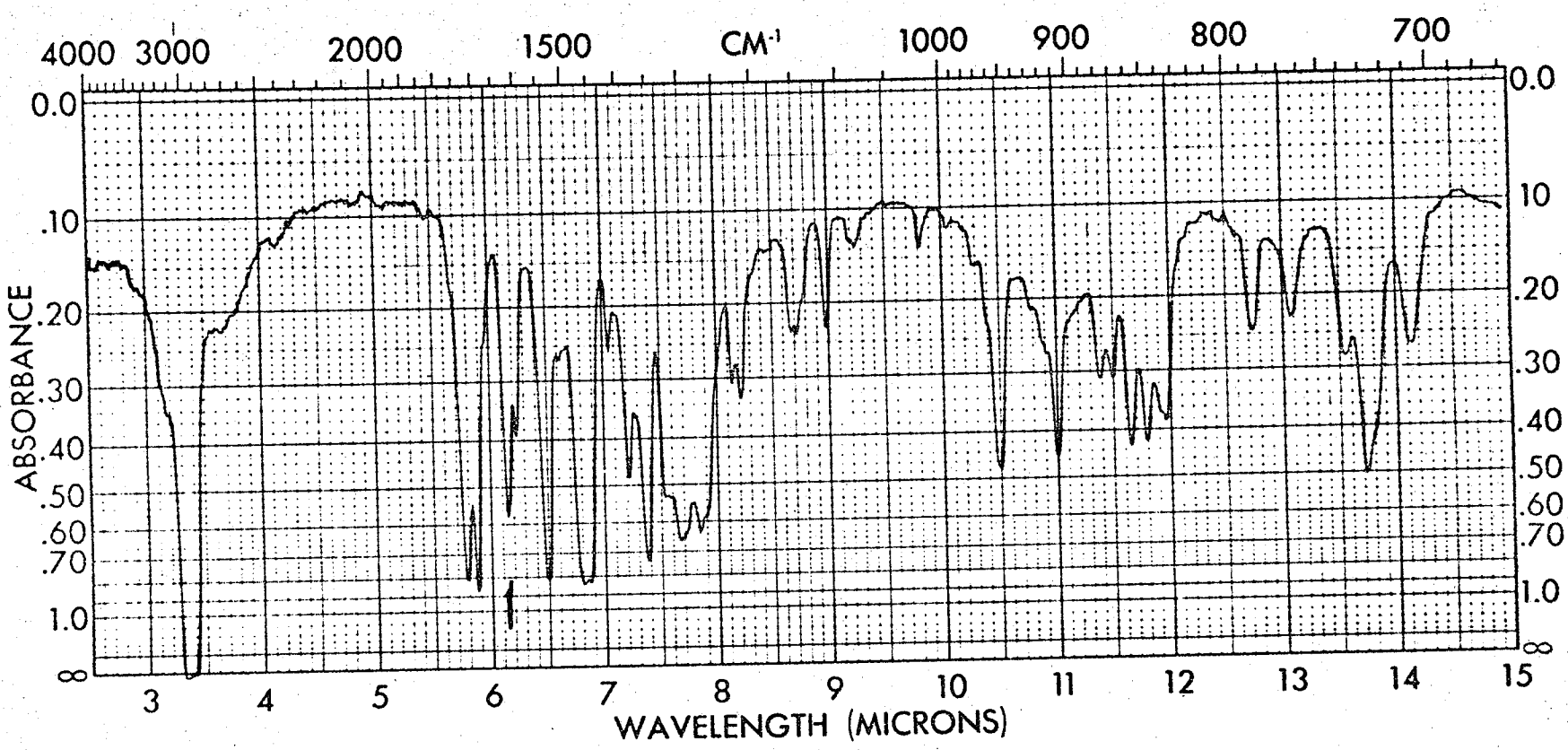
I. R. Spectrum of 2-Hydroxy-4-Chloro-4'-Nitrobenzophenone (XX).

Phase-Nujol Mull.



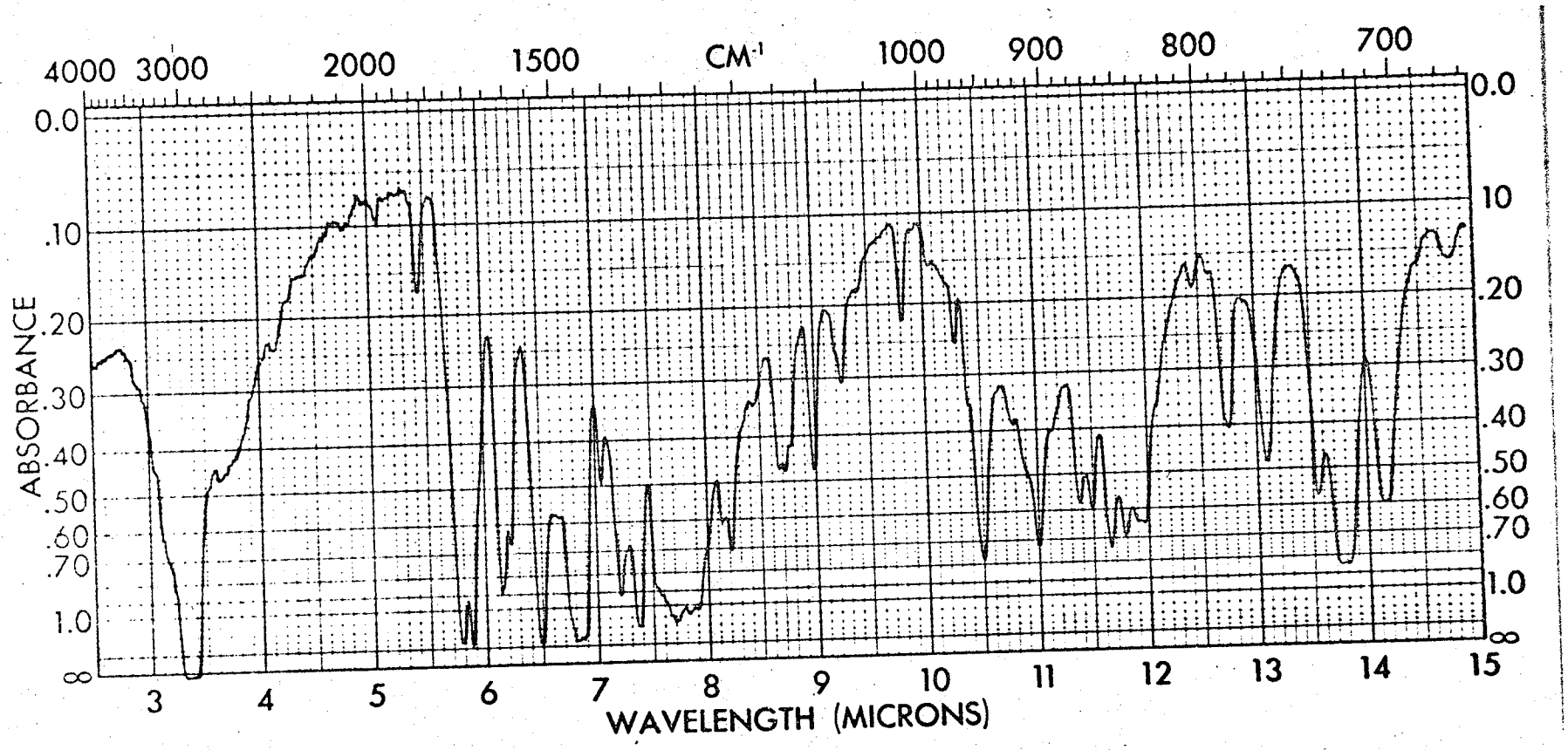
I. R. Spectrum of 4-Fluoro-2-Methyl-4'-Nitrobenzophenone (XXI).

Phase-Nujol Mull.



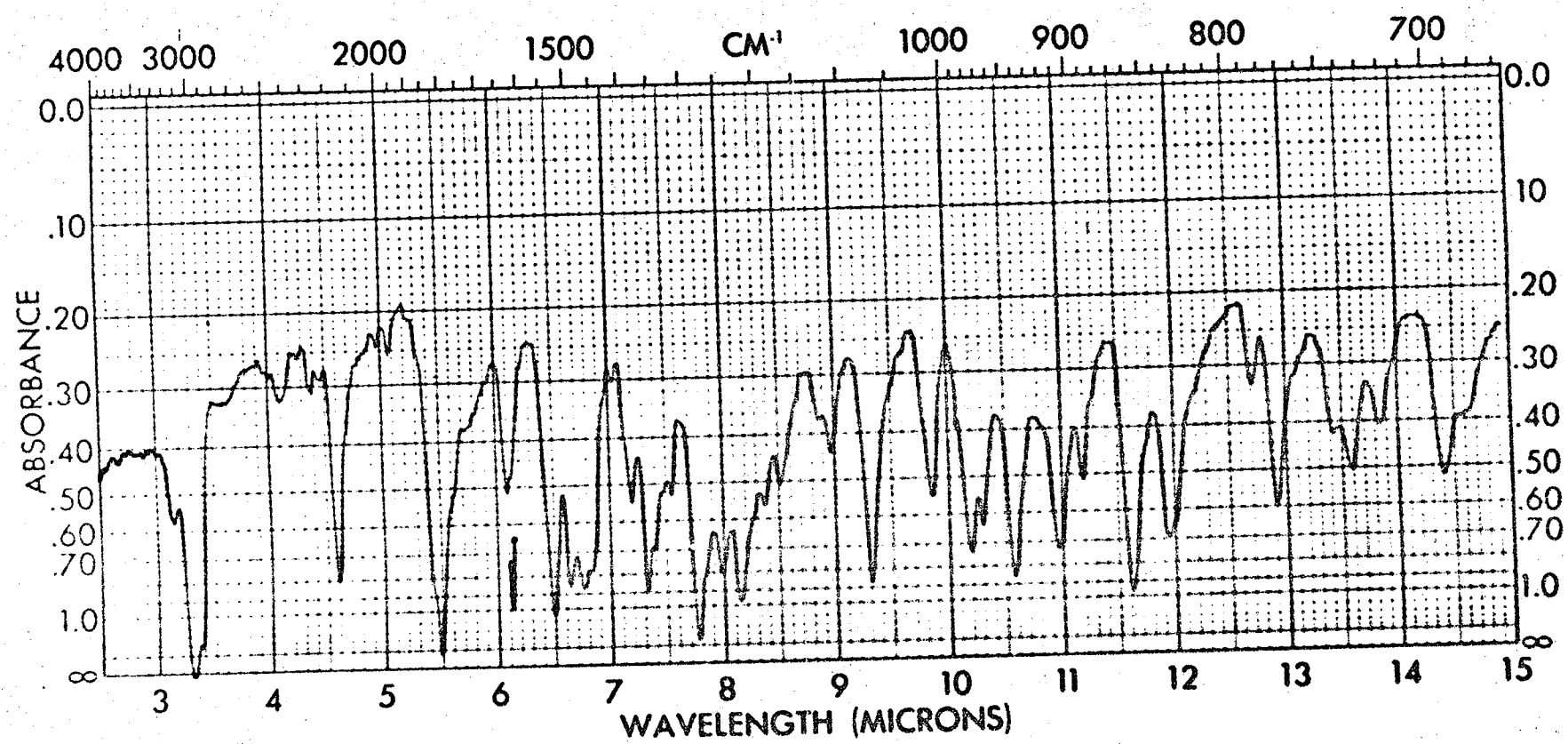
I. R. Spectrum of 5-Fluoro-2-(p-Nitrobenzoyl)-Benzoic Acid (XXII).

Phase-Nujol Mull.



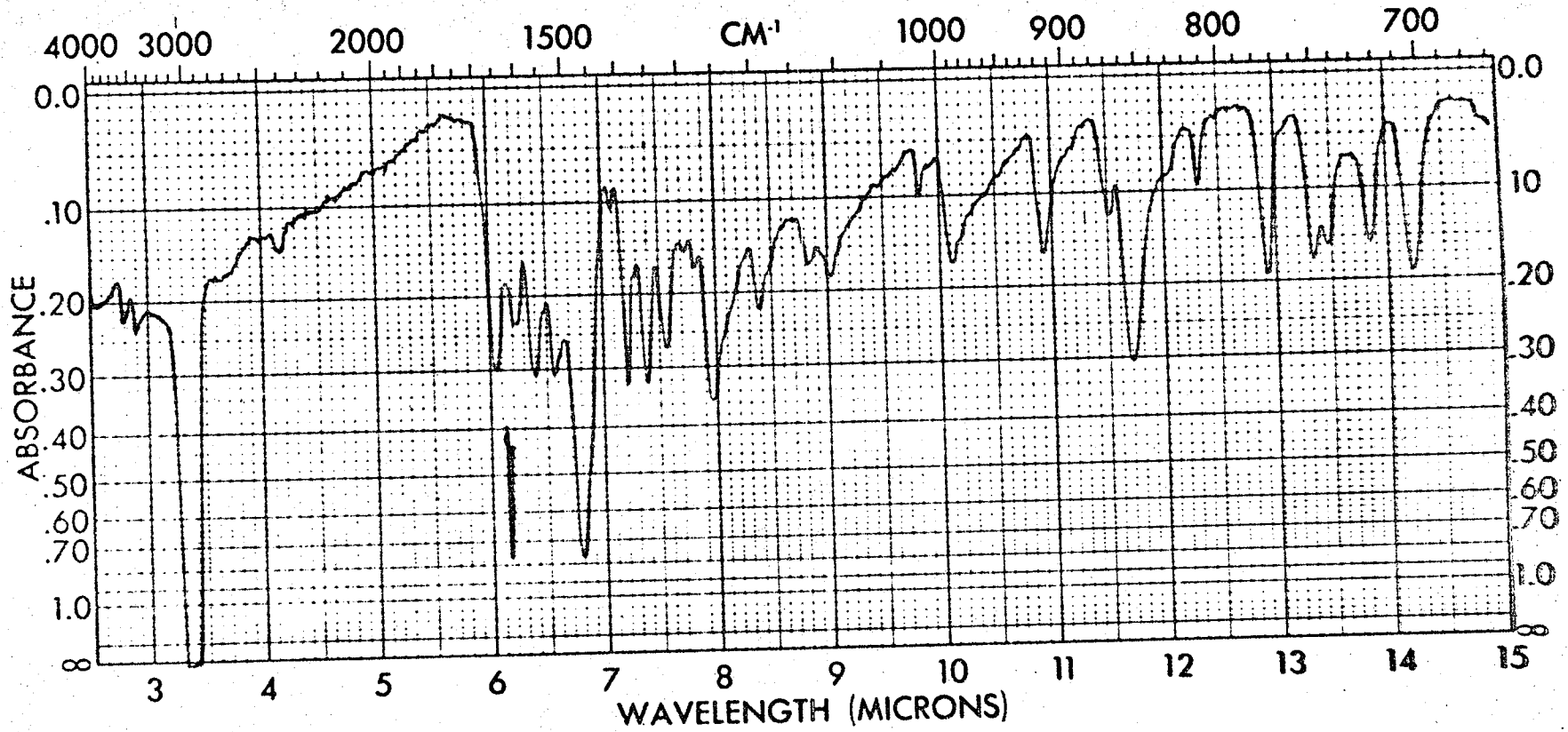
I. R. Spectrum of 5-Fluoro-2-(p-Nitrobenzoyl)-Benzoyl Chloride (XXIII).

Phase-Nujol Mull.



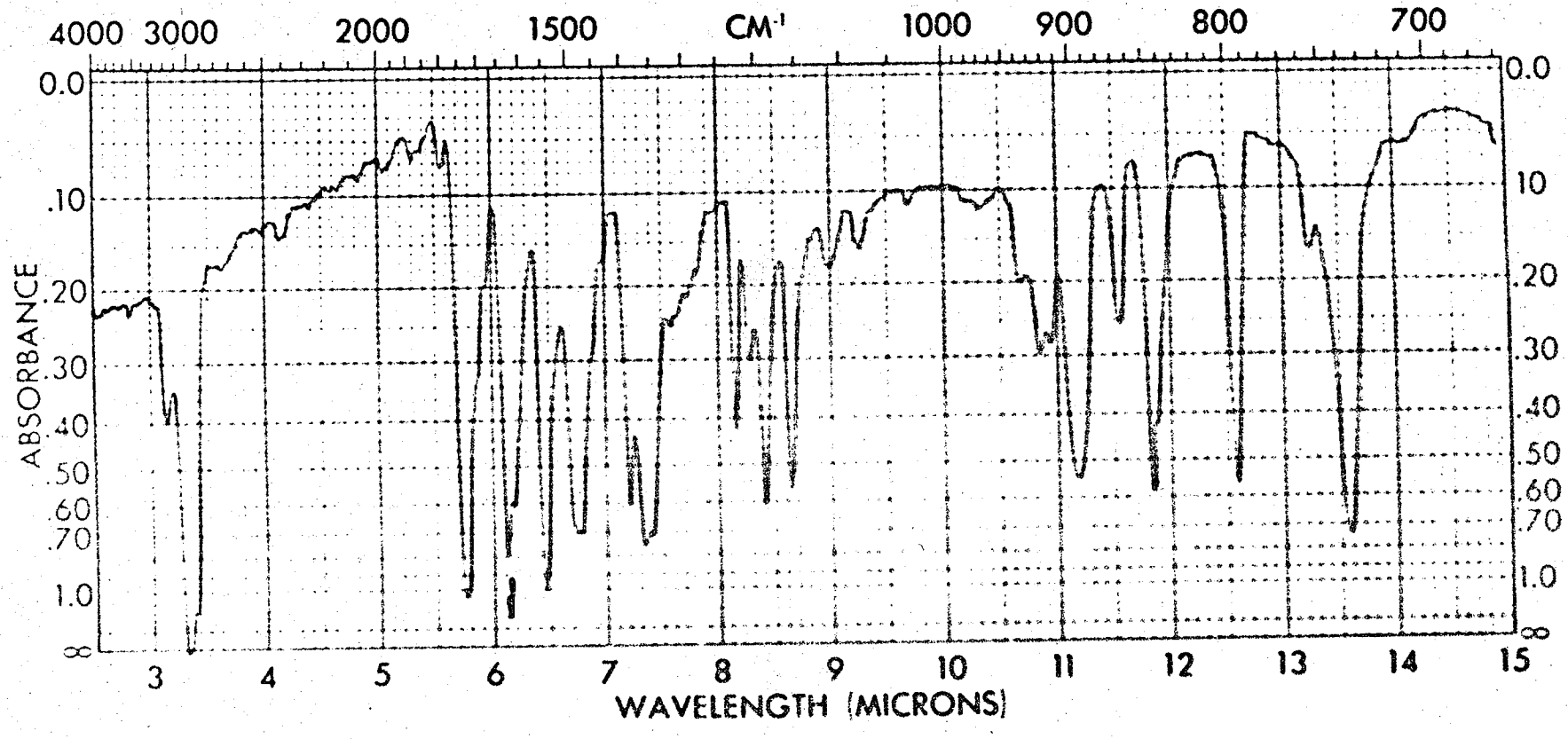
I. R. Spectrum of 5-Fluoro-2-(p-Nitrobenzoyl)-Benzoic Acid Azide (XXIV).

Phase-Nujol Mull.



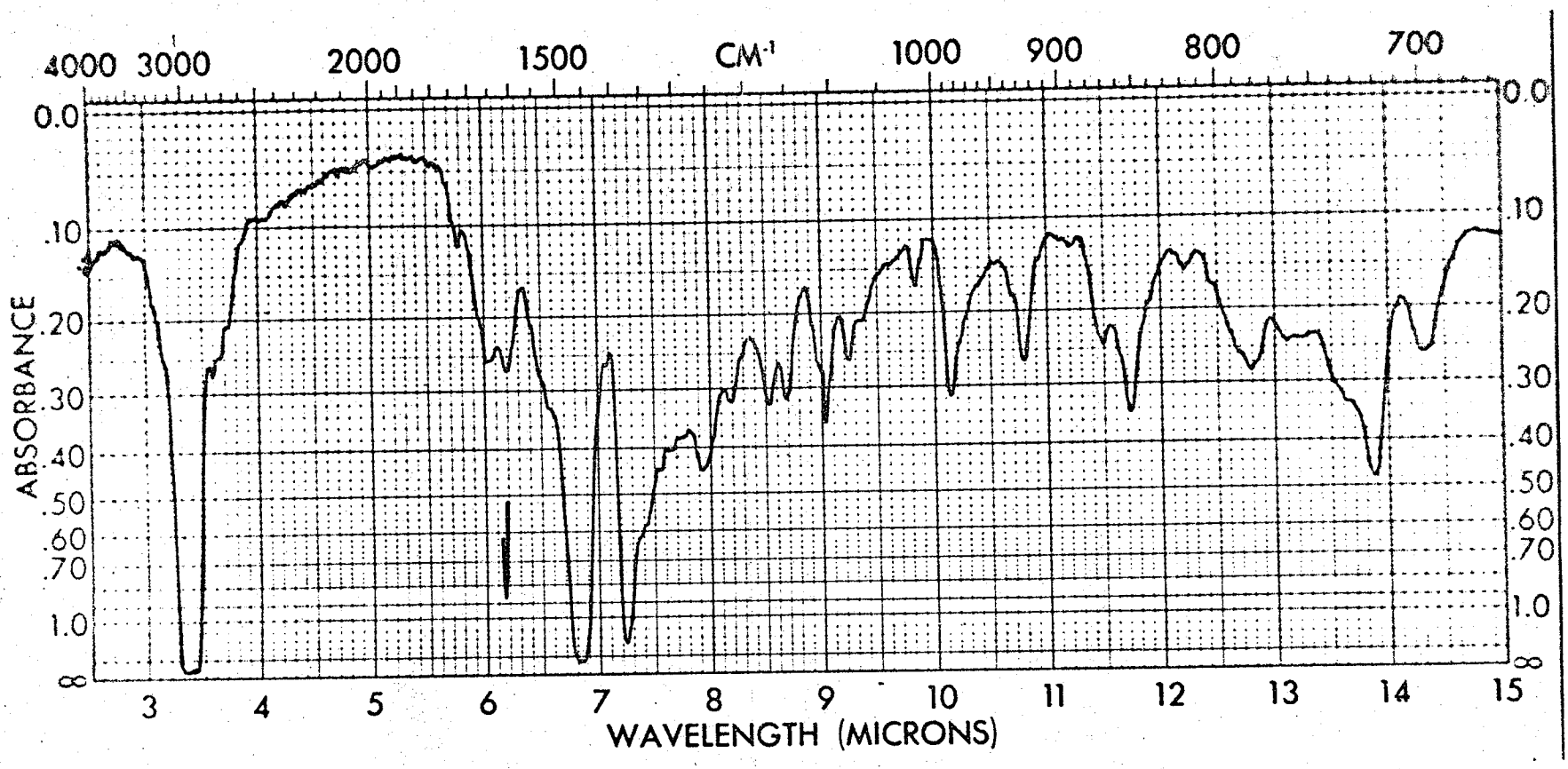
I. R. Spectrum of 5-Fluoro-2-(p-Nitrobenzoyl)-Aniline (XXV).

Phase-Nujol Mull.



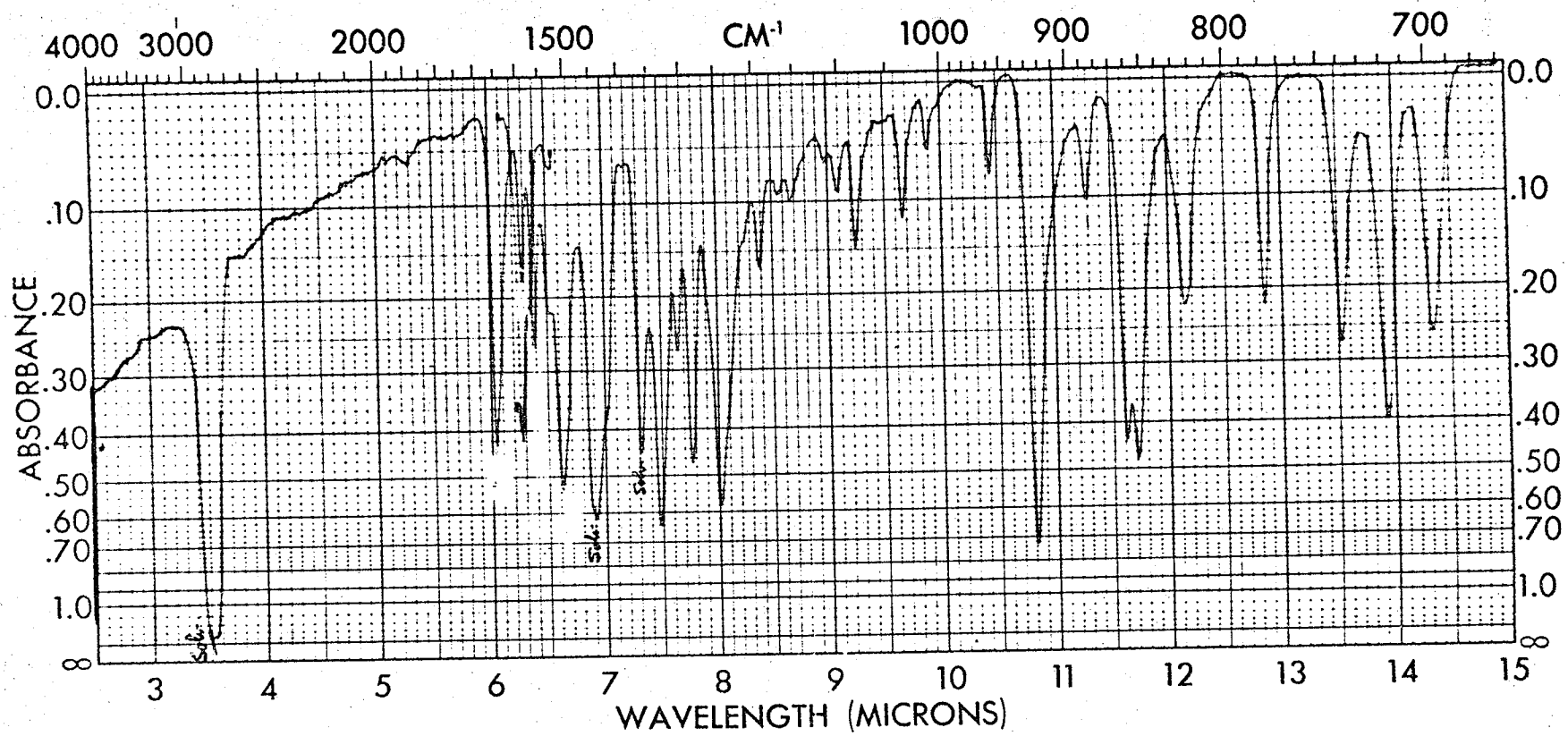
I. R. Spectrum of 3-Fluoro-6-Nitrofluorenone (XXVI).

Phase-Nujol Mull.



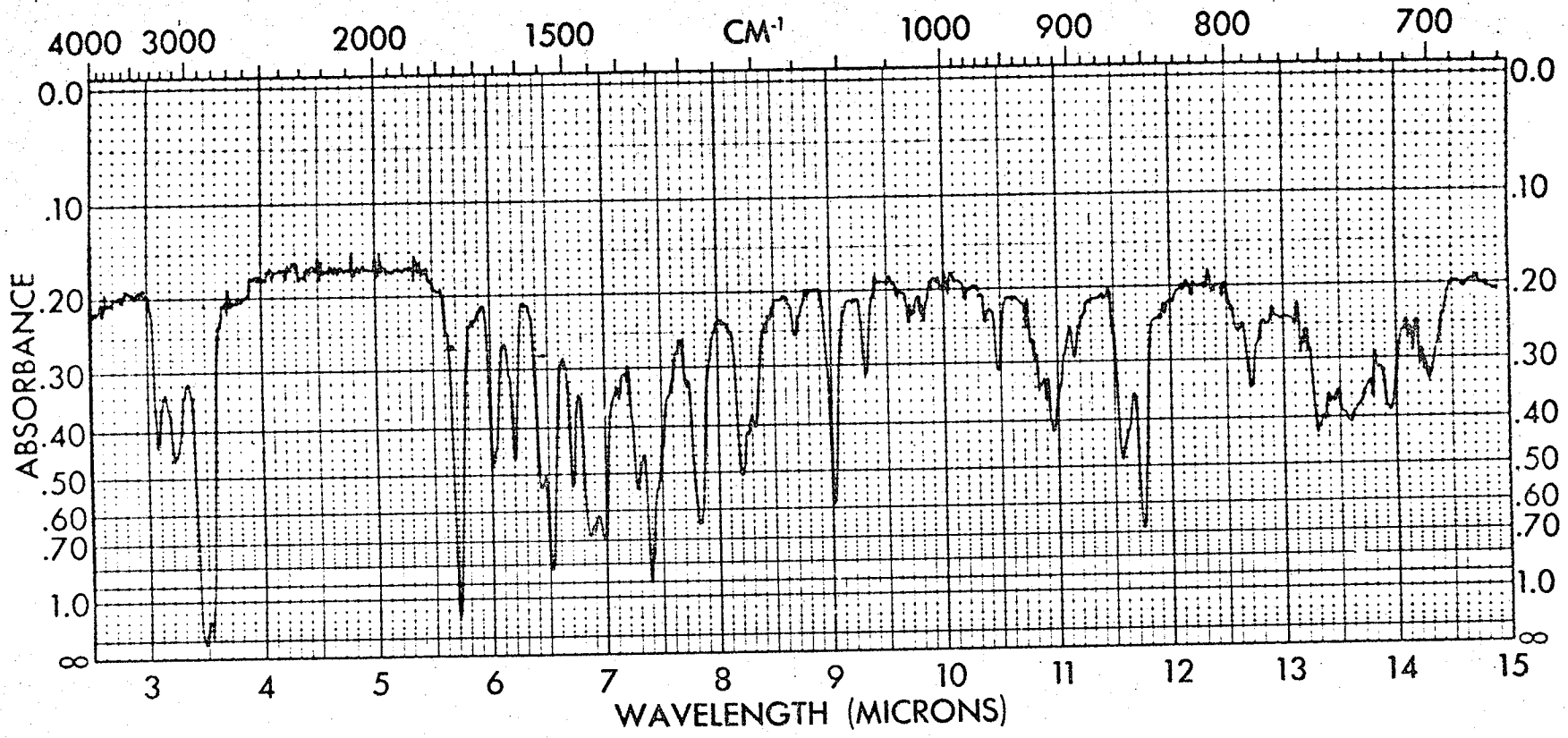
I. R. Spectrum of 2-Hydroxy-4-Fluoro-4'-Nitrobenzophenone (XXVII).

Phase-Nujol Mull.



I. R. Spectrum of 4-Iodo-2-Methyl-4'-Nitrobenzophenone (XXXI).

Phase-Nujol Mull.



I. R. Spectrum of 5-Acetamido-2-(p-Nitrobenzoyl)-Benzoic Acid (XXXIII).

Phase-Nujol Mull.