Some Condensation Reactions of Arylalkylnitriles.

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SOME CONDENSATION REACTIONS OF ARYLALKYLNITRILES

by

Alfred J. Barnard, Jr.

A DISSERTATION
Presented to the Graduate Faculty
of Lehigh University
in Candidacy for the Degree of
Doctor of Philosophy

Lehigh University
1950

Approved and recommended for acceptance as a dissertation in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

E D Amstutz

Accepted, 27 January 1950

Special committee directing the doctoral work of Mr. A. J. Barnard, Jr.

H A Neville Chairman
F. J. Fornoff
R. B. Sawyer.
E. D. Amstutz

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The author wishes to acknowledge his indebtedness to Professor E. D. Amstutz for his advice at various points of the investigations reported in this thesis, and his kind interest in the course of the work.

The ultraviolet absorption data reported in Part III were obtained on a Beckman Spectrophotometer, Model DU, kindly loaned by Professor E. J. Serfass.

A J Barnard, Jr.

A. J. Barnard, Jr.

AUTHOR'S NOTE:

All melting points recorded in this thesis are in degrees, Centigrade, and in the case of those determined by the author are uncorrected, but determined on a single 360° thermometer in a Thiele tube.

References to literature given in the bibliographies accompanying each part of this thesis are enclosed in virgules where cited in the text, thus, /28/.

TABLE OF CONTENTS

A BRIEF SUMMARY OF FINDINGS:

1) Ortho-phenylenediacetonitrile undergoes a novel condensation in the presence of bases with 1,4-dibenzoyl ethylene to give 1,4-dicyano-2-phenylnaphthalene and acetophenone in good yield. The principle involved in this condensation is capable of extension to other groupings than $-CH_2CN$, and to $-NH_2$ in particular.

2) 1,4-dicyano-2-phenylnaphthalene prepared as above is identical with $C_{18}H_{10}N_2$ of unknown structure obtained by Walther and Schickler by the action of phosphorus pentachloride on alpha-formyl-phenylacetonitrile. The course of this reaction is investigated as to scope and limitations. An unusual and novel migration (1,2-shift) of :CN is involved.

3) In the course of proving the structure of 1,4-dicyano-2-phenylnaphthalene obtained by the above routes, the correct structure for the product of the self-condensation of homophthaldehyde (incorrectly given by Baumgarten) has been elucidated to be 2-phenylnaphthalene 2',4-dialdehyde. Compounds derived from this product are assigned correct structures.

PART I

THE MICHAEL REACTION
IN
THE PREPARATION OF BICYLIC
COMPOUNDS

THE CHEMICAL & PHYSICAL PROPERTIES OF O-PHENYLENEDIACETONITRILE:

Ortho-phenylenediacetonitrile, 1,2-$C_4H_4(CH_2CN)_2$, is prepared in 60-70% yield by the procedure of Thorpe /2,5,27,30/ by the interaction of potassium cyanide and o-xylylene bromide, 1,2-$C_6H_4(CH_2Br)_2$, in ethanol-water at the boiling point. This procedure is described in detail in the experimental section.

This compound separates from methanol or ethanol under 18° as needles, and above 18° as yellow-white prisms. The needles are laible and past to the prisms on standing /5,27/. The compound melts at 59-60° /2/. It is somewhat volatile in steam /5/ and is soluble in ethanol and ethyl ether /5/.

By warming with dilute sulfuric acid o-phenylenediacetonitrile is hydrolyzed to o-phenylenediacetic acid /5/, and by the action of concentrated sulfuric acid to a mixture of the diamide and monoamide-acid /12,13/. With concentrated hydrochloric acid in a sealed tube at 110° the dinitrile is hydrolyzed almost quantitatively to the diacid in five hours /10/. By the action of alkalis the dinitrile is also hydrolyzed to the diacid /10/. With boiling ethanolic hydrogen chloride the dinitrile is converted to the diester /31/.

By the action of sodium ethoxide in boiling ethanol on o-phenylenediacetonitrile, 2-imino-1-cyano-hydrindene (m.p. 196°, colorless prisms) is produced; by the action of concentrated sulfuric acid at 0° the latter compound passes to 2-amino-indene 1-carboxylic acid /27/. With dilute acid the imino-compound passes to 2-indanone 1-carboxylic acid /27/.

Ruggli and co-workers /32-34/ reported that o-phenylenediacetonitrile is reduced by hydrogen at 90-100° and 75 atmospheres of pressure over a nickel to the cyclic imine, sym.-homotetrahydro-isoquinoline.

The reduction of o-phenylenediacetonitrile by sodium metal and ethanol has been studied by several workers /10, 16,39/. The major products of the reaction are 1,2-bis(beta-aminoethyl)benzene, $1,2\text{-}C_6H_4(CH_2CH_2NH_2)_2$, and 2-amino-2-methyl-indane.

Challenor and Ingold /12/ brominated o-phenylenediacetonitrile with bromine in chloroform to give the dibromo-derivative, $1,2\text{-}C_6H_4(CHBrCN)_2$, that on mild heating lost hydrogen bromide to give a resin analyzing for $(C_{10}H_4N_2)_x$. The dibromo-derivative on treatment with sodio-malonic ester at 0° for ten days passed to a polymer and ethyl 1-carboxamide-4-cyano-3-hydroxy-2-napthoate. The latter on basic hydrolysis passes first to 1,4-dicarboxamido-3-hydroxy-2-naphthoic acid, and then to 3-hydroxy-napthalene-1-carboxamide.

Several groups of workers have studied the condensation of o-phenylenediacetonitrile with 1,2-dicarbonyl systems. Hinsberg /22/ and Wislicenus and Penndorf /38/ in 1910 reported the use of sodium alkoxides in alcohols as effective agents for carrying out such condensations. With oxalic esters at room temperature 1,4-dicyano-2,3-dihydroxy-naphthalene and some of the corresponding amide-nitrile is obtained. Under similar conditions benzil produces 4-cyano-2,3-diphenylnaphthalene 1-carboxamide and some of the corresponding dinitrile. Similar reactions were observed with 9,10-phenanthrenequinone, and camphorquinone. In the last few years Moureau and co-workers /28/ have restudied the condensations of these 1,2-dicarbonyl systems with o-phenylenediacetonitrile using piperidine (aqueous, ethanolic, or absolute as the case required). The reaction in most cases was found to parallel the reaction with sodium alkoxides but seemed less generally in application. The reaction was successful in the case of biacetyl, 1,2-cyclohexanedione, 1,2-naphthoquinone, acenaphthenequinone, benzil, camphorquonone. The reaction failed with oxalylurea and isatin, piperidine itself reacting. With diethyl cyclopentane-1,2-dione 3,5-dicarboxylate and other alpha-keto-esters the reaction failed to proceed with piperidine or sodium alkoxides.

Fieser and Pechet /18,30/ reported the novel condensation of o-phenylenediacetonitrile with o-phthaldehyde, o-$C_6H_4(CHO)_2$, under the influence of sodium ethoxide in refluxing ethanol to give in 47% yield 3,8-dicyano-1,2,5,6-dibenzocycloöctatetraene. The latter on hydrolysis to the diacid and decarboxylation passed to 1,2,5,6-dibenzocyclooctatetraene and diphen-10--succindene.

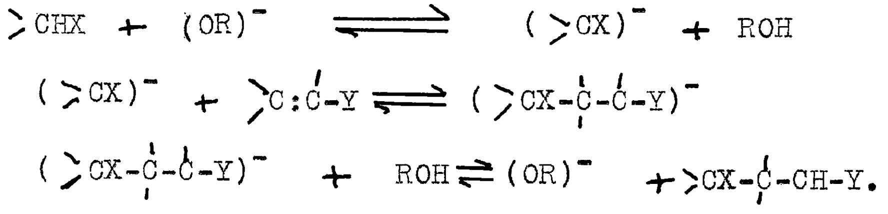
Waldmann and Pitschak /36/ have reported the condensation of o-phenylenediacetonitrile with o-nitrobenzaldehyde in ethanol in the presence of sodium hydroxide to yield 1,2-bis (2'-nitro-benzylidene-o-phenylenediacetonitrile. This compound could by hydrolyzed to the diacid, and the nitro groups reduced to amino groups. Diazotisation and the action of copper powder produced 12,13-picene dicarboxylic acid.

* * * * * *

PHENYLACETONITRILE IN MICHAEL CONDENSATIONS:

Alpha-beta unsaturated esters, ketones, and nitriles have all been reported to undergo Michael type condensations with phenylacetonitrile and certain of its nuclear substituted derivatives /1,3,4,6,15,17,21,23/. The monograph of Migridchian /26/ should be consulted for detailed examples. Such condensations have been carried out usually under the influence of sodium alkoxides in alcohols or ethers. In a few cases the reaction has been carried in moderate yield in the absence of any solvent /23/. In all cases the initial addition has been in accord with the general form of the Michael reaction.

The Michael reaction when brought about by treating a mixture of an alpha-beta-unsaturated compound and a substance containing an active methylene group with an alkoxide, it proceeds /23/ through the following stages where 'X' and 'Y' are electrophilic groups



$$>CHX + (OR)^- \rightleftharpoons (>CX)^- + ROH$$

$$(>CX)^- + >C{:}\overset{|}{C}-Y \rightleftharpoons (>CX-\underset{|}{\overset{|}{C}}-\overset{|}{C}-Y)^-$$

$$(>CX-\underset{|}{\overset{|}{C}}-\overset{|}{C}-Y)^- + ROH \rightleftharpoons (OR)^- + >CX-\underset{|}{\overset{|}{C}}-CH-Y.$$

But since, as Koelsch /23/ has observed not only the anion formed from the active methylene compound but also the alkoxide anion can add to the unsaturated system, the reaction involves also the equilibrium

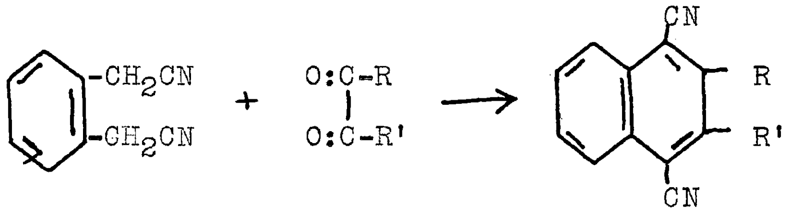
$$>CX-\underset{|}{\overset{\backslash\ |}{C}}-\overset{|}{C}H-Y \quad + \quad ROH \rightleftharpoons >CHX + >C(OR)-\overset{|}{C}H-Y.$$

However, in most cases the tendency for the latter alkoxy compound is relatively small, and the Michael reaction can be carried out successfully in alcoholic solution (cf. ref. 23, however).

The addition of a phenylacetonitrile derivative nuclear substituted with a second reactive group to alpha-beta-unsaturated carbonyl systems under conditions allowing the formation of a fused, six-membered ring system was not investigated prior to the present work.

O-PHENYLENEDIACETONITRILE CONDENSATIONS WITH 1,4-DICARBONYL SYSTEMS:

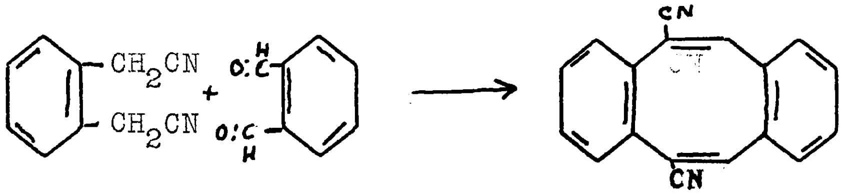
As described earlier under the reactions of o-phenylenediacetonitrile, the reactions of this compound with 1,2-dicarbonyl systems has been extensively studied. Such a reaction takes the general course



where R and R' are -OH ~~-OC$_2$~~H$_5$, alkyl or aryl groups, or a part of a ring system.

The reaction of o-phenylenediacetonitrile with 1,3-dicarbonyl systems seems not to have been investigated.

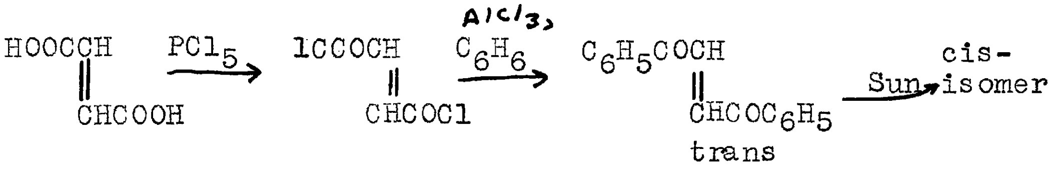
The reaction of o-phenylenediacetonitrile with the 1,4-dicarbonyl system of homophthaldehyde has been investigated by Fieser and Pechet /18/. In this case the rigidity of the benzene permits the formation of the fused, eight-membered ring system in 48% yield.



The present worker has now investigated in a more general fashion the interaction of o-phenylenediacetonitrile with 1,4-dicarbonyl systems.

In the hands of present workers using sodium alkoxides as the condensing agent, o-phenylenediacetonitrile gave no reaction with acetonylaceton, $CH_3COCH_2CH_2COCH_3$, and only resinous material with succinaldehyde, $OHCCH_2CH_2CHO$. Further work with 2,3-saturated-1,4-dicarbonyl systems was dropped. In an attempt to simulate the structure of o-phthaldehyde in an aliphatic compound malealdehyde OHCCH:CHCHO, and its acetal synthesized. From the reaction of either compound with o-phenylenediacetonitrile in the presence of sodium methoxide in methanol, no crystalline material could be isolated, only brown, tarry, apparently resinous material. These above observations were made at Harvard Univeristy in 1943 by the present worker.

In a further attempt, the study was directed toward 2,3-unsaturated-1,4-diketone structures as these are more stable to basic conditions and are relatively easy to prepare. For an initial experiment cis-1,4-dibenzoylethylene, $C_6H_5COCH{:}CHCOC_6H_5$, was chosen in view of its ready preparation from fumaroyl chloride and benzene in the presence of anhydrous aluminum chloride, followed by conversion of the resulting trans-form to the cis-form by exposure to direct sunlight in alcohol or acetone solution or suspension.

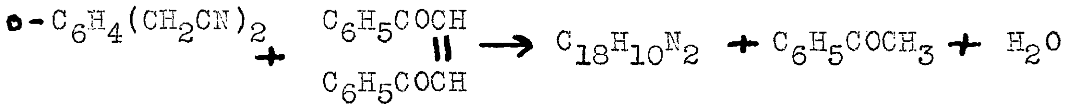


$$\begin{matrix}HOOCCH\\ \|\\ CHCOOH\end{matrix} \xrightarrow{PCl_5} \begin{matrix}lCCOCH\\ \|\\ CHCOCl\end{matrix} \xrightarrow[C_6H_6]{AlCl_3,} \begin{matrix}C_6H_5COCH\\ \|\\ CHCOC_6H_5\\ \text{trans}\end{matrix} \xrightarrow{Sun} \text{cis-isomer}$$

* * * * * * *

Reaction of Ortho-Phenylenediacetonitrile with 1,4-Dibenzoyl Ethylene:

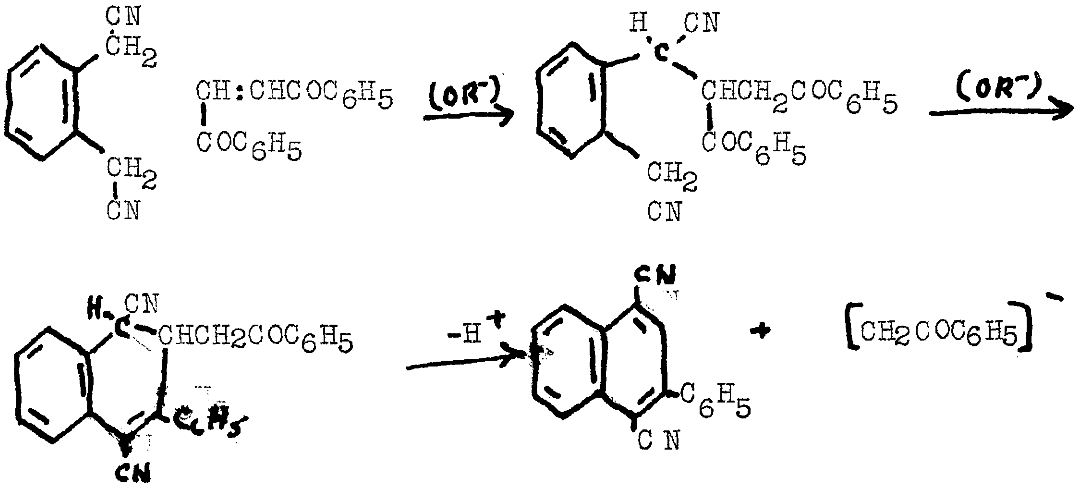
By the interaction of o-phenylenediacetonitrile with cis-1,4-dibenzoyl ethylene in warm, absolute ethanol or methanol in the presence of two or more moles of sodium methoxide it was found that a white to pale yellow precipitate appeared on cooling (without acidification) in the form of thin needles. The solution also had the strong odor of acetophenone. By dilution and/or concentration of the solution, further crops of the white to pale yellow precipitate appeared. On sublimation at 160-170° and 4 mm. pressure the crude precipitate sublimed readily as a pure white fluffy sublimate; reamining as residue was a small amount of yellow material. The white sublimate after recrystallization, on heating contracted at 182°, and melted at 183-183.5. Only with extensive recrystallization could the melting point be raised to 185°. This white compound gave a pale blue fluorescence in alcohol solution, and could be obtained in the form of long fluffy needles. It analyzed for $C_{18}H_{10}N_2$. As the presence of acetophenone in the reaction was conformed by its isolation as the p-nitro-phenylhydrazone, the reaction takes the course



$$o\text{-}C_6H_4(CH_2CN)_2 + \begin{matrix}C_6H_5COCH\\ \| \\ C_6H_5COCH\end{matrix} \longrightarrow C_{18}H_{10}N_2 + C_6H_5COCH_3 + H_2O$$

This compound $C_{18}H_{10}N_2$ is obtained in 70-80% of theory according to the above equation, and is demonstrated by the present work to be 1,4-dicyano-2-phenylnaphthalene. It is further demonstrated to be identical with the compound $C_{18}H_{10}N_2$ of unknown structure obtained by Walther and Schickler /37/ by the action of phosphorus pentachloride on alpha-formyl-phenylacetonitrile (see Part III, this thesis).

The novel course of this condensation of o-phenylenediacetonitrile with cis-1,4-dibenzoyl ethylene in the presence of alkoxides may be formulated as passing through the following intermediates or their conceptional equivalents:



It will be seen that the initial formation of intermediate A involves the addition of one acetonitrile grouping to the alpha-beta unsaturated carbonyl system under basic catalysis, and properly is described as a Michael reaction (see earlier in this thesis for brief discussion of the mechanism of the reaction). The formation of intermediate B from intermediate is of known type (aldol) involving base catalyzed addition of the acetonitrile grouping (as the anion) to the carbonyl group followed by the elimination of water. This intermediate B is able to aromatize as the carbon alpha to the upper nitrile group (in B, as written above) still bears a hydrogen atom that under the alkoxide catalysis can be ionized off leaving its electron pair behind. This pair can shift into the ring accompanied by the elimination of the anion of acetophenone (the latter being stabilized by the basic conditions prevailing). It will be noted that after the Michael addition, forming intermediate A, the double bond is destroyed and the subsequent steps would be the same whether the 1,4-dibenzoyl ethylene has the cis- or transconfiguration. The only possible difference in the course of the reaction with the cis- and with the trans-form might be in the rate of addition to the double bond in the initial step. In the Michael addition of aniline to 1,4-dibenzoyl ethylene /40,41/ both the cis- and trans-forms react in high yield, so that the rate of addition is probably of the same order in both forms. In the hands of the present worker both cis- and trans-dibenzoyl ethylene reacted to give 1,4-dicyano-2-phenylnaphthalene in similar yields if the trans- form was of the same degree of purity.

* * * * * *

The Proof of Structure of 1,4-Dicyano-2-Phenylnaphthalene:

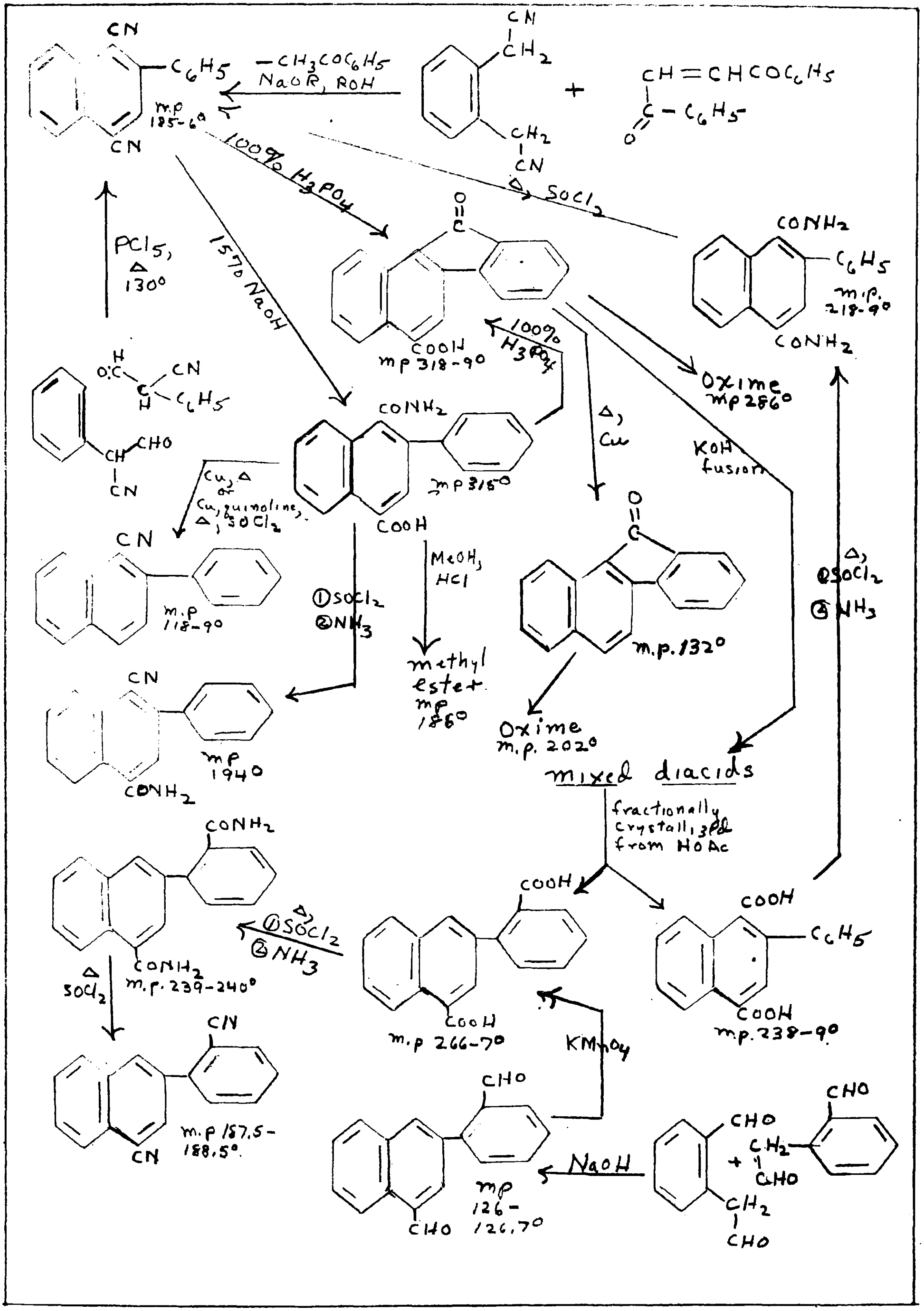
To prove the structure of this product $C_{18}H_{10}N_2$ to be that of 1,4-dicyano-2-phenylnaphthalene, the condensation of phenylglyoxal, C_6H_5COCHO, with o-phenylenediacetonitrile was attempted. However the condensation failed to proceed with either sodium methoxide in alcohol or piperidine alone or in alcohol as a catalyst, or when phenylglyoxal hydrate was employed. Such negative results were not anticipated in view of the ease with which benzil, $C_5H_5COCOC_6H_5$, or biacetyl, $CH_3COCOCH_3$, condense with o-phenylenediacetonitrile /22, 28,38/. However in this connection it may be noted that alpha-keto-esters fail to undergo the condensation, while in contrast oxalic esters react smoothly.

As a second approach the hydrolysis of the compound was studied. By the action of 15% potassium hydroxide in ethanol, the compound was hydrolysed to an amide-acid (4-amido-3-phenyl--1-naphthoic acid) clearly indicating that one nitrile group is more highly hindered than the other. Attempts at further alkaline hydrolysis using higher temperatures (196°, potassium hydroxide in ethyleneglycol) were unsuccessful. The action of hot sulfuric acid failed to hydrolyze the amide grouping, as also did the nitrous acid (Bouveault's method).

By the action of 100% phosphoric acid at 150-155° after the method of Berger and Olivier /9,29/ both the parent compound, 1,4-dicyano-2-phenylnaphthalene and its basic hydrolysis product were converted to a keto-acid having the properties of a fluorenone-acid, which gave on decarboxylation the known chrysofluorenone (i.e., 1,2-benzofluorenone). Thus the original parent compound is seen to have a 2-phenylnaphthalene structure, and a nitrile group on the 1- position. The ultraviolet spectra reported in Part III of this thesis also suggests a 2-phenylnaphthalene structure.

The proof that the second nitrile group is at position 4- is involved somewhat in the question of the nature of the correct structure of the dialdehyde obtained by Baumgarten /7,8/ by the self-condensation of homophthaldehyde and is discussed in greated detail in Part II of this thesis. A chart of reactions carried out by the present author, to demonstrate the presence of this cyano group on position 4- follows this page, and is probably easier to follow than any lengthy verbose explanation.

In passing it should be observed that the nitrile grouping cannot be at position 3- , as alkali cleavage of the fluorenone acid would yield 2-phenylnaphthalene 1,3-dicarboxylic acid and 2-phenylnaphthalene 2',3-dicarboxylic acid. The latter acid has been prepared /42/ in unambigous fashion, and differs in properties with either of the diacids actually obtained by the present worker on potassium hydroxide


CN
C₆H₅
m.p 185-6°
CN
-CH₃COC₆H₅
NaOR, ROH
CN
CH₂
CH₂
CN
+
CH=CHCOC₆H₅
C-C₆H₅
O
100% H₃PO₄
Δ, SOCl₂
PCl₅, Δ 130°
15% NaOH
O
C
COOH
mp 318-9°
CONH₂
C₆H₅
m.p. 218-9°
CONH₂
H
O:C
C
H
CN
C₆H₅
CH
CHO
CN
100% H₃PO₄
Oxime
mp 286°
CONH₂
mp 315°
COOH
Δ, Cu
KOH fusion
Cu, Δ or Cu, quinoline, Δ, SOCl₂
CN
m.p 118-9°
① SOCl₂
② NH₃
MeOH, HCl
methyl ester
mp 186°
O
C
m.p. 132°
Δ, ① SOCl₂ ② NH₃
CN
mp 194°
CONH₂
Oxime
m.p. 202°
mixed diacids
fractionally crystallized from HOAc
CONH₂
Δ, ① SOCl₂ ② NH₃
COOH
COOH
C₆H₅
CONH₂
m.p. 239-240°
Δ SOCl₂
COOH
m.p 266-7°
COOH
m.p. 238-9°
CN
KMnO₄
CN
m.p 187.5-188.5°
CHO
CHO
CH₂
+
CHO
CHO
NaOH
mp 126-126.7°
CHO
CH₂
CHO

fusion of the fluorenone-acid obtained from the parent compound.

The condensation of o-phenylenediacetonitrile with 1,4-dibenzoyl ethylene has also been brough about by the present worker at room temperature in absolute piperidine with a reaction time of several days. The yield is slightly below that obtained by the use of sodium methoxide. With piperidine as with sodium methoxide a small amount of yellow by-product is obtained. These results are interesting as Lutz and co-workers /42/ have reported that piperidine adds to 1,4-dibenzoyl ethylene on heating.

This yellow by-product in the reaction of o-phenylenediacetonitrile with 1,4-dibenzoylethylene, melts in the range 310-320°, seems crystalline, sublimes slowly at a bath temperature of 185-205° and 4-6 mm. pressure, shows no unsaturation to bromine in carbon tetrachloride, is neutral, is unaffected by prolonged treatment with 15% potassium hydroxide in ethanol can be separated from 1,4-dicyano-2-phenylnaphthalene by the insolubility of the latter in chloroform, and apparently analyzes for $(C_{16}H_{10-12}NO)_x$, however the nitrogen content seems variable from sample to sample. The use of sodium ethoxide as the condensing agent rather than sodium methoxide seems to lead to a higher yield of this yellow by-product, but this observation is made with reservation as the data are meager. This yellow by-product has not been subjected to further study, and no compound of similar empirical formula and properties was revealed on cursory search of formula indexes of relevant compendio.

* * * * * *

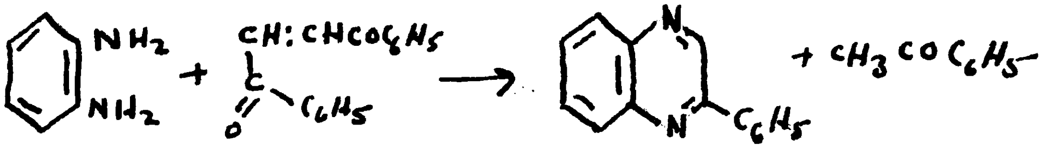
Attempted Reactions of Ortho-Phenylenediacetonitrile with Other Unsaturated Carbonyl Systems:

In an attempt to extend this novel condensation of ortho-phenylenediacetonitrile with 2,3-unsaturated-1,4-dicarbonyl systems, the reaction was attempted with ethyl maleate, $C_2H_5OCOCH:CHCOOC_2H_5$, with sodium methoxide (in methanol or without solvent) or piperidine in ethanol with negative results. The results were also negative with maleic anhydride and sodium methoxide, and with 1,4-naphthoquinone.

* * * * * *

The Reaction of Ortho-Phenylenediamine with 1,4-Dibenzoyl Ethylene:

In a further study consideration was given to what other functional groups might be used instead of acetonitrile groups. Paal and Schulze /41/ and Lutz and co-workers /42/ have shown that aniline and certain aliphatic and cyclic amines due undergo Michael condensation with cis- and trans-1,4-dibenzoyl ethylene on mere warming. In view of this finding, o-phenylenediamine, x o-$C_6H_4(NH_2)_2$, was studied. On warming of this compound with cis-1,4-dibenzoyl ethylene in alcohol, 2-phenylquinoxaline was isolated and the solution had the odor of acetophenone. The reaction proceeded in moderate yield with or without the addition of minute amounts of sodium methoxide.



EXPERIMENTAL WORK, PART I

Preparation of Fumaroyl Chloride /16/:

Mix 355 grams of powdered phosphorus pentachloride and 101.5 grams of fumaric acid in a round bottom flask under a hood. Swirl the flask to provide adequate mixing. The mixture liquefies with the evolution of hydrogen chloride. When liquefaction is complete, distill through a short column. From 106-110° a phosphorus oxychloride fraction distills off, followed by fumaroyl chloride fraction from 155-162°. Redistillation of this latter fraction gives fumaroyl chloride of suitable purity for the preparation of dibenzoyl ethylene.

* * * * *

Preparation of O-Phenylenediacetonitrile /1,2,17,19/:

To a boiling solution of 27 grams of potassium cyanide in 100 ml. of water and 200 ml. of 95% ethanol, 40 grams of powdered o-xylylene bromide (Eastman) was added gradually at such a rate that the heat of reaction was just sufficient to keep the solution boiling. After standing one hour at room temperature, the solution was diluted with water, and oil separating was extracted with ether. The combined ether extracts were dried over either sodium sulfate or magnesium sulfate, and evaporated to dryness to a dark crystalline residue. Recrystallization from ethanol with treatment with Norite gave 14.5 grams (62%) of o-phenylenediacetonitrile as light yellow prisms, melting point 59-60°. (Literature: 59.5 - 60.5°/28/).

* * * * * *

Preparation of Trans-1,4-Dibenzoyl-Ethylene /14/:

In a 2l. round bottomed flask fitted with a dropping funnel, liquid seal stirrer, and a reflux condenser having a hydrogen chloride trap was placed 1000 g of dry benzene and 400 g of finely powdered anhydrous aluminum chloride. During the period of one hour 200 g. of fumaryl chloride (b.p. 159-161°) was added with constant stirring. The stirrer was removed and the solution was refluxed for two hours. The initially red reaction mixture progressively lightens to a yellow pasty mass. The reaction mixture was cooled to room temperature and poured into a 3l. beaker partially filled with ice and 100 ml. of dilute hydrochloric acid. The temperature was allowed to come to room temperature, and sufficient benzene added to get all organic material into solution. The benzene layer was separated, and evaporated to dryness. The residue was dissolved in hot 95% ethanol, treated with Norite, and recrystallized. The yield was 258 grams (85% on fumaryl chloride) of trans 1,4-dibenzoyl-ethylene as yellow needles. Melting point 110°. Alternately the reaction product can be recrystallized from benzene or acetone.

Preparation of Cis-1,4-Dibenzoyl-Ethylene from its Trans Form /14/:

The yellow crystals of trans-1,4-dibenzoyl-ethylene were placed in contact with 95% ethanol or acetone, and allowed to stand in direct sunlight until the solution and crystals became very faint yellow to white in color. The crystals were filtered off, and further crops obtained by dilution or concentration of filtrate. Recrystallization from ethanol-water or benzene gave long, white needles of cis-1,4-dibenzoyl-ethylene, melting point 134°. The conversion is quantitative.

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Reaction of Ortho-Phenylenediacetonitrile with Cis-1,4-Dibenzoyl Ethylene:

Two grams of (0.0870 moles) of sodium metal under exclusion of moisture was dissolved in 200 ml. of absolute methanol that had been distilled directly into the reaction vessel from magnesium methoxide-methanol mixture (Lund and Bjerrum, Ind. Eng. Chem., Anal. Edit., _6_, 151 (1931)). 6.7 grams (0.0429 moles) of finely powdered o-phenylenediacetonitrile previously dried over sulfuric acid _in vacuo_ was added, and the vessel swirled to hasten solution. The solution became yellow to brown in color. 10.1 grams (0.0428 moles) of finely powdered cis-1,4-dibenzoyl ethylene previously dried over sulfuric acid _in vacuo_ was added, and the vessel again swirled to effect total solution. The solution became progressively deep red in color, and was allowed to stand at room temperature for thirty minutes, followed by warming in a water bath at 55-60° for thirty minutes. The reaction mixture was cooled to -3° in a ice-salt mixture. The faint yellow precipitate that had appeared during the course of the reaction or on cooling was suction filtered, washed with water, followed by a little cold methanol, and dried. The water and methanol wash had the strong odor of acetophenone and was combined with the main filtrate. By concentration under reduced pressure and dilution further white to yellow precipitates were obtained. On acidification of the final filtrate with acetic acid, a small amount of tarry material separated that was possibly unreacted o--phenylenediacetonitrile, and a small amount of acetophenone as an oil.

The precipitate was in the form of thin needles, and the successive crops were more yellow in color. The combined dried precipitates were sublimed at 165-170° and 4 mm. pressure or at 170-180° at 15 mms. The combined white fluffy crystalline sublimate weighed about 8.70 grams, and in a sealed capillary melted at 180-181.5°. Recrystallization from ethanol or acetone-water gave 8.50 grams (0.0334 moles) of 1,4-dicyano-2-phenylnaphthalene as white, long feathery needles shrinking at 182° and melting at 183.0-183.5°, and on resolidification melting at 185.2-186.0°. The yield is 78% of theory. <u>Analysis</u>: Theory for $C_{18}H_{10}N_2$, C, 85.02, H, 3.96, N, 11.02%; <u>found</u>: C, 85.09%, H, 3.74%, N, 10.87%, 11.05%.

Remaining in the sublimation tube was a fluffy, canary yellow, crystalline residue. This was sublimed slowly at a bath temperature of 185-200° and 4-6 mm. pressure. About 0.9 grams of canary yellow sublimate was obtained melting at 315-319°. (See further for discussion of this product).

From the acidified filtrate or the methanol distallate obtained in the concentration process, by the action of p-nitro-phenylhydrazine, the p-nitro-phenylhydrazone of acetophenone could be isolated as red crystals. These on recrystallization from absolute ethanol melted at 183.5-184°, and showed no depression on mixed melting point of an authentic sample of the hydrazone (melting point, 184°) prepared from commercially available acetophenone.

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4-Amido-3-Phenyl-1-Naphthoic Acid from 1,4-Dicyano-2-Phenylnaphthalene:

A solution of 1 g. (1/254 mole) of 1,4-dicyano-2-phenylnaphthalene in 50 ml. of 15% ethanolic potassium hydroxide solution was refluxed for 16 hours. The ethanol was evaporated, and the residue taken up in 100 ml. of distilled water. The acidity of the resulting solution was adjusted to about pH 8, it was filtered, and the filtrate was chilled and acidified with dilute hydrochloric acid solution. The resulting precipitate was filtered, washed with water, again taken up in alkali, and reprecipitated. After drying there was obtained 1.08 g. (94.5% yield) of 4-amido-3-phenyl-1-

naphthoic acid as an off white, decomposing at 312-315° on rapid heating. Recrystallization from ethanol gave minute needles shrinking at 312-3° (uncor.) melting with decomposition at 315-6° (uncor.). Analysis: Cald. for $C_{18}H_{13}O_3N$: C, 74.22%; H, 4.50%; N, 4.81%; Found: C, 74.32; H, 4.54; N, %. Neutral equivalent: theory, 291.29; found, 297.

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Preparation of 1-Cyano-2-Phenylnaphthalene from 4-Amido-2-Phenyl-1-Naphthoic Acid:

Procedure A: 500 milligrams of 4-amido-2-phenyl-1-napthoic acid and 500 milligrams of copper bronze that had been washed with ether in quinoline were heated at a bath temperature of 225° for two hours when evolution of carbon dioxide had ceased. The quinoline layer was decanted, and the copper bronze was rinsed several times with hot benzene. The benzene wash was combined with the quinoline and the mixture heated to drive off all the benzene. The resulting quinoline solution was mixed with 50 ml. of concentrated hydrochloric acid and the precipitate appearing on solution of the quinoline was separated in a sintered glass filter by suction, washed with concentrated hydrochloric acid, water, dilute sodium hydroxide to remove any unchanged starting material, finally, with water, and dried in vacuo. Recrystallization from alcohol with treatment with Norite gave 270 mgs. (68.9%) of 1-cyano-2-phenylnaphthalene as glistening, white crystalline plates, m.p. 119-119.6°. Analysis: Theory for $C_{17}H_{11}N$: C, 89.07% H, 4.84%, N, 6.11%; Found C, ; H, N, 6.04%.

Procedure B: 380 milligrams of 4-amido-2-phenyl-1-naphthoic acid placed in test tube with 2 grams of copper powder that had been washed with ether (largely mixed with the acid and covered with a layer). Heated to 285° where slow evolution of carbon dioxide comenced. Heating continued for two hours when gas evolution ceased. On the upper cooler walls of the tube the condensation of water was noted, and on the walls near the hot zone pale yellow-white crystals clung. The crystals were taken up in acetone, and the copper residue washed with acetone, and the combined acetone solutions were evaporated to dryness. The residue was sublimed in vacuo at 150° and 15 mm. The sublimate was recrystallized from ethanol-water with treatment with Norite gave 182 milligrams of 1-cyano-2-phenylnaphthalene (60.8%) as faint yellow plates of melting point 118.2-118.6°, mixed melting point with material from Procedure A, 119°. From residue of unsublimed material by repeated recrystallization from ethanol-water 36 milligrams of deep yellow plates, m.p. 113.5-115° were obtained. In other runs where the heating was conducted at temperature greater than 285°, the product was yellow in color of m.p. 113-115°, and could only by purified by repeated recrystallization and sublimation.

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Action of Potassium Hydroxide in Ethylene Glycol on 4-Amido-3-Phenyl-1-Naphthoic Acid.

0.178 grams of 4-amido-3-phenyl-1-naphthoic acid, 2.5 grams of potassium hydroxide, and 15 ml. of ethylene glycol heated at 190° for 8 hours. Most of the ethylene glycol was stripped under reduced pressure, and the residue was taken up in 100 ml. of distilled water. The acidity of the solution was adjusted to about pH 8, the solution was filtered. Acidificatio, filtration, washing with water, and drying *in vacuo* yielded 0.160 grams of slightly tan material of m.p. 255-7° with decomposition and of neutral equivalent of 286 (theory for $C_{18}H_{10}NO_3$, 291.3). The product is probably a mixture of unchanged 4-amido-3-phenyl-1-naphthoic acid and 4-cyano-3-phenyl-1-naphthoic acid.

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Methyl, 4-Amido-3-Phenyl-1-Naphthoate:

250 mgs. of 4-amido-3-phenyl-1-naphthoic acid suspended in 20 ml. of methanol. On saturation with dry hydrogen chloride gas, total solution was affected. The solution was allowed to stand at room temperature for 6 hours. After evaporation to small volume, water was added, and the precipitate was filtered, washed with dilute alkali followed by water. On drying *in vacuo*, 245 mgs. of slightly yellow prisms were obtained, melting at 181-182.5°. Recrystallization from methanol with treatment with Norite yielded 230 mgs. (87%) of methyl, 4-amido-3-phenyl-1-naphthoate as white prisms melting at 185.5-186°. Analysis: Cald. for $C_{19}H_{15}O_3H$: N, 4.59%; Found: N, 4.54%.

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11-Keto-5-Chrysofluorene Carboxylic Acid from 1,4-Dicyano-2-Phenylnaphthalene.

Ten grams of phosphorous pentoxide was added in small portions to 20 grams of 85% phosphoric acid in a round bottomed flask, and the mixture warmed until it was homogeneous. On cooling to room temperature 1 gram of 1,4--dicyano-2-phenylnaphthalene was added and stirred into the phosphoric acid. The flask was fitted with a drying tube and heated in an oil bath at 150-160° for six hours. The contents of the flask becomes deep red in color. After cooling to room temperature, the reaction mixture was drowned in a large volume of ice water, and the resulting aqueous suspension of highly dispersed red material was heated to boiling for fifteen minutes with occasional stirring. Cooled to room temperature, and suction filtered. The red-orange precipitate after washing with warm water, was taken up in dilute alkali, filtered, cooled to 0-5° and made acid by the slow addition of hydrochloric acid with continual stirring. If the operation was conducted properly, a flocculent, orange-red precipitate was obtained that could be suction filtered, washed with water, and without drying recrystallized from acetic acid. Alternately, if the precipitate was almost colloidal in size, the fluorenone was extracted with ether, the ether layer was washed with water and evaporated, and the residue without drying recrystallized from glacial acetic acid. After drying in vacuo over sodium hydroxide, 790 milligrams (73.3%) of 11-keto-5-chrysofluorene carboxylic acid was obtained as minute orange needles or red prisms of melting point 318-319° (uncor.) with decomposition in an open capillary tube. No depression in melting point with the compound prepared according to the method of Baumgarten /8/ and previously described as 11-keto-4-fluorene carboxylic acid. Analysis: Theory for $C_{18}H_{10}O_3$: C, 78.82%, H, 3.68%, neutral equivalent, 274.3; found: C, 78.97, 79.19%; H, 4.81%, 4.61% (sample hard to free of all water), neutral equivalent in ethanol with outside indicator due to marked color of solution, 265.

In runs at higher temperatures (~~270-290~~ 170 290°) appreciable charring was observed, and substantial amounts of chrysofluorenone (melting point 131.5-132° after recrystallization) could be recovered from the neck of the flask where it had sublimed and from the residue remaining after the reaction product was taken up in alkali according to the above procedure.

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11-Keto-5-Chrysofluorene Carboxylic Acid from 4-Amido-3-Phenyl-1-naphthoic Acid

One gram of 4-amido-3-phenyl-1-naphthoic acid was treated with 100% phosphoric acid essentially according to the above procedure for 1,4-dicyano-2-phenylnaphthalene. After recrystallization from glacial acetic acid, and drying *in vacuo* over sodium hydroxide, 860 milligrams (91.4%) of 11-keto-5-chrysofluorenone carboxylic acid, melting point, 318-9° (uncor.) with decomposition, was obtained.

Oxime of 11-Keto-5-Chrysofluorene Carboxylic Acid:

An attempt to prepare the oxime of 11-keto-5-chrysofluorene carboxylic acid by Procedure B, page 202 of Shriner and Fuson (Identification of Organic Compounds, 3rd Edition, Wiley, 1948) failed unless excess alkali and a longer period of heating (two hours) was employed. On dilution with water and acidification, the crude oxime precipitated. Recrystallization from acetic acid gave the oxime as a yellow-orange powder, melting point 285.5-286.5°. Analysis: Calculated for $C_{18}H_{11}NO_3$, N, 4.84%, Found; N, 4.77%.

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Chrysofluorenone and its Oxime from 11-Keto-5-Chrysofluorene Carboxylic Acid:

294 mgs. (0.00107 moles) of 11-keto-5-fluorene carboxylic acid was mixed with 2 g. of copper powder (J.T.Baker) in round bottom flask fitted with air condenser and carbon dioxide trap. The flask was maintained at 275° for three hours when evolution of carbon dioxide ceased. A small amount (8 mgs.) of red crystalline material condenser, melting point 141-3°, and was not further investigated. The contents of the flask were repeatedly treated with hot acetone, and the combined acetone extracts were filtered, and evaporated to dryness. Washing of the residue with dilute alkali alkali revealed no acidic material remaining. The residue after washing with water to remove alkali was taken up in glacial acetic acid. A small amount of tarry material that

did not dissolve readily was filtered out. The hot filtrate was adjusted to the point of incipient precipitation with water, and allowed to stand overnight at room temperature, then cooled to 5°. The crop of yellow crystalline plates was filtered, and further crops obtained by concentration and addition of water. The combined yield of yellow plates of chrysofluorenone, m.p. 132° (132.5°, /8/), was 197 mgs. (0.000856 moles) or 79.9%.

Chrysofluorenone oxime, m.p. 202° (literature, 202°) was prepared from the above sample of chrysofluorenone after Method B of Shriner and Fuson, "The Systematic Identification of Organic Compounds", 3rd edition, p. 202, but with the reaction mixture refluxed for two hours.

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Cleavage of 11-Keto-5-Chrysofluorene Carboxylic Acid to Mixed Diacids:

Ten grams of potassium hydroxide and 1.5 ml. of water was melted in a iron crucible and one gram (0.00365 moles) of 11-keto-5-chrysofluorene carboxylic acid was stirred in. The temperature was raised slowly to 200-205°, and maintained for two hours. The crucible was cooled and the black-red mass taken up in water. The acidity of the water solution was adjusted to about pH 8.5 and it was suction filtered. The filtrate was made acid with hydrochloric acid, and the precipitate filtered. The precipitate was redissolved in dilute alkali and treated with active carbon that removed most of the yellow color. Acidification, filtration, washing with water, and drying in vacuo yielded 950 mgs. (0.00324 moles) or 89.2% of a mixture of 2-phenylnaphthalene 2',4-dicarboxylic acid and 2-phenylnaphthalene 1,4-dicarboxylic acid, melting range 242-251°, neutral equivalent 153 (theory for $C_{16}H_{10}(COOH)_2$, 146.14).

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11-Keto-5-Chrysofluorene Carboxylic Acid from Mixed Diacids:

Forty mgs. of the mixture of 2-phenylnaphthalene 2',4-dicarboxylic acid and 2-phenylnaphthalene 1,4-dicarboxylic acid was added to 3 ml. of concentrated sulfuric acid, and stirred to bring about solution. Allowed to stand at room temperature fifteen minutes, and drowned in 30 mls. of water. The red-orange precipitate was suction filtered, dried in vacuo, m.p. 317-318° with decomposition; mixed melting point with 11-keto-5-chrysofluorene carboxylic acid showed no depression .

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2-Phenylnaphthalene 1,4- and 2'4-Dicarboxylic Acids From Mixed Diacids:

900 mgs. of the mixed diacids from the potassium hydroxide fusion of 11-keto-5-chrysofluorene carboxylic acid was crystallized fractionally from warm glacial acetic acid. The 2-phenylnaphthalene 2',4-dicarboxylic acid is the least soluble of the two diacids and separates in the earlier fractions. By repetition of the process, and final recrystallization from absolute ethanol, 490 mgs. of 2-phenyl-

naphthalene 2',4-dicarboxylic acid, melting point 266-267° as a white powder, and 220 mgs. of 2-phenylnaphthalene 1,4-dicarboxylic acid, melting point 238-239° as a faint yellow powder. The 2-phenylnaphthalene 2',4-dicarboxylic acid showed no depression on mixed melting point determination with a sample from the oxidation of 2-phenylnaphthalene 2',4-dialdehyde (obtained by the method of Baumgarten /8/).

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<u>2-Phenylnaphthalene 2',4-Dicarboxamide from 2-Phenylnaphthalene 2',4-Dicarboxylic Acid</u>:

<u>Procedure A</u>: 300 mgs. of 2-phenylnaphthalene 2',4-dicarboxylic acids and 30 mls. of dry benzene and 3 mls. of thionyl chloride were warmed for ten minutes, and then evaporated to dryness on water bath. 30 mls. more of benzene and 3 mls. of thionyl chloride were added, and again evaporated to dryness. To the residue was dissolved in dry acetone and was added to chilled concentrated aqueous ammonia dropwise. After dilution with water, the precipitate was filtered, washed with 5% alkali, water and dried. Recrystallization from 95% ethanol gave 259 mgs. (90.4%) of 2-phenylnaphthalene 2',4-dicarboxamide as a white powder, melting point 239-240°. <u>Analysis</u>: Calculated for $C_{18}H_{14}N_2O_2$: N, 9.65%; <u>Found</u>: N, 9.56%.

<u>Procedure B</u>: 170 mgs. of 2-phenylnaphthalene 2',4-dicarboxylic acid was refluxed one hour in dry benzene with about 0.275 g. of phosphorus pentachloride. Dry ammonia

gas was then bubbled in under good cooling, the benzene was evaporated, and water was added to the residue. The precipitate was filtered, washed with 5% alkali solution, water, and dried in vacuo to a white powder, melting point 238-240°. Recrystallization from 95% ethanol gave 0.155 g. (91.8%) of 2-phenylnaphthalene 2',4-dicarboxamide as a white powder, melting point 239-240°.

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2',4-Dicyano-2-Phenylnaphthalene from 2-Phenylnaphthalene 2',4-Dicarboxamide:

250 milligrams of 2-phenylnaphthalene 2',4-dicarboxamide was refluxed in 6 ml. of thionyl chloride and 6 ml. of dry benzene for one hour. Additional thionyl chloride was added and reflux continued for thirty more minutes. The reaction mixture was evaporated to dryness. The residue was washed with water, and recrystallized from ethanol with treatment with Norite then sublimed at 170° at 5 mm. pressure. The white, crystalline sublimate softened at 185° and melted at 187.5-188.5° in a sealed capillary. Mixed melting point with 1,4-dicyano-2-phenylnaphthalene (melting point 185-186°) showed depression of melting point to 155-164°. Analysis: Calcd. for $C_{18}H_{10}N_2$; N, 11.03%; Found: N, 10.71%.

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2-Phenylnaphthalene 1,4-Dicarboxamide from 2-Phenylnaphthalene 1,4-Dicarboxylic Acid:

200 milligrams of 2-phenylnaphthalene 1,4-dicarboxylic acid (melting point 238-239°) and 0.4 grams of phosphorus

pentachloride refluxed in 20 ml. of dry benzene for 30 minutes. Dry ammonia was then passed in under good cooling. The benzene was evaporated, and water added to the residue. The precipitate was suction filtered, washed with 5% alkali solution, water, and dried *in vacuo*. 160 milligrams of 2-phenylnaphthalene 1,4-dicarboxamide were thus obtained as a white powder of melting point 217-219°. Sublimation at 165° and 4 mms. pressure gave a white microcrystalline powder melting point 218-219°. *Analysis:* Calcd. for $C_{18}H_{14}N_2O_2$; N, 9.65%; *Found:* N, 9.37%.

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1,4-Dicyano-2-Phenylnaphthalene from 2-Phenylnaphthalene 1,4-Dicarboxamide:

100 milligrams of 2-phenylnaphthalene 1,4-dicarboxamide was refluxed with 3.5 ml. of thionyl chloride and 4 ml. of dry benzene for one hour. Additional thionyl chloride was added and refluxed continued for thirty more minutes. The reaction mixture was evaporated to dryness. The residue was washed with water, taken up in the minimum amount of hot acetone; this evaporated off in an open sublimation tube, and the residue was sublimed at 165° at 5 mms. pressure. The white sublimate melted at 184-185° with preliminary softening at 182.5°. Mixed melting point with 1,4-dicyano-2-phenylnaphthalene obtained by the reaction of o-phenylenediacetonitrile with 1,4-dibenzoyl ethylene showed no significant depression (melting point 184-184.5°).

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4-Cyano-3-Phenylnaphthalene 1-Carboxamide from 4-Amido 3-Phenyl-1-Naphthoic Acid:

290 mgs. (0.00099 moles) of 4-amido-3-phenyl-1-naphthoic acid refluxed with 6 ml. of thionyl chloride for one and one-half hours. The excess thionyl chloride was evaporated off and the residue was taken up in acetone(dried over calcium chloride and distilled). The chilled acetone solution was added to chilled concentrated aqueous ammonia. The resulting mixture was diluted with a little water, cooled to 5° and suction filtered. The precipitate was recrystallized from acetone-water. The yield was 140 mgs. (0.00047 moles) of 4-cyano-3-phenylnaphthalene 1-carboxamide (51.4% yield) as a white powder of melting point 210-211°. Analysis: Calcd. for $C_{18}H_{12}N_2O$: N, 10.28%; Found: N, 10.07%.

From the aqueous filtrate by acidification about 60 mgs. of acidic material of melting point 302-303° with decomposition was recovered; it is largely unchanged 4-amido-3--phenyl-1-naphthoic acid.

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Reaction of Phenylglyoxal with Ortho-Phenylenediacetonitrile:

Variation A: 30 ml. of methanol was distilled into the reaction vessel from a magnesium methoxide-methanol mixture, and 0.14 grams (0.006 moles) of sodium metal were dissolved in it under exclusion of moisture. 0.31 grams (0.002 moles) of o-phenylenediacetonitrile was added and solution effected by shaking and swirling of the reaction vessel. 0.27 grams (0.002 moles) of anhydrous phenylglyoxal (freshly distilled) was added, and the solution turned wine red in color. The solution was heated on a water bath, refluxed for ten minutes, and allowed to stand at room temperature for twelve hours. A large portion of the methanol was evaporated on a water bath, and as no precipitate had appeared on cooling, the solution was diluted with about 100 ml. of water. Material of apparently resinous nature separated. Attempts at isolating crystalline material from this by the use of solvent pairs failed. Boiling of the resinous material with water and cooling, led to the separation of a small amount of phenylglyoxal hydrate.

Variation B: The reaction described above was attempted in dioxan using sodium methoxide (Eastman, practical grade). On working up only tarry material and unreacted phenylglyoxal could be isolated.

Variation C: The reaction was carried out as described under variation A, except that phenylglyoxal hydrate was employed. Most of the phenylglyoxal was recovered unchanged as the hydrate. A small amount of neutral material was recovered, purple in color that melted in the range 150-160°, that sublimed only with decomposition at 150° and 4 mms. pressure. It was not further investigated.

Variation D: 0.320 grams (0.00205 moles) of o-phenylenediacetonitrile was dissolved in 3.5 ml. of piperidine (dried in contact with potassium hydroxide), and 0.300 grams (0.00197 moles) of phenylglyoxal hydrate was added. The solution warms slightly and turns yellow-orange in color.

The reaction mixture was warmed at 60-70° for a few minutes and allowed to stand at room temperature for one and one-half hours. On dilution with water the starting materials could be largely recovered unchanged. A small amount of unidentified melting below 70°.

Variation E: Similar to variation D, except that a small amount of piperidine in absolute ethanol was used with phenylglyoxal itself or its hydrate. Allowed to stand three days. Only unchanged starting material and some low melting resinous material was isolated.

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The Yellow By-product from the Reaction of Ortho-Phenylenediacetonitrile with 1,4-Dibenzoyl Ethylene:

On sublimation of the 1,4-dicyano-2-phenylnaphthalene from the precipitate obtained as product of the condensation of o-phenylenediacetonitrile with 1,4-dibenzoyl ethylene in the presence of sodium ethoxide or piperidine, lemon to canary yellow material remained behind. It could be sublimed at a bath temperature of 185-215° and 4 to 6 mm. pressure to a fluffy light yellow sublimate. Alternately it was separated from 1,4-dicyano-2-phenylnaphthalene by virtue of its solubility in chloroform in which the latter is insoluble.

This yellow by-product is neutral, is insoluble in concentrated hydrochloric acid, shows no unsaturation to bromine in carbon tetrachloride, and is unattacked by treatment with refluxing 15% ethanolic potassium hydroxide for 70 hours.

All samples of this yellow product melted with decomposition over a range of four or five degrees within the temperature limits of 310-320°. The material remaining after the treatment with ethanolic potassium hydroxide melted more sharply at 317-319°.

The use of sodium ethoxide as the condensing agent in a single run led to a higher yield of this yellow by-product than with the use of sodium methoxide, but the conclusion must be accepted with reservation in view of the meager data.

Analysis: Found: C, 82.21%, 82.00; H, 4.76%, 4.80%; N, 6.03%. Calculated for $C_{16}H_{11}NO$: C, 82.68%, H, 4.77%, N, 6.01%. The analytical molecular weight for one nitrogen is (14.008/6.03) x 100 = 233. With two other samples of the yellow by-product apparently purified by the same procedures the nitrogen content was 5.41% and 4.30%.

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Reaction of Maleic Anhydride with Ortho-Phenylenediacetonitrile:

0.312 grams (0.002 moles) of o-phenylenediacetonitrile and 0.216 grams (0.004 moles) of sodium methoxide (Eastman, practical grade) was dissolved in 30 ml. of absolute ethanol, and 0.196 grams (0.002 moles) of maleic anhydride (freshly distilled and purified) added. The reaction mixture was warmed to boiling for a few minutes and allowed to stand at room temperature for one and one-half days. Water was added, with the appearance of no significant amount of precipitate. On acidification only tarry material separated, from which by fractional precipitation from benzene-petroleum ether a small amount of unchanged o-phenylenediacetonitrile and tacky, apparently resinous material were isolated.

Reaction of Ortho-Phenylenediacetonitrile with Cis-1,4-Dibenzoyl Ethylene in Piperidine:

624 milligrams (0.004 moles) of o-phenylenediacetonitrile that had been dried *in vacuo* over sulfuric acid and 944 milligrams (0.004 moles) of cis-1,4-dibenzoyl ethylene also dried over sulfuric acid *in vacuo* were placed in 10 ml. of piperidine that had been dried in contact with potassium hydroxide. Total solution was effected by allowing the stoppered reaction tube to stand in water bath at 60° for twenty minutes, and by occasional shaking. The solution became orange-red in color, and was allowed to stand at room temperature for three days. About 2 ml. of distilled water was then added and stirred in, and the reaction mixture allowed to stand twelve hours at room temperature. The solution became entirely filled with a fine suspension of solid material. This was suction filtered, and washed with water. The precipitate on drying was white to pale yellow and consisted largely of microscopic needles. On sublimation at a bath temperature of 160-170° and 4 mms. of pressure, 470 milligrams of 1,4-dicyano-2-phenylnaphthalene was obtained, melting in a sealed capillary tube at 182.5-183.5°, and at 184-185° on mixed melting point determination with a very pure sample of this compound of melting point 185-186°. Remaining as residue in the sublimation tube were 100 mgs. of yellow crystalline material melting in the range 314-318° with apparent decomposition.

By dilution of the original piperine filtrate with the first wash water, further crops of almost white material were obtained, that gave on sublimation 290 mgs. of 1,4-dicyano-2-phenylnaphthalene and about 30 mgs. of yellow residue. By acidification of the piperidine-water filtrate, some brown, tarry material slowly settled out at the bottom. It was probably unreacted starting material, the solution had the odor of acetophenone.

The total yield of 1,4-dicyano-2-phenylnaphthalene was 710 mgs. (0.00279 moles) or 70% of theory. The total yield of yellow by product was about 130 mgs.

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The Reaction of Ortho-phenylenediacetonitrile with Ethyl Maleate:

300 mgs. (0.0130 moles) of sodium metal was dissolved in 50 ml. of absolute methanol (distilled directly from a magnesium methoxide-methanol mixture) and 700 mgs. (0.0045 moles) of o-phenylenediacetonitrile was added, and solution effected by gentle swirling and warming. 780 mgs. (0.00456 moles) of ethyl maleate (Eastman grade, washed with soda, followed by water, and dried over magnesium sulfate) was added. Allowed to stand at room temperature for three days. One portion of the reaction mixture was diluted with water; only oily material separated having the distinct odor of unchanged ester. A second portion was evaporated to small volume, and cooled; no crystalline material separated. A third portion was diluted with small amount of water and acidified, only tarry material separated consisting apparently

of unchanged nitrile.

In a second run identical to the above except that 600 mgs of sodium was used, no more favorable a result was observed.

In a third run dry sodium methoxide was mixed the nitrile and ester in theorectical amounts and allowed the mixture to stand three days at room temperature. Only unreacted nitrile was recovered.

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2-Phenylquinoxaline from Ortho-Phenylenediamine and Cis-1,4--Dibenzoyl-Ethylene:

160 mgs. (0.00148 moles) of o-phenylenediamine (Eastman, grade) dissolved in 10 ml. of absolute ethanol. About 20 milligrams of sodium methoxide (Eastman, practical grade) and 350 mgs. of cis-1,4-dibenxoyl-ethylene were added. The reaction mixture was heated on steam bath for fifteen minutes. It developed the odor of acetophenone. The ethanol was then largely evaporated, and the residue was taken up in water; the solution made strongly acid with concentrated hydrochloric acid. Most of precipitate redissolved, and the solution was filtered. The filtrate was made neutral and cooled. The precipitate resulting was washed and dried *in vacuo*. It was light tan in color, and melted at 74-75°. Recrystallization from ethanol-water, gave light tan crystals of 2-phenylquinoxaline melting point 77.5-78.5°. The yield was 190 mgs. (0.00092 moles) or about 61% of theory.

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PART II

THE SELF-CONDENSATION OF HOMOPHTHALDEHYDE

THE SELF-CONDENSATION OF HOMOPHTHALDEHYDE

Baumgarten and Olshausen /2/ in 1931 in an investigation of the sulfur trioxide addition complexes of heterocyclic nitrogen compounds (the so-called N-sulfonic acids), studied in detail the effect of strong bases on the so-called N--isoquinolinium sulfonic acid. This substance was prepared by these workers by the action of chlorosulfonic acid on isoquinoline in chloroform cooled in an ice-salt mixture, molecule of isoquinoline hydrochloride also being produced in the reaction. The reaction was reported to proceed in 76% yield based on the amount of chlorosulfonic acid used (i.e., a 38% yield of the N-isoquinolinium sulfonic acid) according to the equation:

$$2C_9H_7N + Cl.SO_3H \xrightarrow{(76\%)} C_9H_7\overset{+}{N}.SO_2O^- + C_9H_7N.HCl$$

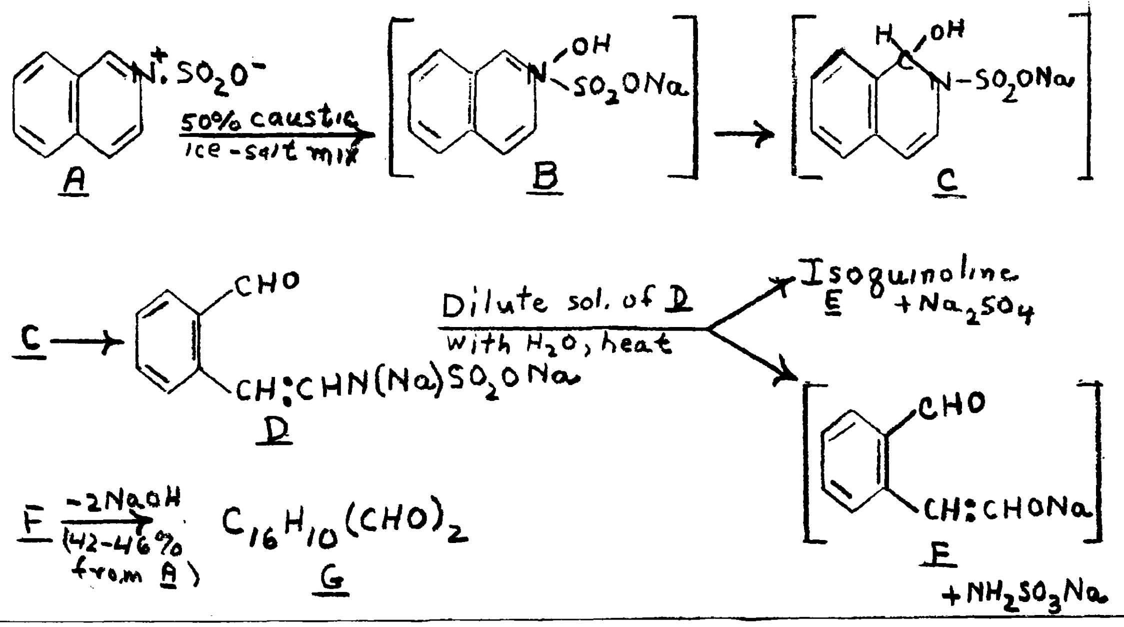
Alternately the compound was prepared by the action of ethyl chlorosulfonate (commercially available) on isoquinoline in dry ether in a salt-ice mixture. The yield reported was 88.3% of theory (based on the limiting reagent, ethyl chlorosulfonate) according to the reaction:

$$C_9H_7N + Cl.SO_3C_2H_5 \xrightarrow{(88.3\%)} C_9H_7\overset{+}{N}.SO_2O^- + C_2H_5Cl$$

In the hands of the present worker, this latter procedure of Baumgarten and Olshausen /2/ has proved unsatisfactory (see experimental section for details). In working up a sticky product resulted that could not be filtered or washed easily, and that required drying on a clay plate followed by extensive drying in vacuo to obtain a relatively anhydrous product.

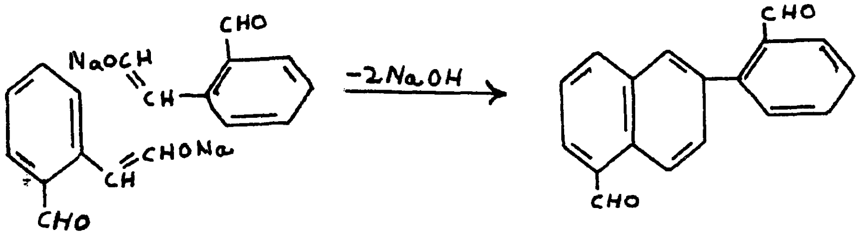
As described in the experimental section, the present worker has modified this procedure using chloroform rather than dry ether to give in 86.0% yield N-isoquinolinium sulfonic acid by mere filtration from the chloroform solution (in which it is insoluble), followed by washing on the filter with chilled chloroform, and freeing of adhering chloroform in vacuo over paraffin.

Baumgarten and Olshausen /2/ investigated the effect of alkali on this N-isquinolinium sulfonic acid. The course of this hydrolysis may be summarized in the following series of reactions, retaining the notation of the original authors. Compounds in brackets were not isolatable and were assumed to be intermediates.



1,2-$C_6H_4(CHO)(CH_2CHO)$. Baumgarten /1/ in 1935 prepared homophthaldehyde (action of lead tetra-acetate on trans-hydrindenediol) and found that in strongly alkaline solution it did, in fact, pass to the compound $C_{16}H_{10}(CHO)_2$. More recently Fieser and Pechet /3/ attempted the condensation of homophthaldehyde with diethyl beta-oxo-glutavate, $CO(CH_2COOC_2H_5)_2$, in an alkaline medium, but found that each component only condensed with itself, and that the compound $C_{16}H_{10}(CHO)_2$ could be isolated from the reaction mixture.

Baumgarten and Olshausen /2/ proposed for this compound $C_{16}H_{10}(CHO)_2$ the structure of 2-phenylnaphthalene 2',5-dialdehyde. The reasoning of these workers was that the intermediate enolate of homophthaldehyde (F) could be considered like phenylacetaldehyde to condense to a 2-phenylnaphthalene, the formyl groups not being involved in the reaction. These workers cited the paper of Zincke /5/ that phenylacetaldehyde condenses under both basic and acidic conditions to 2-phenylnaphthalene. This self-condensation of phenylacetaldehyde has been reviewed comprehensively in Part III of this thesis and is not further discussed at this point. The reaction as viewed by Baumgarten and Olshausen /2/ and by Baumgarten /1/ takes the course:



None of the past workers (Baumgarten and Olshausen /2/, Baumgarten /1/, and Fieser and Pechet /3/) seem to have considered the possibility that the formyl groups might participate in the condensation. The very low yield of 2-phenylnaphthalene from phenylacetaldehyde under basic conditions as contrasted acidic conditions (see Part III, this thesis) casts doubt on the correctness of the analogy drawn in the present case. Further the observation of Meerwein /4/ that phenylacetaldehyde and benzaldehyde *in the cold in and about 0.8% aqueous potassium hydroxide* condense to alpha-phenylcinnamaldehyde in moderate yield also raise doubts that the analogy is properly drawn.

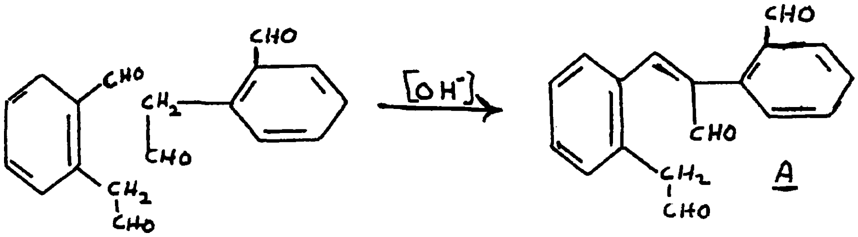
$$C_6H_5CHO + C_6H_5CH_2CHO \xrightarrow[\text{KOH, cold}]{0.8\%} C_6H_5CH{:}C(C_6H_5)CHO$$

The work of the present author now reveals that this compound of Baumgarten and Olshausen, $C_{16}H_{10}(CHO)_2$, is not 2-phenylnaphthalene *2',5*-dialdehyde, but is in fact the isomeric 2-phenylnaphthalene *2',4*-dialdehyde. The proof of this structure is discussed in subsequent pages.

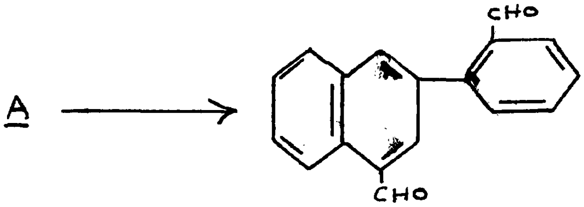
The course of the formation of this 2-phenylnaphthalene 2',4-dialdehyde from homophthaldehyde itself (or its enolate produced *in situ* by the alkaline hydrolysis of N-isoquinolinium sulfonic acid) by the action of alkaline reagents may be described by the following sequence of reactions:

(1) Initial condensation of a formyl group with the methylene group of a second molecule. This is equivalent to the condensation of benzaldehyde and phenylacetaldehyde that according to Meerwein /4/ and Cf. above) proceeds

even in 0.8% caustic solution in moderate yield.



(2) Further ring closure and dehydration to 2-phenylnaphthalene 2',4-dialdehyde.



In the above two equations the participation of the enol form of the homophthaldehyde has not been given explicit expression. However this form is implicit in the aldol condensation under alkaline conditions.

Baumgarten and Olshausen /2/ have shown that the dialdehyde under consideration, $C_{16}H_{10}(CHO)_2$, on oxidation with potassium permanganate or acetone or ammonical silver nitrate gives the diacid, $C_{16}H_{10}(COOH)_2$ of melting point 263-4° (or 267-8° when potassium permanganate was used as the oxident). This diacid on heating with calcium oxide produces 2,3 benzofuorenone and a small amount of 2-phenylnaphthalene. This diacid on heating alone at 330-360° passes to a fluorenone--acid of melting point 320° (uncorrected), which on decarboxylation passes to chrysofluorenone of melting point 132° (oxime, melting point 203°).

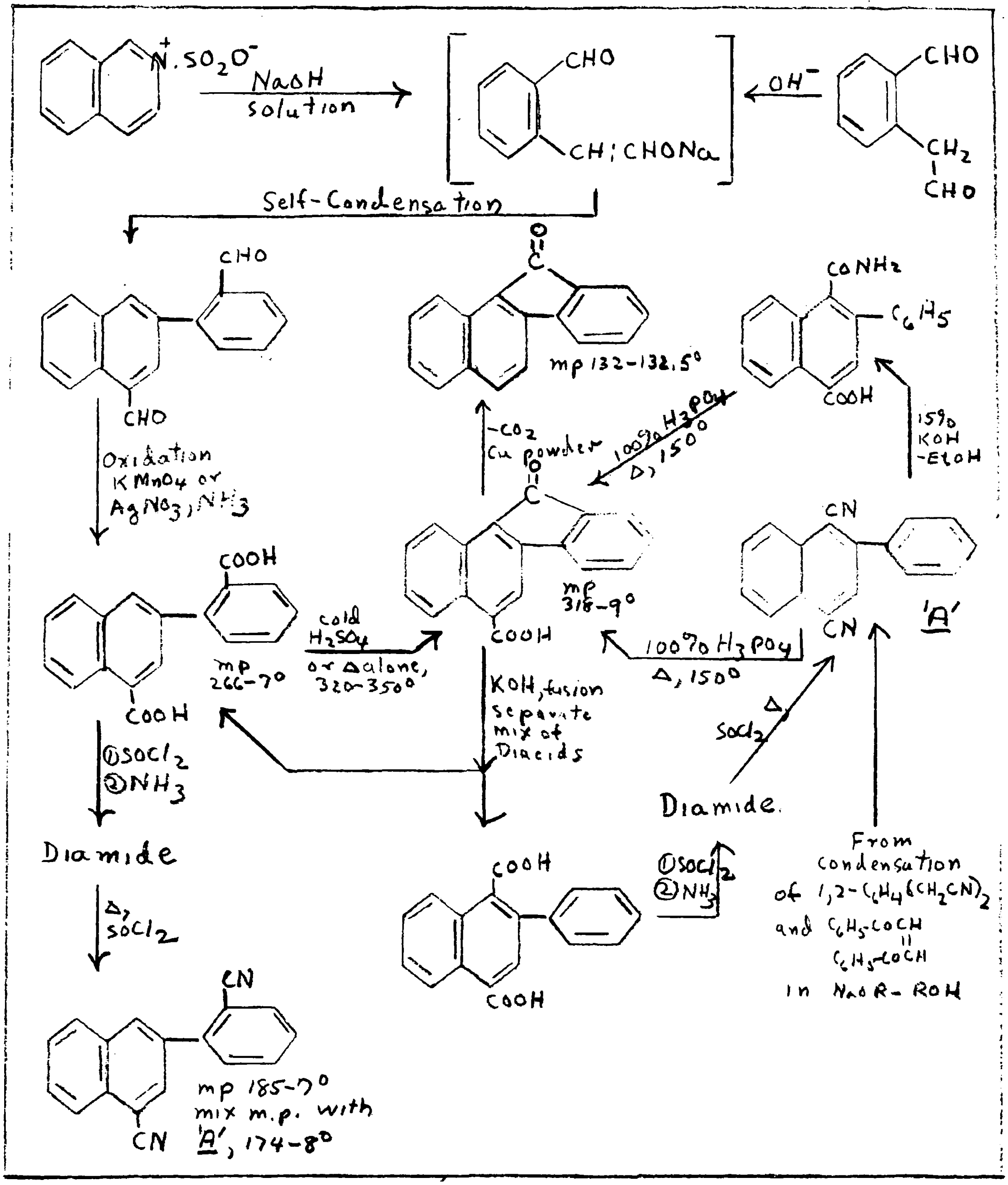
The details of carrying out this course of reactions is given in the experimental section. The reaction is carried out by suspending one mole of the N-isoquinolinium sulfonic acid (*A*) in six moles of about 50% caustic cooled in an ice-salt mixture. With vigorous grinding with a pestle the reaction mixture soon takes on the color and consistency of butter. The yellow material is the disodium salt of (o-formyl-styryl)-aminosulfonic acid (*D*) (from which the free acid can be obtained by acidification for purposes of proof of structure). The yellow reaction mixture is diluted with a large volume of ice water, and after total solution is effected, the solution is warmed slowly. The solution soon becomes filled with a suspension of fine white needles. On filtration, washing, and drying *in vacuo*, these needles analyze (according to the data of Baumgarten and Olshausen /2/ and of Baumgarten /1/) for $C_{16}H_{10}(CHO)_2$ (*G*). The molecular weight determination is in agreement with this molecular formula, and the formation of a dioxime and a diphenylhydrazone demonstrates the presence of two aldehyde groupings. The overall yield of *G* from N-isoquinolinium sulfonic acid acid is 42-46% of theory according to Baumgarten and Olshausen /2/ or 46.8% in the repetition of the work by the present worker (see the experimental section).

This compound $C_{10}H_{10}(CHO)_2$ was conceived by Baumgarten /1,2/ as being formed by the condensation of two molecules of intermediate *F* in the above series of reactions. Intermediate *F*, it will be noted, is the sodium enolate of homophthaldehyde, The present worker by the action of 100% phosphoric acid on 1,4-dicyano-2-phenylnaphthalene has obtained 11-keto-5-chrysofluorene carboxylic acid of melting point 318-319° with decomposition (uncorrected) as is described in detail in Part I of this thesis. Cleavage of this compound with potassium hydroxide gave a mixture of diacids that could be separated to a diacid of melting point 266-7° (uncorrected) and one of melting point 238-239°.

The higher melting diacid, 2-phenylnaphthalene 2',4-dicarboxylic acid, shows no depression on mixed melting point depression with the diacid obtained by the oxidation of the compound $C_{16}H_{10}(CHO)_2$ (obtained by the method of Baumgarten from N-isoquinolinium sulfonic acid). Further the 11-keto-5-chryso-fluorene carboxylic acid showed no depression of melting point with the fluorenone-acid obtained from the diacid of Baumgarten by the convenient action of cold concentrated sulfuric acid.

These relationships can be seen most readily from the accompanying reaction scheme.

The observation that the higher melting diacid has the 2',4-structure is consistent with the known cleavage of other benz fluorenone systems (i.e., the benzoic derivative is always higher melting than the isomeric naphthoic acid) and with the identity of the dinitrile synthesized from the lower melting acid with 1,4-dicyanonaphthalene and the non-



N.SO2O⁻
NaOH solution
CHO
CH:CHONa
OH⁻
CHO
CH2
CHO
Self-Condensation
CHO
CHO
Oxidation KMnO4 or AgNO3, NH3
COOH
COOH
mp 266-7°
cold H2SO4 or Δ alone, 320-350°
mp 132-132.5°
-CO2 Cu powder
100% H3PO4 Δ, 150°
CONH2
C6H5
COOH
15% KOH -EtOH
mp 318-9°
COOH
CN
CN
'A'
100% H3PO4 Δ, 150°
KOH, fusion separate mix of Diacids
Δ, SOCl2
Diamide.
①SOCl2 ②NH3
Diamide
Δ, SOCl2
COOH
COOH
①SOCl2 ②NH3
From condensation of 1,2-C6H4(CH2CN)2 and C6H5-COCH ‖ C6H5-COCH in NaOR-ROH
CN
CN
mp 185-7° mix m.p. with 'A', 174-8°

identity of the dinitrile from the higher melting acid with this compound.

The compounds described by Baumgarten /1,2/ as 2-phenylnaphthalene 2',5-dialdehyde, 2-phenylnaphthalene 2',5-dicarboxylic acid, and 11-keto-4-chrysofluorene carboxylic acid are therefore demonstrated to be 2-phenylnaphthalene 2',4-dialdehyde, 2-phenylnaphthalene 2',4-dicarboxylic acid, and 11-keto-5-chrysofluorene carboxylic acid, respectively.

* * * * *

EXPERIMENTAL WORK, PART II

Preparation of the N-Isoquinolinium Sulfonic Acid:

To 54.2 grams (0.419 moles) of isoquinoline (Eastman Practical Grade, dried over potassium hydroxide) dissolved in 70 ml. of chloroform and cooled to 0° in an ice-salt mixture, 53.3 grams (0.368 moles) of ethyl chlorosulfonate (Eastman) was added dropwise under exclusion of moisture. The reaction mixture was swirled and shaken during the addition to prevent any local heating. It was allowed to remain in the salt-ice mixture for a total period of thirty minutes. The white precipitate was suction filtered, washed quickly with several portions of chilled chloroform, and dried *in vacuo* over paraffin. By concentration of the filtrate and wash liquid at reduced pressure several further small crops of precipitate could be obtained. The combined yield of N-isoquinolinium sulfonic acid as a dense white powder was 66.0 grams (0.315 moles) or 85.7% based on the amount of ethyl chlorosulfonate used. It melted in a sealed capillary tube in the range 232-237°. Baumgarten /2/ reports a melting point of 239° or the complex of analytical purity, but by further intensive drying it could be raised to 250-254°.

In a preliminary experiment the method of Baumgarten and Olshausen /2/ employing dry ether as a solvent was followed. However the precipitate was sticky in nature, could not be filtered rapidly, required drying on a clay plate, and extended drying _in vacuo_ to obtain a relative anhydrous product. The reported yield of 88.3% could not be verified.

Preparation of 2-Phenylnaphthalene 2',4-Dialdehyde /2/:

To 66 grams of N-isoquinolinium sulfonic acid placed in a porcelain dish cooled in an ice-salt mixture was ground in a cold solution of 75.8 grams of potassium hydroxide in 210 ml. of water. The solution became yellow, and by good mixing with a pestle a very rigid yellow mass was obtained. This was diluted with continued stirring with about 120 ml. of water until it had a homogeneous butter-like consistency. Under ice cooling the reaction mixture was dissolved in 4 liters of ice cold water. By mechanical stirring total solution was accomplished to yield a clear yellow solution having only a slight odor of isoquinoline. The cold solution was then heated slowly on a hot plate to 80° and maintained at this temperature for one hour. The solution had become filled with clusters of white crystals, cooled, and the crystals were filtered, and washed repeated on the filter with water to remove contaminating isoquinoline. The needles remaining were pure white, and were dried in vacuo, melting point 125-6°. By reboiling of the alkaline filtrate for fifteen minutes, and allowing to stand overnight at room temperature, an additional small crop of crystals were obtained. The combined crystal crop was recrystallized from 95% ethanol and dried in vacuo, melting point 126.2-126.7° (Baumgarten /1/ gives 126.50). The yield of pure white, microscopic needles of 2-phenylnaphthalene 2',4-dialdehyde was 19.2 grams (.0738 moles) or 46.8%, of theory from N-isoquinolinium sulfonic acid used or 40.1% based on ethyl chlorosulfonate used initially.

2-Phenylnaphthalene 2',4-Dicarboxylic Acid from 2-Phenylnaphthalene 2',4-Dialdehyde /2/:

To a solution of 10 grams (0.0385 moles) of 2-phenylnaphthalene 2',4-dialdehyde in 50 ml. of acetone (distilled from potassium permanganate, and dried by potassium carbonate) was added 8.40 grams (0.0532 moles) of finely powdered potassium permanganate. Allowed to stand at room temperature one hour, with occasional shaking, warmed to boiling briefly, and allowed to stand over night. At the end of this time the violet color of the permanganate had been discharged, and the solution was deep brown in appearance due to suspended manganese dioxide. The reaction probably proceeds according to the reaction

$$3C_{16}H_{10}(CHO)_2 + 4KMnO_4 \longrightarrow C_{16}H_{10}(COOH)_2 + 2C_{16}H_{10}(COOK)_2 + 4MnO_2 + 2H_2O.$$

As the diacid and its dipotassium salt are both insoluble in acetone, they were separated with the manganese dioxide by suction filtration. Washing of the precipitate on the filter repeatedly with cold water lead to the removal of the dipotassium salt, from which the free diacid was liberated by acidification with hydrochloric acid. Solution again in dilute alkali, treatment with charcoal, filtration, reacidification, filtration and drying <u>in vacuo</u> gave 6.10 (0.0209 moles) of 2-phenylnaphthalene 2',4-dicarboxylic acid as a white powder, melting point 265-6° (no depression on mixed melting point with a sample of the acid from the alkali cleavage of 11-keto-5-chrysofluorene carboxylic acid), neutral equivalent, /5/ (theory for $C_{16}H_{10}(COOH)_2$ 146.14).

The manganese dioxide precipitate was next washed repeatedly with dilute alkali until acidification of the wash liquid showed no further precipitation. The alkalinity of the combined alkaline wash was adjusted to about pH 8.5, filtered through a fine sintered glass filter, and the deep yellow filtrate chilled. By the addition of very dilute hydrochloric acid dropwise, and filtration of the precipitate, the acidic material was separated into four fractions. The first fraction was orange in color, and later fractions were yellow to gray. By recrystallization of the later fractions from ethanol, with repeated treatment with Norite, and re-separation into acidic fractions as above, 2.30 grams (0.0079 moles) of impure diacid (m.p. 258-266°) was obtained as a light cream colored powder neutral equivalent: 153, (theory for $C_{16}H_{10}(COOH)_2$ 146.14) as well as smaller acidic fractions of total weight 0.96 grams yellow orange to orange-red in color melting at 254.8-256°, 237-241, 231-7°.

Evaporation of the acetone filtrate, and washing of the grown, tacky residue with dilute alkali revealed no further acidic material. The residue gave a positive Fuchsin aldehyde test and probably contains some unreacted dialdehyde.

The yield from 10 grams (0.0385 moles) of dialdehyde was 6.10 grams (0.0209 moles) of pure diacid, 2.30 grams (0.0079 moles) of impure diacid, and 0.96 grams of colored acidic material.

Comparison of Melting Points:

Mixed melting determination of the higher melting diacid (2-phenylnaphthalene 2',4-dicarboxylic acid) (m.p. 266-7°) from the potassium hydroxide fusion of 11-keto-5-chrysofluorene carboxylic acid and the diacid (m.p. 265-6°) resulting from the oxidation of the dialdehyde, $C_{16}H_{10}(CHO)_2$, from the self-condensation of homophthaldehyde showed no depression.

Mixed melting point determinations of 11-keto-5-chrysofluorene carboxylic acid (m.p. 318-319°) from the above diacid from both sources and from the action of 100% phosphoric acid on 1,4-dicyano-2-phenylnaphthalene showed no depression.

The above diacid (m.p. 266-7°) from either source on conversion to the dinitrile (2',4-dicyano-2-phenylnaphthalene) showed the melting point 185-187° and displayed a depression of melting point to about 174-178° on mixture with a sample of 1,4-dicyano-2-phenylnaphthalene.

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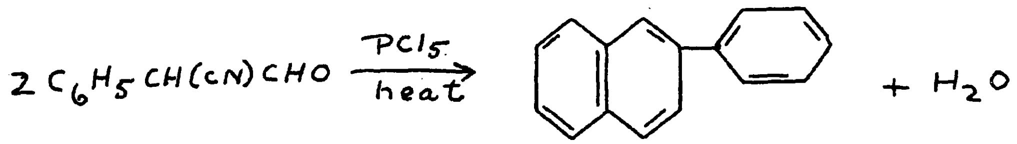
PART III

THE REACTION
OF
WALTHER AND SCHICKLER

THE REACTION OF WALTHER AND SCHICKLER:

In 1897 Walther and Schickler /48/ reported the preparation of alpha-formyl-phenylacetonitrile, $C_6H_5CH(CN)CHO$, by the condensation of benzyl cyanide and formic esters in the presence of sodium alkoxides, and also investigated some of its chemical properties. In an attempt to determine whether the compound should be described as having a "hydroxymethylene" structure, i.e. the enol, $C_6H_5C(CN):CHOH$, or a formyl structure, $C_6H_5CH(CN)CHO$, these workers studied the action of phosphorus pentachloride on it. On mixing three grams of the compound with five grams of phosphorus pentachloride and warming, a vigorous reaction set in at about 90° accompanied by the evolution of hydrogen chloride and by liquefaction of the reaction mixture. After the cessation of the gas evolution the reaction mixture was heated a long time at about 130°. On cooling, the reaction mixture solidified to a brown yellow mass. From this, by its solubility in alcohol or benzene, Walther and Shickler isolated a compound analyzing for $C_{18}H_{10}N_2$ as white needles, melting at 186-187° and showing a blue fluorescence in dilute alcohol. These workers presumed that as the compound was free of chlorine it might have arisen from the loss of hydrogen chloride from such an intermediate as $C_6H_5C(CN):CHCl$ and might have the formula $C_6H_5C(CN):C:C:C(CN)C_6H_5$. "Further investigation", these workers state without further details, "through oxidation and especially reduction experiments were without results, and brought no clarification of this assumption".

This compound of Walther and Schickler has now been demonstrated by the present worker to be 1,4-dicyano-2-phenylnaphthalene, indentical in properties with samples of this compound in an ambiguous fashion.



The nature and scope of this reaction is discussed further in the following.

THE CHEMICAL AND PHYSICAL PROPERTIES OF α-FORMYL PHENYLACETONITRILE:

The preparation of alpha-formyl-phenylacetonitrile from benzyl cyanide and formic esters in the presence of sodium alkoxides is described in detail in the experimental section of this thesis.

Alpha-formyl-phenylacetonitrile forms as white flakes melting at 157-8°, soluble in ethanol, benzene, hot water, but insoluble in petroleum ether /48/. Heated somewhat over its melting point it volatilizes to a pungent, suffocating gas, but on resolidification the melting point is unchanged. The water solution of the compound is strongly acid /48/. With dilute ferric chloride solution either alcoholic or aqueous, the compound gives an intense blue-violet color /48/. It forms a precipitate with most heavy metal salts; barium chloride giving a white and copper sulfate a blue precipitate /48/. Alpha-formyl-phenylacetonitrile on warming in a weak ammonical silver nitrate solution gives a silver mirror /48/. With strong potassium or sodium hydroxide solution alpha-formyl-phenylacetonitrile decomposes slowly in the cold to benxyl cyanide /48/.

Treatment of alpha-formyl-phenylacetonitrile with concentrated hydrochloric acid at 130-140° for six to eight hours yields carbon dioxide, carbon monoxide, ammonium chloride phenylacetic acid, and a yellow powder insoluble in the usual solvents, contains nitrogen, darkening at 270°, and not melting at 300° /48/. Oxidation of the nitrile with alkaline permanganate followed by filtration of the manganese dioxide and acidification with hydrochloric acid produces ammonium chloride, benzoic acid, and small amounts of hydrocyanic acid. No aldehydic or ketonic material is detected /48/.

By passage of the ammonia over alpha-formyl-phenyl-acetonitrile heated to 160°, a compound $C_{18}H_{13}N_3$ is obtained as yellow plates (m.p. 175°) that dissolves in alkali with an intense yellow color. The compound is presumably the imine formed from two molecules of the nitrile and one of ammonia, $(C_6H_5C(CN){:}CH)_2NH$. This imine on reaction with potassium hydroxide releases benzyl cyanide as indentified by its odor. With boiling ethanolic potassium hydroxide, phenylacetic acid and ammonia are obtained. With ethanolic hydrogen chloride in the cold, alpha-formyl-phenylacetonitrile is regenerated from this imine /48/.

If in place of ammonia, methylamine is passed over alpha-formyl-phenylacetonitrile, the product analyses for $CH_3N(CH;C(CN)C_6H_5)_2$, melting at 88-9° /48/. If methylamine hydrochloride is added to an alcoholic solution of alpha-formyl-phenylacetonitrile, the product is $C_6H_5C(CN){:}CHNHCH_3$, melting at, 73-75° /48,39/.

Alpha-formyl-phenylacetonitrile on solution in liquid ammonia at -40° for six hours produces an ammonium salt, melting at 177-8° with decomposition. This salt on solution in toluene, followed by distillation of the solvent with the passage of ammonia gives iminomethyl-phenylacetonitrile, $C_6H_5C(CN)CH{:}NH$, this latter compound also results from the distillation of the solvent from a solution of alpha-formyl-phenylacetonitrile in toluene accompanied by the passage of ammonia. If benzene is the solvent used in this procedure, the ammonium salt is the principal product. These procedures also go in good yield with the para-chloro, para-hydroxy, and para-methoxy-alpha-formyl-phenylacetonitriles, and in low yield with the p-nitro analogue /9/.

Alpha-formyl-phenylacetonitrile reacts with either one or two equivalents of aniline to form $C_6H_5C(CN){:}CHNHC_6H_5$, melting at 155-6°, that is unchanged by boiling with alkali or acid and gives only a faint yellow color with ferric chloride /48,39/. An attempt to produce a nitroso derivative of this compound gave a red compound (shrinking at 90° and melting at 107-110°) with a nitrogen content of 23.05% (theory for the nitroso derivative, 16.86%) /48/.

The action of hydroxylamine on alpha-formyl-phenylacetonitrile gives a compound analyzing for $C_9H_8N_2O$ that after warming with hydrochloric acid gives a positive silver mirror test with ammoniacal silver nitrate. The compound is presumably, $C_6H_5C(CN){:}CHNHOH$ /48/. Phenylhydroxylamine reacts similarly in acetic acid solution to give $C_6H_5C(CN){:}CHN(C_6H_5)OH$, melting at 155°, that cannot be hydrolyzed to an acid /39/. Phenylhydrazine reacts in a similar manner /48,39/. Analogous reactions occur with p-hydroxy-alpha-formyl-phenylacetonitrile and phenylhydroxylamine or phenylhydrazine /39/.

The sodium salt of alpha-formyl-phenylacetonitrile reacts with benzene diazonium chloride to give a canary yellow precipitate that after recrystallization from absolute ethanol melts at 117-8°. This product is somewhat soluble in sodium hydroxide solution, but unchanged by hydochloric acid. It has not been investigated further /48/. In the analogous case of alpha-formyl-2-naphthylacetonitrile, 2-$C_{10}H_7CH(CN)CHO$, the potassium salt is reported to react with benzene diazonium chloride with the split of the -CHO group and the formation of 2-$C_{10}H_7C(CN){:}NNHC_6H_5$ /51/.

Phenylisocyanate, C_6H_5NCO, adds at room temperature to alpha-formyl-phenylacetonitrile to give $C_6H_5C(CN){:}CHOCONHC_6H_5$ /51/.

Alpha-formyl-phenylacetonitrile is reduced in the presence of a nickel catalyst at room temperature and atmospheric pressure to the aldimine, $C_6H_5CH(CHO)CH{:}NH$, which on hydrolysis passes to phenylmalondialdehyde, $C_6H_5CH(CHO)_2$ /40,41/. At 50-70° and 100-150 atmospheres the reduction proceeds to beta-phenylpropylamine, $CH_3CH(C_6H_5)CH_2NH$ /29/.

Simultaneous hydrolysis and esterification of alpha-formyl-phenylacetonitrile has not been accomplished. On heating of this compound with ethanol and hydrogen chloride, only a resin results. On heating with methanol and hydrogen chloride, an oil results that on heating with sodium hydroxide, has the odor of benzyl cyanide. This oil on standing deposits a few crystals melting at 90° /48,54/.

The action of benzoyl chloride on alpha-formyl-phenylacetonitrile gives the benzoyl derivative $C_6H_5C(CN){:}CHOCOC_6H_5$, as needles melting at 116-7° /48,5/.

Badhwar and co-workers /5,6/ have reported that alpha-formyl-phenylacetonitrile reacts with phenols in a Houben-Hoesch reaction with zinc chloride to give 3-phenylcoumarins in moderate to low yield and none of the isomeric isoflavones (Cf. reference 24). Thus with alpha-formyl-phenylacetonitrile and resorcinol there is obtained after hydrolysis 7-hydroxy-3-phenylcoumarin. With the monomethyl ether of resorcinol the analogous 7-methoxy compound results. In similar reactions phloroglucinol and its ethers and p-methoxy- or 3,4,5-trimethoxy-alpha-formyl-phenylacetonitrile react similarly.

The triacetate of hydoxyhydroquinone (hydroxy-quinol) condenses with alpha-formyl-phenylacetonitrile to form 6,7-dihydroxy-3-phenylcoumarin, and condenses with its benzoyl derivative, $C_6H_5C(CN):CHOCOC_6H_5$, to give 2,4,5-trimethoxy-acetophenone.

The condensation of α-formyl-phenylacetonitrile in the presence of phosphorus petachloride to give a compound $C_{18}H_{10}H_2$, now demonstrated by the present worker to be 1,4-dicyano-2-phenylnaphthalene, is described at length in the following pages.

These chemical reactions of alpha-formyl-phenylacetonitrile discussed above have been outlined in an accompanying chart. The chemical properties of alpha-formyl-1-(and 2-) naphthyl-acetonitriles have been investigated by Wislicenus and co-workers /52,53,55/. They have not been discussed in detail due to their general similarity to those of the phenyl analogue, but are outlined also in an accompanying chart.

REACTIONS OF α-FORMYL-PHENYLACETONITRILE, $C_6H_5C(CN):CHOH$

With Nitrogen Cmpds.:

Heat 160°, pass $NH_3 \longrightarrow (C_6H_5C(CN):CH)_2NH$

Liquid NH , -40° $\longrightarrow C_6H_5C(CN):CHONH_4$

Distill C_6H_6 from sol. as pass $NH_3 \longrightarrow C_6H_5C(CN):CHONH_4$

Distill $C_6H_5CH_3$ from sol. as pass $NH_3 \longrightarrow C_6H_5CH(CN)CH:NH$

$C_6H_5C(CN):CHONH_4 \xrightarrow{\text{Distill } C_6H_5CH_3 \text{ from sol. as pass } NH_3} C_6H_5CH(CN)CH:NH$

$CH_3NH_2.HCl$, EtOH $\longrightarrow (C_6H_5CH(CN):CHNHCH_3$

Aniline $\longrightarrow C_6H_5C(CN):CH - NHC_6H_5$

$NH_2OH \longrightarrow C_6H_5C(CN):CHNOH$

$C_6H_5NHOH \longrightarrow C_6H_5C(CN):CHN(C_6H_5)OH$

$C_6H_5N_2Cl$ on Na salt $\longrightarrow C_6H_5C(CN):NNHC_6H_5$ (?)

$C_6H_5NCO \longrightarrow C_6H_5C(CN):CHOCONHC_6H_5$

With Acids and Bases:

Conc. HCl, 130-140° $\longrightarrow C_6H_5CH_2COOH$, CO_2, CO, NH_4Cl, & resin

Heat, HCl-EtOH $\longrightarrow$ resin

Heat, HCl-MeOH $\longrightarrow$ oil and few crystals (m.p. 70°)

KOH or NaOH sol., cold $\longrightarrow C_6H_5CH_2CN$

With Oxidizing & Reducing Agents:

Alkaline permanganate $\longrightarrow C_6H_5COOH$, NH_3, trace of HCN

$AgNO_3$, $NH_3 \longrightarrow$ silver mirror

H_2, Ni, room temp, 1 atmos. $\longrightarrow C_6H_5CH(CHO)CH:NH \xrightarrow{H^+} C_6H_5CH(CHO)_2$

H_2, Ni, 50-70°, 110-150 atmos. $\longrightarrow C_6H_5CH(CH_3)CH_2NH_2$

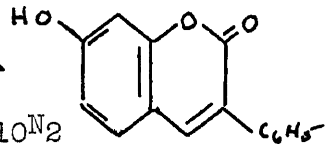
Other Reactions:

$FeCl_3 \longrightarrow$ blue-violet color

heavy metal salts $\longrightarrow$ insol. precipitates (salts)

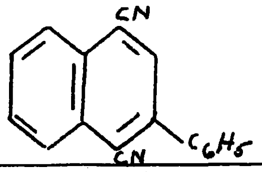
$C_6H_5COCl \longrightarrow C_6H_5C(CN):CHOCOC_6H_5$

resorcinol, $ZnCl_2 \longrightarrow$



PCl_5, heat, 130° $\longrightarrow C_{18}H_{10}N_2$

Structure by present work:



REACTIONS OF α-FORMYL-1-NAPHTHYLACETONITRILE, $1\text{-}C_{10}H_7C(CN){:}CHOH$:

With aniline → $1\text{-}C_{10}H_7C(CN){:}CHNHC_6H_5$

With NH_2OH → $1\text{-}C_{10}H_7C(CN){:}CHNHOH$

With C_6H_5NCO → $1\text{-}C_{10}H_7C(CN){:}CHOCONHC_6H_5$

With Br_2 → takes up theor. amt. of Br for enol form.

REACTIONS OF α-FORMYL-2-NAPHTHYLACETONITRILE, $2\text{-}C_{10}H_7C(CN){:}CHOH$

With aniline → $2\text{-}C_{10}H_7C(CN){:}CHNHC_6H_5$

With NH_2OH → $2\text{-}C_{10}H_7C(CN){:}CHNHOH$

With Br_2 → takes up theor. amt. of Br for enol form

With $C_6H_5N_2Cl$ on K salt → $2\text{-}C_{10}H_7C(CN){:}NNHC_6H_5$

With C_6H_5COCl → $2\text{-}C_{10}H_7C(CN){:}CHOCOC_6H_5$

With I_2 → $2\text{-}C_{10}H_7CH(CN)CH(CN)C_{10}H_7\text{-}2$

With I_2, NaOH → $2\text{-}C_{10}H_7C(CN){:}C(CN)C_{10}H_7\text{-}2$

With Zn(Hg) → $2\text{-}C_{10}H_7CH(CH_2OH)_2$

With $C_6H_5NHNH_2$ → $2\text{-}C_{10}H_7\text{-}\underbrace{CH\text{-}CO\text{-}N(C_6H_5)\text{-}N{:}CH}$

* * * * * *

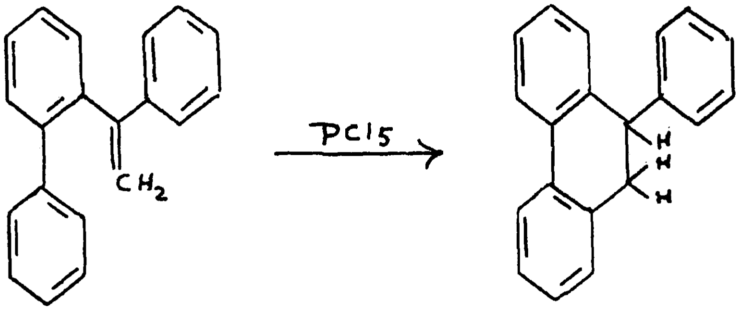
THE PHOSPHORUS HALIDES AS AGENTS FOR CONDENSATION & CYCLIZATION:

The studies reported in the literature of the phosphorus halides (i.e., phosphorus pentachloride, phosphorus trichloride, phosphorus oxychloride, and their other halogen analogues) as agents for promoting condensation and cyclization reactions have been relatively cursory in scope.

Phosphorus pentachloride and oxychloride have found some use as dehydrohalogenation agents expecially of acid chlorides (for examples, the reaction of benzoyl chloride with naphthalene /26/, and the ring closure of the chlorides of arylalkylcarboxylic acids and biphenyl carboxylic acids /1,31/, but in recent years this use has become rather minor in the alicylic field with the development of anhydrous ether, and further worked up by distillation at reduced pressure, Taylor obtained 23 grams of a fraction containing some unchanged acetophenone, but largely alpha-chlorostyrene, and a second fraction of four grams of dypnone, $C_6H_5C(CH_3)$: $CHCOC_6H_5$. It should be noted in passing that dypnone can be obtained in better yield by the action of dry hydrogen chloride on acetophenone /27/.

The use of phosphorus halides in ring closure reactions of heterocyclic systems is not reviewed in this thesis, however, in passing it may be noted that phosphorus pentachloride and oxychloride find use in the condensation of acyl acetic esters with phenols to yield chromanes /25/.

Bergmann and Bondi /9/ in the course of studies on the addition of phosphorus pentachloride to ethylenic systems found that 1-(2-biphenylyl)-1-phenylethlene was cyclized by phosphorus pentachloride ion benzene at room temperature to 9-phenyl-9,10-dihydrophenanthrene.



Nathanson /36/ used phosphorus pentachloride for the cyclization of $C_6H_5COC(C_6H_5)ClCOOC_2H_5$ to 2-phenylindanedione, and Wislicenus and co-workers /53/ by the action of limited aluminium chloride and other agents.

Backes /4/ in 1933 reported that the action of phosphorus oxychloride on aldehydes at 30-35° in which the alpha-carbon is not completely substituted leads to condensations of the aldol type. In the case of aldehydes with the alpha-carbon completely substituted only chlorination is observed. Thus phosphorus oxychloride and propionaldehyde, CH_3CH_2CHO, produce 2-methyl-3-hydroxy-1-pentanal, $CH_3CH_2CHOHCH(CH_3)CHO$, and a compound dimeric with this. This hydroxy aldehyde on treatment with more phosphorus oxychloride passes to the corresponding unsaturated aldehyde, $CH_3CH_2C{:}C(CH_3)CHO$. Backes reported similar results with higher aliphatic aldehydes, both normal and branched-chain, without giving yields. Backes further reported that by the action of phosphorus oxychloride on an equimolar mixture of benzaldehyde and acetalaldehyde at 30-35°, with rigid control of the temperature, cinnamaldehyde, $C_6H_5CH{:}CHCHO$, is produced and could be distilled from the reaction mixture. Similarly with benzaldehyde and enanthaldehyde, $C_6H_{13}CHO$, gives alpha-amyl-cinnamaldehyde, $C_6H_5CH{:}C(C_5H_{11})CHO$, in 70% yield. Benzaldehyde alone on treatment with one-third mole of phosphorus pentachloride in benzene and boiled for 25 hours passes to a mixture of benzoyl chloride, C_6H_5COCl, and beta,beta-dichloro-ethylbenzene, $C_6H_5CH_2CHCl_2$, and some resinous material. By the action of phosphorus pentachloride on formaldehyde only bis-(chloromethyl) ether, $(ClCH_2)_2O$, is obtained. According to Backes, sulfuryl chloride produces similar condensations, but no details were disclosed.

Olivier and Weber /37/ in 1933 reported that the action of the calculated amount of phosphorus pentachloride on 2,6-dichlorobenzaldehyde produces a temperature rise and liquefaction. On extraction with dry ether, there is obtained bis-(alpha-2,6-trichlorobenzyl) phosphorus pentachloride the dichloride of 2,6-dichlorobenzaldehyde, 2,6--$Cl_2.C_6H_4CHCl_2$, results in theoretical yiedl. Chlorinated ethers had previously been obtained in the reaction between nitrobenzaldehydes and phosphorus pentachloride by Kliegl /29/.

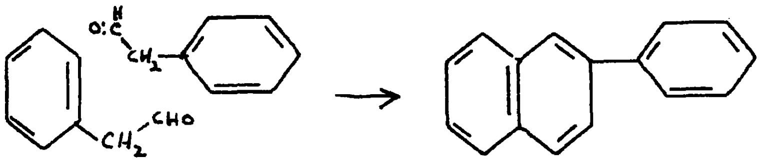
Taylor /46/ reported in 1939 a study of the action of phosphorus trichloride, pentabromide, pentachloride, and phosphorus trichloride-dibromide (PCl_3Br_2) in limited and excess amounts of acetophenone. With limited amounts of the trichloride-dibromide the main products were $C_6H_5COCH_2Br$ and $C_6H_5C(Br):CHBr$ with small amounts of $C_6H_5COCHBr_2$ and $C_6H_5CBr_2CH_3$. With excess of this reagent $C_6H_5COCHBr_2$ and $C_6H_5CBr:CHBr$ were the only products isolated. With the pentabromide much elementary carbon resulted with a trace of $C_6H_5COCH_2Br$. With phosphorus pentachloride in contact with the acetopheone for a short period of time, the products isolated were $C_6H_5CCl_2CH_3$ and $C_6H_5CCl:CH_2$. From twenty grams of acetophenone and 40 grams of phosphorus pentachloride allowed to stand overnight at room temperature, drowned with water, and the organic material extracted with phosphorus pentachloride on $C_6H_5COCH(C_6H_5)COOC_2H_5$ obtained $C_6H_5C(Cl):C(C_6H_5)COOC_2H_5$ which could be cyclized by the action of phosphorus oxychloride to 1-chloro-2-phenylindanone. Both cyclizations involve the loss of one molecule of alcohol.

Several groups of workers /32,34,62,63/ have studied the condensation and cyclization of esters of phenylpropiolic acid, $C_6H_5C\equiv CCOOR$, under the influence of phosphorus oxychloride and other reagents to 1-phenylnaphthalene 2,3-dicarboxylic acid.

* * * * * *

THE SELF-CONDENSATION OF PHENYLACETALDEHYDE AND RELATED CMPDS.:

In 1884 Zincke and Breuer /59/ reported that boiling fifty percent sulfuric acid with either phenylacetaldehyde, $C_6H_5CH_2CHO$, or phenyl-ethyleneglycol, $C_6H_5CHOHCH_2OH$, produced a solid hydrocarbon in low yield. This was subsequently proved by Zincke /57/ to be 2-phenylnaphthalene.



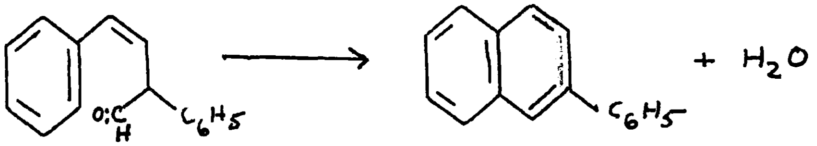
The steps assumed by Zincke /56,59/ in the formation of 2-phenylnaphthalene from phenyl-ethyleneglycol were

(1) Dehydration of the glycol to phenyl acetaldehyde. Earlier using hot, twenty percent sulfuric acid, Zincke /56/ had carried out this step and actually isolated phenyl acetaldehyde.

$$C_6H_5CHOHCH_2OH \longrightarrow C_6H_5CH_2CHO + H_2O$$

(2) $$C_6H_5CH_2CHO \rightarrow C_6H_5CH_2CHOHCH(C_6H_5)CHO \searrow \left\{\begin{array}{c} C_6H_5CH{:}CHCH(C_6H_5)CHO \\ \text{or} \\ C_6H_5CH_2CH{:}C(C_6H_5)CHO \end{array}\right.$$

(3) cyclization by dehydration to 2-phenylnaphthalene



The condensation and cyclization of phenylacetaldehyde to 2-phenylnaphthalene has been carried under a variety of conditions usually in only moderate to low yield. These include: boiling 61% sulfuric acid /2,3/, boiling 50% sulfuric acid /59,57,47/, dilute hydrochloric acid at 170-180° /3,47/ or at lower temperatures /16,47/, water at 170-180° /17/, alkali (accompanied by polymerization) /57/, 41% hydrobromic or hydroiodic acids /2/, sulfuric-acetic acid mixture /23/, and hydrochloric-acetic acid mixture /18/. The papers of Breuer and Zincke /16,17,58-59/ include a discussion of the efficacy of these various agents.

The action of warm alcoholic potassium hydroxide on phenylacetaldehyde produces 1,3,5-triphenylbenzene, 1,3-diphenylpropene, and three isomeric compounds ($C_{24}H_{22}O_2$, melting points 165°, 135°, and 133°), presumably forms of alpha-delta-diphenyl-beta-benzyl-delta-valerolactone. In the earliest work the presence of 1,3-diphenylcyclobutane was claimed, but proved in later work to be 1,3-diphenylpropene. The presence of 2-phenylnaphthalene was not detected /44,45/.

Von Auwers and Keil /2,3/ by the action of water at 170-180° on p-methyl-(beta,beta-dichloroethyl)benzene, $4-CH_3.C_6H_4.CH_2CHCl_2$, obtained 7-methyl-2-(p-tolyl)naphthalene; $4-CH_3.C_6H_4.CH_2CHO$, was the assumed intermediate.

Similar reactions to produce 2-phenylnaphthalene have been observed with compounds that might be expected to produce phenylacetaldehyde in the presence of strong acids. Among such compounds recorded in the literature are phenyl-ethyleneglycol, $C_6H_5CHOHCH_2OH$ (see above) /57,59/, alpha-chloro-beta-hydroxy-phenylpropionic acid, $C_6H_5CHOHCHClCOOH$ /2,3/, phenylserine, $C_6H_5CHOHCH(NH_2)COOH$, /10,18,22/, phenylserine methyl ether, $C_6H_5CH(OCH_3)CH(NH_2)COOH$ /18/, beta-phenyl-beta-hydroxy-ethylamine, $C_6H_5CHOHCH_2NH_2$ /18/, alpha-hydroxy-beta-phenylpropionic acid, $C_6H_5CH_2CHOHCOOH$ /21,35/, and ethyl alpha-formyl-phenylacetate, $C_6H_5CH(CHO)COOC_2H_5$ /11,20,28/.

Von Auwers and Keil /2,3/ have also reported that beta-styrylchloride, $C_6H_5CH{:}CHCl$, (prepared from phenylacetaldehyde dichloride, $C_6H_5CH_2CHCl_2$, by the action of ethanol potassium hydroxide) condenses to 2-phenylnaphthalene in low yield by the action of dilute hydrochloric acid or 41% hydrobromic or hydroiodic acids. At 170-180°, 4-methyl-beta-styryl chloride reacts analogously.

Baumgarten /7,8/ reported that homophthaldehyde, $1,2-C_6H_4(CHO)(CH_2CHO)$, condensed in the presence of strong caustic in a fashion analogous to phenylacetaldehyde to give 2-phenylnaphthalene-2',5-dialdehyde. But as now shown by the present worker (see Part II, this thesis) the product is actually the 2'-4-dialdehyde, and the reaction is therefore no analogous to of the phenylacetaldehyde condensation.

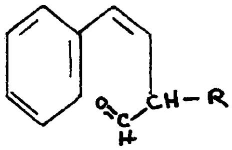
Stobbe and Lippold /43/ have found that the action of cold 10% sodium hydroxide or piperidine on phenylacetaldehyde leads to the formation of an amorphous dimer that can be depolymerized at 90-100°, and that shows no aldehyde properties.

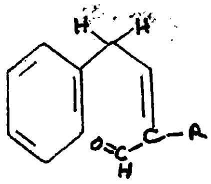
Späth /42/ has reported that phenylacetaldehyde in dilute ethanol in the presence of potassium cyanide, undergoes aldol condensation to $C_6H_5CH_2CHOHCH(C_6H_5)CHOHCN$ and also to an amorphous compound ($C_{32}H_{30}O_3$, boiling point 260-268° at 0.1 mm.). This is the only well characterized case known to the present worker in which phenylacetaldehyde undergoes self-condensation without ring closure, and makes reasonable step 2 of the scheme proposed by Zincke (see above) in the formation of 2-phenylnaphthalene from phenylacetaldehyde.

In this second step proposed by Zincke, namely,

$$C_6H_5CH_2CHO \longrightarrow C_6H_5CH_2CHOHCH(C_6H_5)CHO \longrightarrow \begin{cases} C_6H_5CH{:}CHCH(C_6H_5)CHO \\ \text{or} \\ C_6H_5CH_2CH{:}C(C_6H_5)CHO \end{cases}$$

it will be noted that the last structures are in one case a styrylacetaldehyde and in the other a benzylacrolein both substituted on the carbon adjacent to the aldehyde grouping.

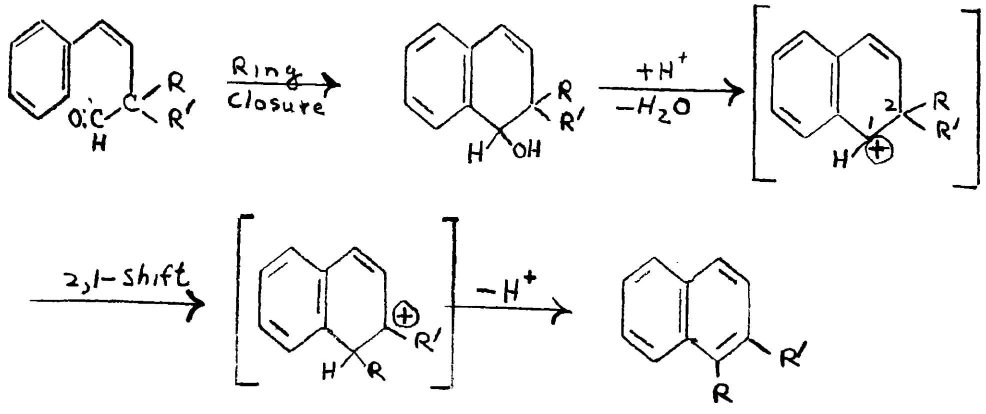




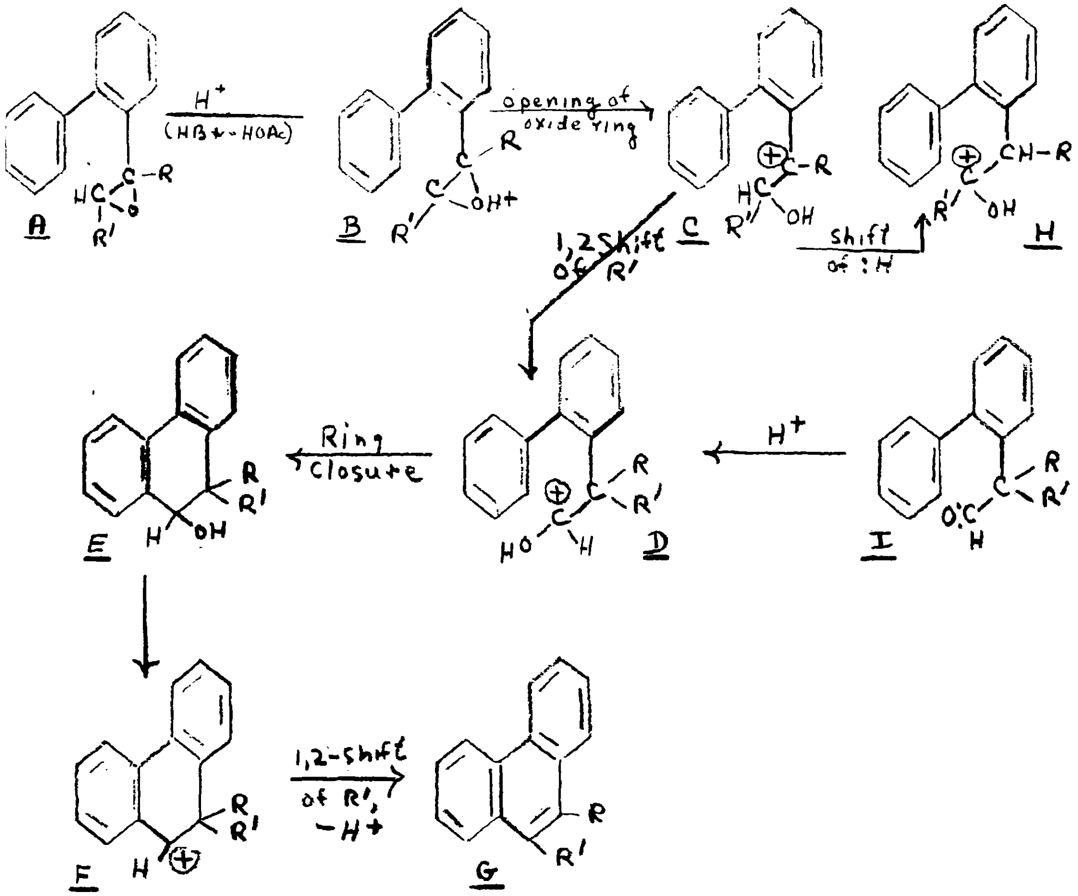
The beta-styrylacetaldehyde has the ortho position more highly activated and hence would be expected to undergo cyclization more readily.

The ring closure of such structures has been described by Bradsher /12/ as "aromatic cyclodehydration" and reviewed comprehensively by him in 1946 /13/. This ring closure is complicated by the fact that only one of the two possible steric configurations can undergo closure, the other leading to polymerization. Bradsher and co-workers (/13/, and references cited therein) have introduced a mixture of hydrobromic and acetic acids as a highly effected agent in carrying out aromatic cyclodehydrations.

In passing it should be noted that neither Bradsher nor any other workers known to the present writer have discussed generally, or in reference to the formation of a bicylic system, the possible ring closure of beta-styrylacetaldehydes disubstituted on the carbon adjacent to the aldehyde grouping and subsequent aromatization by molecular rearrangement of one of the substituents to the carbon involved in the ring closure. Such rearrangement would be favored by the strongly acid media usually employed for such cyclizations.



Bradsher and Rappoport /14,13/ have discussed the possible course of the aromatic cyclodehydration of 2-biphenylyl-ethylene oxides to phenanthrene derivatives. One possible route would involve **two** 1,2-shifts of a substituent. The course proposed is outlined below. It should be noted that intermediate C D is the conjugate acid of the alpha-alpha-disubstituted 2-biphenylylacetaldehyde (I), and that the series I ⟶ D ⟶ E ⟶ F ⟶ G is conceptionally equivalent to the possible course proposed for a disubstituted beta-styrylacetaldehyde in the above paragraph. I, in fact, can be considered a beta-styrylacetaldehyde in which the double bond has been incorporated into a benzene ring.



However this reaction of biphenylyl-ethylene oxides is subject to alternate interpretations including cleavage of the oxide conjugate acid (B) and ring closure (which would not require any rearrangement), or hydride (:H) shift in intermediate C to give H and subsequent ring closure and dehydration without further rearrangement, or the reaction may proceed through a fluorene carbinol intermediate (such compounds being known to rearrange to phenanthrenes under the conditions of the reaction). The review of Bradsher /13/ should be consulted for the full details of these alternate possible reaction paths. Experimental data now available does not make a decision possible as to which mechanism is the most likely.

Börner /11/ has reported the action of warm 50% sulfuric acid of ethyl alpha-formyl-phenylacetoacetate, $C_6H_5CH(CHO)COOC_2H_5$, forms 2-phenylnaphthalene. However, no rearrangement is necessary, as saponification and decarboxylation to phenylacetaldehyde precedes the condensation. Employing more dilute sulfuric acid or boiling 90% acetic acid Jenner /28/ and Dieckmann /20/, respectively, have isolated the intermediate phenylacetaldehyde from the reaction mixture.

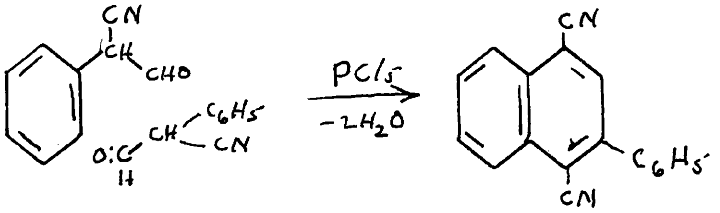
* * * * * *

THE COMPOUND $C_{18}H_{10}N_2$ OF WALTHER AND SCHICKLER /48/:

The compound $C_{18}H_{10}N_2$ isolated from the reaction of phosphorus pentachloride on alpha-formyl-phenylacetonitrile by Walther and Schickler /48/ has been found by the present worker to be identical in physical and chemical properties with 1,4-dicyano-2-phenylnaphthalene (prepared as described earlier in this thesis by the unambiguous condensation of o-phenylenediacetonitrile and cis-1,4-dibenzoylethylene).

The ultraviolet spectral maximum for the compound from either source was identical (248 millimicrons) and in good agreement with the reported value for 2-phenylnaphthalene (250 millimicrons /60/). The slight differences in shape of the experimental curves for the compound from the two sources are within the experimental error, and the resemblance to the curve for 2-phenylnaphthalene recorded in the literature /60/ is excellent. (See the experimental section for curves and data).

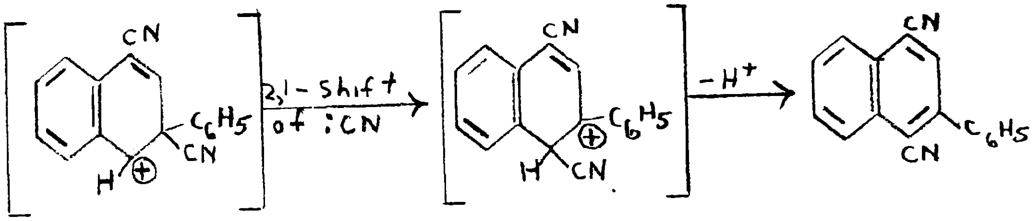
Mixed melting point determinations of the compound from either source or of the 11-keto-5-chrysofluorene carboxylic acid produced by the action of 100% phosphoric acid on samples of the dinitrile from both sources showed no depression. Comparison of the melting points of the basic hydrolysis product (4-amido-3-phenyl-1-naphthoic acid) was less satisfactory as the melting point is accompanied by decomposition and is dependent on the rate of heating. The reaction of Walther and Schickler, therefore, in its overall form involves the loss of two molecules of water from 2 molecules of alpha-formyl-phenylacetonitrile to form 1,4-dicyano-2-phenylnaphthalene in the presence of phosphorus pentachloride and the phosphorus oxychloride formed during the course of the reaction.



THE MECHANISM OF THE REACTION OF WALTHER AND SCHICKLER:

If the reaction of Walther and Schickler is conceived as following the general course of the condensation of phenylacetaldehyde to 2-phenylnaphthalene under the influence of an acid catalyst, it is seen than whatever is assumed to be the intermediate course, aromatization to 1,4-dicyano-2-phenylnaphthalene can only proceed by way of molecular rearrangement.

One plausible course of the reaction would involve at one stage the formation of such a carbonium ion (or its conceptional equivalent) as is given below, which could undergo migration of the cyanide grouping (with its electron pair), followed by loss of a proton to give an aromatic system. This 2,1-shift and earlier possible stages of the reaction are discussed at length in the following.

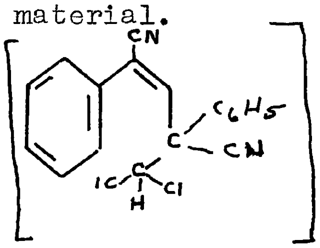


The early course of the reaction (i.e., evolution of hydrogenchloride, accompanied by liquefaction at about 90°, and the presence of oily, strongly lacrymatory material in the reaction mixture) suggests that the alpha-formyl-phenylacetonitrile may initially be converted to alpha-cyano-beta-chlorostyrene, $C_6H_5C(CN){:}CHCl$, or possibly to alpha-cyano-beta,beta-dichloroethylbenzene, $C_6H_5CH(CN)CHCl_2$.

Step 1) ... $C_6H_5C(CN){:}CHOH \longrightarrow \begin{cases} C_6H_5C(CN){:}CHCl \quad \text{or} \\ C_6H_5CH(CN)CHCl_2 \end{cases}$

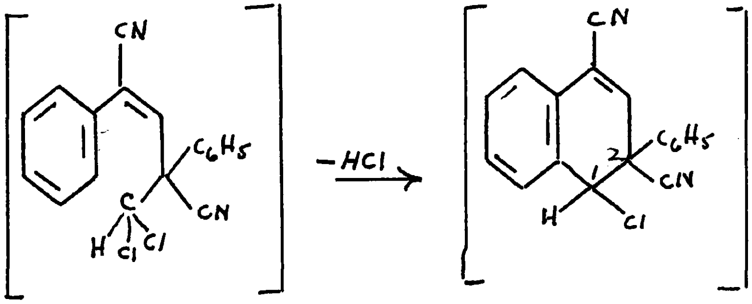
As noted earlier under the condensation reactions of phenylacetaldehyde under acidic conditions beta-chlorostyrene, $C_6H_5CH{:}CHCl$, undergoes condensation to 2-phenylnaphthalene /2,3/, p-methyl-(beta,beta-dichloroethyl)benzene, $4\text{-}CH_3.C_6H_4.CH_2CHCl_2$, reacts similarly /2,3/. And as noted under the phosphorus halides as condensing agents, aldol condensations have been accomplished with aldehydes in the presence of phosphorus oxychloride /4/. Thus as a second step in the reaction of Walther and Schickler, the self-condensation of the above chloro intermediate is reasonable. However, it should be noted that by the action of phosphorus pentachloride on phenylacetaldehyde alone at 0° /23/ or dissolved in petroleum ether in the cold /3/ or alone in the cold followed by heating under reflux for a long time (see experimental sections, this thesis) no crystalline condensation product can be isolated, only the corresponding dichloride, $C_6H_5CH_2CHCl_2$, and resinous material.

Step 2) ... $\left.\begin{matrix} C_6H_5C(CN){:}CHCl \\ \text{or} \\ C_6H_5CH(CN)CHCl_2 \end{matrix}\right\} \longrightarrow$



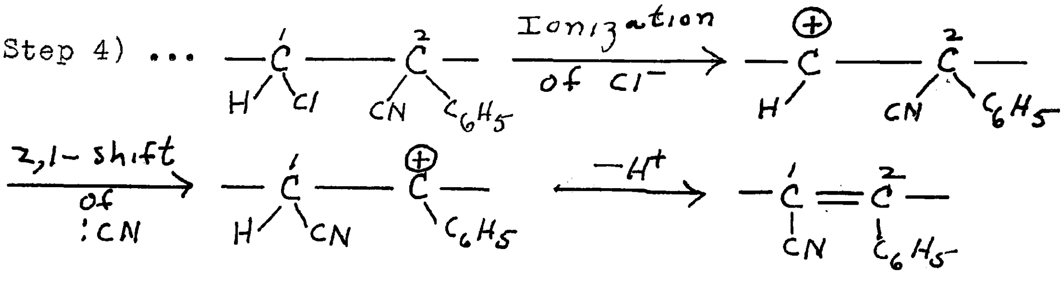
In the above proposed step, the assumed intermediate on the right can be considered the dichloride of a beta-styrylacetaldehyde that is disubstituted on the carbon adjacent to the aldehyde grouping. Under the acidic conditions existing this might reasonably undergo cyclization by dehydrohalogenation.

Step 3) ...

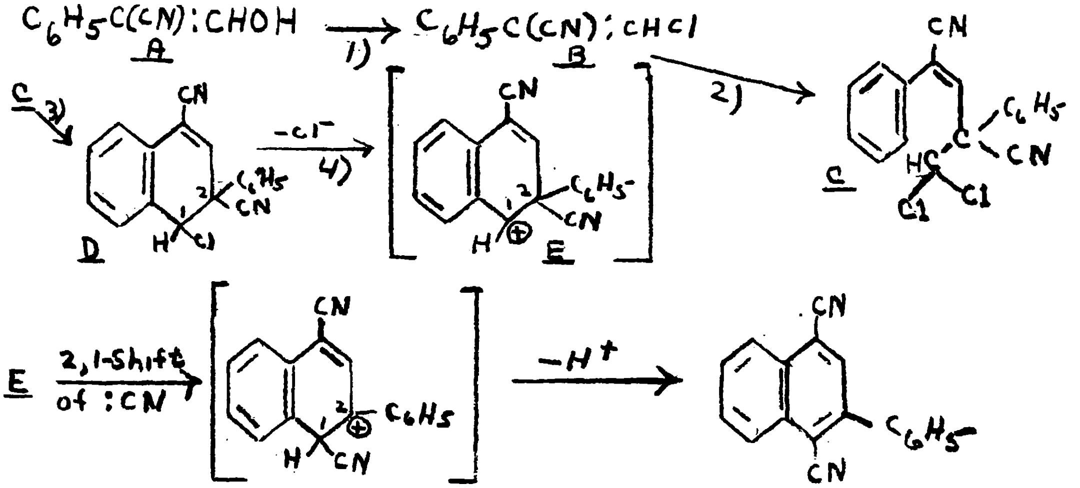


This cyclic intermediate might now undergo a 2,1-shift of the cyanide grouping (:CN) and loss of a proton to leave the ring fully aromatized. For a detailed discussion of 2,1-shifts (the so-called retropinacol or Wagner-Meerwein rearrangement) the monographs of Wheland /50/ and Wallis /49/ should be consulted. The shift envisioned here can be written in the following skeletonized form showing only the carbon atoms directly involved.

Step 4) ...



The above steps, proposed as plausible for the course of the reaction of Walther and Schickler, namely, 1) formation of the chloro derivative, 2) condensation, 3) cyclization by dehydrohalogenation, and 4) aromatization by 2,1-shift of the cyanide grouping, are given in summary form below.



ATTEMPTED VARIATIONS IN THE CONDITIONS AND REACTANTS IN THE REACTION OF WALTHER AND SCHICKLER:

In a series of experiments reported in the experimental section, the present worker studied the effects of varying slightly the conditions in the reaction of alpha-formyl-phenylacetonitrile with phosphorus pentachloride. In no case, however, was the yield increased significantly over that obtained employing the procedure of Walther and Schickler /48/ *in toto*. Such variations as operating at a lower temperature, decreasing or increasing the time of reaction, using greater excesses of phosphorus pentachloride, adding this reactant in several portions during the course of the reaction, and using toluene as a diluent failed to increase the yield significantly, and many such variations led to significantly lower yields.

In a further series of experiments reported in the experimental section, the condensation of alpha-formyl-phenylacetonitrile was attempted in the presence of other reagents. By the action of sulfuric acid, dilute or concentrated, cold or warm, the compound was recovered unchanged, converted to phenylacetic acid, or resinified, depending on the severity of the conditions employed. With concentrated sulfuric acid in the cold compound dissolves to give a cherry red colored solution: on long standing amorphous, yellow material is formed. By the action of warm 85% or 100% phosphoric acid only unreacted or resinous material could be obtained. The literature /48,54/ was confirmed that by the action of hydrogen chloride in refluxing ethanol only resinous material is formed. With 41% hydrobromic acid in glacial acetic acid by refluxing for 24 hours a small amount of 2-pehnylnaphthalene (m.p. 100°, Literature 102°) and of phenylacetic acid was obtained, and yellow, amorphous material (m.p. range, 130-165°); some carbon dioxide was evolved during the course of the reaction.

With refluxing thionyl chloride in large excess, only a high melting, brown, amorphous material was obtained. With anhydrous aluminum chloride in carbon disulphide, no reaction was observed. Alpha-formyl-phenylacetonitrile also failed to react with refluxing glacial acetic acid

Several attempts were also made to carry out a condensation under alkaline conditions. By the action of dilute alkali the compound was recovered unchanged on acidifaction, or it was decomposed to phenylacetonitrile depending on the concentration of alkali and the duration of the reaction. These experiments merely confirm the literature /48/.

An attempt was made to condense alpha-formyl-phenylacetonitrile with itself in refluxing absolute ethanol in the presence of small amounts of piperidine. However the only product obtained besides unreacted starting material, was a substance have the nitrogen content corresponding to $C_6H_5C(CN){:}CH\underbrace{N-(CH_2)_5}$ and decolorizing bromine in carbon-tetrachloride. The course of the reaction to this compound would be analogous to that reported in the literature for the interaction of alpha-formyl-phenylacetonitrile with aniline /39,48/ and with methylamine hydrochloride /48/.

In attempts to learn whether the reaction of Walther and Schickler might proceed with derivatives of phenylacetaldehyde other than the alpha-cyano derivative, the action of phosphorus pentachloride on phenylacetaldehyde itself and on hydratropic aldehyde, $C_6H_5CH(CH_3)CHO$, was studied.

Under mild conditions previous workers /3,23/ had obtained by the action of phosphorus pentachloride on phenylacetaldehyde only beta,beta-dichloroethylbenzene, $C_6H_5CH_2CHCl_2$. Using the more drastic conditions of heating with excess phosphorus pentachloride at 130° for twelve hours, the present worker was unable to demonstrate the presence of 2--phenylnaphthalene or other crystalline material, only chlorine containing material presumably $C_6H_5CH_2CHCl_2$ and resinous material was obtained.

With hydratropic aldehyde and phosphorus pentachloride under the conditions of the Walther and Schickler, no chlorine free or crystalline material could be isolated from the reaction mixture.

Wislicenus and Bilhuber / / have observed that the action of phosphorus pentachloride on ethyl-alpha-formyl--phenylacetate, $C_6H_5CH(CHO)COOC_2H_5$ on a steam bath, followed by removal of phosphorus oxychloride at 125° leads to ethyl beta,beta-dichloro-alpha-phenylpropionate, $C_6H_5CH(CHCl_2)COOC_2H_5$, in moderate yield. The product could be distilled without decomposition.

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SUMMARY OF FINDINGS CONCERNING THE REACTION OF WALTHER AND SCHICKLER:

The reaction of alpha-formyl-phenylacetonitrile with phosphorus pentachloride carried out at a temperature of about 130° for twenty-four hours gives in a yield of the order of fifteen to twenty percent 1,4-dicyano-2-phenylnaphthalene, identical in properties and reactions with samples of the compound obtained by the reaction of o-phenylenediacetonitrile with 1,4-dibenzoyl-ethylene. The reaction is highly specific, failing with several other common basic and acidic reagents, and also failing with phenylacetaldehyde and hydratropic aldehyde as reactants.

EXPERIMENTAL WORK, PART III

Preparation of Alpha-formyl benzyl cyanide /48/

To a solution of 49 grams of sodium metal in 400 ml. of absolute thanol was added 234 grams (2 moles) of freshly distilled benzyl cyanide. The mixture was cooled to 5°, and 130 g. of chilled methyl formate was added in two 65 g. portions with rapid stirring. The reaction mixture was allowed to stand in an ice bath for ten minutes; allowed to come to room temperature and then heated under reflux for one hour. The residual alcohol was then stripped under reduced pressure, caution being necessary to prevent bumping. The pasty, white residue was taken up in 3 liters of distilled water, and extracted with 1 liter of ether in three portions. The water layer was then made acid with concentrated hydrochloric acid. The first oil separating was poured off and on warming to evaporate residual ether it crystallized. These crystals were combined with crystals filtered from the water solution, washed with ether, taken up in ethanol, treated with Norite, and crystallized. The yield of white plates of alpha-formyl benzyl cyanide after drying in vacuo was 252.5 g. (87.3%), melting point 154-5°.

Preparation of 1,4-Dicyano-2-Phenylnaphthalene by Method of Walther and Schickler /48/

12 grams (0.0826 moles) of finely ground, dry alpha-formyl benzyl cyanide were mixed with 21 grams (0.101 moles) of freshly opened phosphorus pentachloride in a round bottom flask fitted with a reflux condenser, drying tube, and a

hydrochloride acid trap. The flask was warmed slowly; in the range 90-95° vigorous evolution of hydrogen chloride occurred accompanied by foaming and liquifaction of the flasks contents. On cessation of gas evolution and foaming, the bath temperature was raised to 135-140°, and the reaction mixture was refluxed for 24 hours. On cooling to room temperature the mixture thickened to a brown mass. To the reaction flask was added 50 ml. of high boiling petroleum ether, and refluxed for a short time; cooled, and the petroleum ether decanted. (Hood!). This operation was repeated twice again. The residual contents of the flask were repeated treated with small portions of hot benzene. The combined benzene extracts were filtered after chilling to 10° and to them high boiling petroleum ether was added. After scratching the walls for some time crystallization was induced. This was hastened by seeding with crystals from previous runs. The crystals were filtered and dried. Further crops of crystals were obtained by further addition of petroleum ether to the filtrate. The combined crops of product were dissolved in hot ethanol, treated with Norite, and recrystalized. The product can be further purified by sublimation at 150-160° and 4 mm. pressure. Yield of sublimed product 2.05 grams (0.00805 moles or 19.5% of theory) of 1,4-dicyano-2-phenylnaphthalene recrystallized from ethanol, as thin needles sintering at 182°, melting point in sealed capillary 186-186.5, and showing in solution in ethanol or acetone a pale blue fluorescence.

Comparison of Physical Data of $C_{18}H_{10}N_2$ by Reaction of Walther and by Michael Reaction of O-phenylenediacetonitrile and Dibenzoyl Ethylene.

Ultraviolet spectral absorption maximum:

Walther:	248 millimicrons; $\text{Log}_{10}E$, 4.76
Michael:	248 millimicrons; $\text{Log}_{10}E$, 4.57
Max. for 2-phenylnaphthalene:	250 millimicrons; $\text{Log}_{10}E$, 4.69

See accompanying graph of ultra-violet spectral data.

Melting points in sealed capillary:

	First Melting	Remelting
Purified Michael:	Shrinks at 182° m.p. 183.0-183.5°	185.2-186.0°
Purified Walther:	Shrinks at 182° m.p. 185.7-186.5	186-186.5
50-50 mixture:	Shrinks at 182° m.p. 184.5-185.5	185.5-186.5°

Comparison of the melting points of the basic hydrolysis product (4-amido-3-phenyl-1-naphthoic acid) obtained by the Walther reaction and the Michael reaction was unsatisfactory as the melting point is accomplished by decomposition and depends on the rate of heating.

Melting points of 11-keto-5-chrysofluorene carboxylic acid obtained by action of 100% H_3PO_4 on 1,4-dicyano-2-phenylnaphthalene from Walther reaction and from Michael reaction (in open capillary):

from Michael product:	317-318°	(uncor.)	with	decomp.
from Walther product:	318-319°	"	"	"
50-50 mixture:	317.5-318.5	"	"	"

Comparison of ultra-violet spectra of 1,4-dicyano-2-phenylnaphthalene obtained from the reaction of Walther and Schickler and by the Michael Reaction of o-phenylenediacetonitrile and cis-dibenzoyl ethylene.

Sample from Walther Reaction at concentration of 1.601 x 10^{-5} molar in 95% ethanol at cell thickness of 1.000 cms.

Wave Length	Slit Width	Percent Transmission	$\log_{10}E$ (calcd.)
218.8 mu	2.00 mm	28.4	4.467
220	2.00	28.9	4.470
223	2.00	31.8	4.508
226	2.00	32.2	4.511
230	2.00	28.6	4.531
235	2.00	25.5	4.569
240	2.00	18.8	4.657
243	1.90	15.6	4.702
245	1.80	13.5	4.735
247	1.70	12.2	4.757
248	1.70	12.0	4.758
249	1.70	13.0	4.744
250	1.70	12.8	4.747
253	1.60	17.0	4.682
255	1.60	23.0	4.601
257	1.50	30.6	4.507
260	1.40	42.4	4.367
263	1.40	49.7	4.276
265	1.30	51.1	4.261
270	1.20	51.3	4.258
275	1.10	52.5	4.243
280	1.00	57.0	4.205
283	1.10	60.0	4.142
285	1.00	63.3	4.094
288	1.00	68.5	4.012
290	0.90	72.5	3.941
295	0.70	77.5	3.840
296	0.70	79.7	3.790
298	0.70	79.5	3.795
300	0.80	78.6	3.815
305	0.80	76.0	3.873
310	0.60	73.1	3.930
320	0.64	66.5	4.044
330	0.80	65.0	4.068

Max. for 2-phenylnaphthalene at 250 mu; log E, 4.69

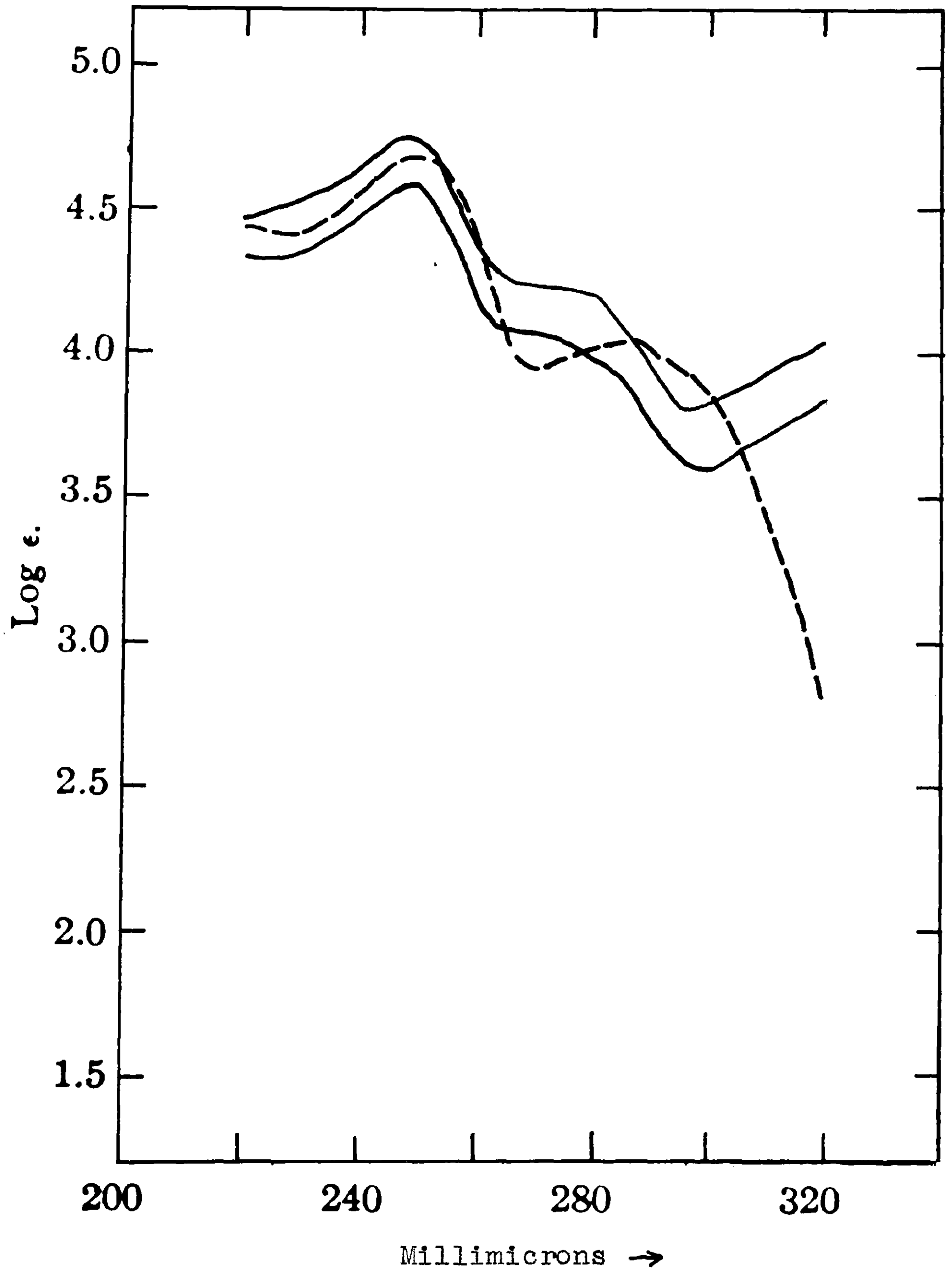
See accompanying graph formed from these data.

Sample from Michael reaction at concentration of 1.593 x 10^{-5} molar in 95% ethanol at cell thickness of 1.000 cms.

Wave Length	Slit Width	Percent Transmission	$\log_{10}E$ (calcd.)	
220.3 mu	2.00 mm.	45.8	4.328	
221.5	2.00	47.2	4.311	
224	2.00	48.6	4.295	
226	2.00	47.5	4.308	
228	2.00	45.8	4.328	
230	2.00	44.4	4.328	
231	1.90	43.1	4.360	
233	1.90	41.4	4.381	
235	1.80	41.1	4.384	
237	1.70	38.9	4.398	
240	1.60	34.4	4.465	
243	1.50	30.0	4.516	
245	1.40	27.5	4.549	
247	1.40	25.8	4.568	
248	1.40	25.7	4.569	Max. for 2-phenyl-naphthalene at 250 mu; log E, 4.69
249	1.40	25.8	4.568	
250	1.40	26.2	4.562	
253	1.40	31.2	4.501	
255	1.40	37.4	4.428	
257	1.30	45.1	4.336	
258.5	1.20	51.2	4.261	
260	1.20	57.1	4.184	
263	1.05	64.1	4.084	
265	1.00	66.0	4.054	
268	1.00	65.8	4.057	
270	0.95	66.0	4.054	
275	0.90	67.4	4.036	
280	0.80	70.4	3.981	
285	0.75	74.4	3.906	
287	0.70	76.2	3.869	
290	0.70	81.9	3.736	
295	0.70	85.4	3.634	
296	0.70	86.0	3.615	
298	0.70	86.9	3.584	
300	0.70	87.0	3.578	
302	0.70	85.4	3.634	
305	0.60	84.0	3.676	
310	0.60	82.5	3.719	
320	0.60	78.3	3.824	
330	0.50	75.9	3.877	

See accompanying graph formed from these data.

Ultra-Violet Absorption Spectra of 1,4-Dicyano-2-Phenylnaphthalene, and 2-Phenylnaphthalene



Dotted curve, 2-phenylnaphthalene from ref. 60.

Upper of solid curves, 1,4-dicyano-2-phenylnaphthalene from reaction of Walther and Schickler.

Lower of solid curves, same from condensation of o-phenylenediacetonitrile and dibenzoylethylene.

Variations in the Conditions of the Reaction of Walther & Schickler:

The following experiments were performed after the procedure of Walther and Schickler /48/ as give directly above with such modifications as noted. The product in all cases refers to the crystalline material isolated from the reaction mixture and merely sublimed at reduced pressure and melting in a sealed capillary at a temperature varying from experiment to experiment from 179° to 185°. In view of the amount of reactants employed in the following experiments, and the nature of the isolation process, the order of the yield, rather than its actual numerical value is the important fact to be noted. In none of the variations attempted was any significant improvement in the order of the yield observed.

Variation A: The temperature was maintained at 100° for 26 hours. From 3 grams of alpha-formyl-phenylacetonitrile and 5.2 grams of phosphorus pentachloride, about 0.12 grams of 1,4-dicyano-2-phenylnaphthalene was obtained (about 4.5% yield). The working up was made difficult by the presence of increased amounts of semi-liquid material of a lachrymatory nature.

Variation B: The time of reaction was decreased to three hours (after the cessation of hydrogen chloride evolution). From 3 grams of the nitrile and 5.3 grams of the halide, about 0.14 to 0.16 grams of product was obtained or about 5.5% yield.

Variation C: The time of reaction was increased to 48 hours. From 3 grams of the nitrile and 5.2 grams of the halide about 0.47 grams or about 18% yield.

Variation D: The use of a diluent was attempted. Three grams of the nitrile in 30 ml. of toluene (dried over sodium) and 5.4 grams of phosphorus pentachloride were refluxed 24 hours. On working up, 0.25 grams of product was obtained or about 9.5% yield. Considerable material of a lachrymatory nature was present and made working up difficult.

Variation E: The use of larger excesses of phosphorus pentachloride was attempted. 3 grams of alpha-formyl-phenylacetonitrile and 6.4 grams of phosphorus pentachloride heated for about 24 hours. On working up about 0.31 grams (12%) of product was isolated. Considerable semi-liquid material was present that was lachrymatory in nature.

Variation F: The addition of phosphorus pentachloride in slight excess during the course of the reaction proceeded in about 13% yield. From 3 grams of nitrile and 6 grams of phosphorus pentachloride (4.9 grams initially and 1.1 grams at the end of two hours reflux) gave about 0.35 grams.

Variation G: Allowing the reaction mixture to stand initially at room temperature for some time (about five hours), followed by heating at 130° for 20 hours gave no improvement in yield.

Action of Sulfuric Acid on Alpha-Formyl-Pehnylacetonitrile:

Concentrated Sulfuric Acid: 600 mgs. of alpha-formyl-phenylacetonitrile was added to 15 ml. of concentrated sulfuric acid at room temperature. The material went slowly into solution with the devlopment of a deep cherry red color. After standing at room temperature for four hours, the reaction mixture was drowned in water. The yellow precipitate that separated slowly was suction filtered, washed with water, followed by 5% alkali, and again water. The alkali wash on acidification showed no significant precipitate. The yellow precipitate was treated on the filter repeatedly with small portions of hot 95% ethanol. The alcoholic filtrate gave no coloration with ferric chloride and on cooling deposited a fine, yellow precipitate that was insoluble in base, did not take up bromine in carbon tetrachloride, and failed to melt on heating up to 328°, but darkened slightly above 280°. The aqueous acidic filtrate had an odor suggestive of phenylacetaldehyde and was yellow in appearance. On near neutralization and dilution with alcohol, it gave no significant coloration with ferric chloride. On adding excess alkali it deposited on long standing a small amount of yellow, apparently non-crystalline material that was not further investigated. The precipitate remaining on the filter after treatment with ethanol, was dirty yellow in color and failed to melt on heating up to 315°.

Cold, Dilute Sulfuric Acid: 650 mgs. of alpha-formyl-phenylacetonitrile added to 50 ml. of dilute sulfuric acid (1.5 molar) allowed to stand at room temperature for seven days. On drowning in water semi-solid material slowly settled out, and the supernatant solution was decanted. The residue was washed with water, followed by 5% alkali. On acidification of this alkaline wash, an off-white precipitate appeared with slight odor of unchanged starting material. The precipitate was taken up in alkali, re-acidified, and suction filtered. The resulting white material (about 60 mgs.) melted at 72-74° (melting point for phenylacetic acid, 76-7°). The main, yellow-brown precipitate after further washing with water was treated repeatedly with small amounts of hot 95% ethanol. The alcohol solution gave a moderately intense blue color with ferric chloride, indicating the presence of unchanged alpha-formyl-phenylacetonitrile. On dilution with water only amorphous material could be isolated, and was not further investigated.

Hot, Dilute Sulfuric Acid: The findings were similar to the above, except that a slight odor suggestive of that of phenylacetaldehyde was noted in the reaction mixture after drowning in water. No unchanged -formyl-phenylacetonitrile was detected, and a portion of the amorphous material melted in the range 115-160° with decomposition.

* * * * * * *

Action of Acetic and Hydrobromic Acids on Alpha-Formyl-Phenylacetonitrile:

Two grams of alpha-formyl-phenylacetonitrile, 25 ml. of glacial acetic acid, and 20 ml. of 48% hydrobromic acid were refluxed together for 28 hours. The solution turned progressively from red-brown to black, and some carbon dioxide was evolved. On cooling the reaction mixture was drowned in 800 ml. of water. The yellow-red material separating was extracted with ether, and the yellow-orange ether layer was extracted with 5% alkali. This alkali extract on acidification gave a precipitate that on recrystallization from acetone-water melted in the range 73-75° (phenyl acetic acid melts at 76-77°). The ether layer on washing with water, drying over sodium sulfate, and evaporation to dryness left a yellow residue. This on solution in hot 95% ethanol and dilution with water gave several solid fractions. The first (about 70 mgs.) melted at 98-100°, and probably was 2-phenylnaphthalene. The further fractions melted in the range 115-165°, were yellow in color, failed to give a significant coloration with ferric chloride in alcohol, did not take up bromine in carbon tetrachloride, and could not be sublimed at 160° and 4 mm. pressure without decomposition to a low melting (below 70°) sticky material.

* * * * * * *

ACTION OF ACETIC ACID ON ALPHA-FORMYL-PHENYLACETONITRILE:

250 milligrams of alpha-formyl-phenylacetonitrile was refluxed in 20 ml. of glacial acetic acid for nine hours. The reaction mixture was diluted with 200 ml. of water; potassium hydroxide was added to increase the pH somewhat, and extracted with ether. The ether extract was washed with water to remove acetic acid, evaporated to dryness, and residue had the odor of alpha-formyl-phenylacetonitrile, gave the characteristic deep blue color of this compound with ferric chloride in ethanol, and melted in the range 148-150°. Recrystallization from ethanol gave crystals of melting point 155-156°; pure alpha-formyl-phenylacetonitrile melts at 157-158°.

* * * * * * *

REACTION OF ALPHA-FORMYL-PHENYLACETONITRILE WITH ETHANOL-HCl:

500 mgs. of alpha-formyl-phenylacetonitrile was dissolved in 20 ml. of absolute ethanol, and the solution was saturated with anhydrous hydrogen chloride. Refluxed under exclusion of moisture for one hour. Five ml of distilled water was added and reflux continued for another thirty minutes. The ethanol was distilled off; cooled. The water layer was decanted from an resinous, semisolid residue. The latter was washed with several portions of warm, five percent potassium hydroxide solution, followed by water. The residue was taken up in benzene, chilled, and petroleum ether added. None of the material fractionally precipitated

by the addition of petroleum ether was crystalline, but tarry to oily in character, and was not further investigated. None of the fractions showed a positive ferric chloride test.

* * * * *

REACTION OF ALPHA-FORMYL-PHENYLACETONITRILE WITH-ALKALIS:

With 5% KOH: Alpha-formyl-phenylacetonitrile was dissolved in 5% chilled KOH solution; allowed to stand in icebox for two days. An oil separated on the surface; on separation it had the characteristic odor of phenylacetonitrile. On neutralization of the alkaline solution, the precipitate on solution in alcohol and treatment with ferric chloride gave the characteristic deep blue color of alpha-formyl--phenylacetonitrile.

With boiling 15% KOH: Alpha-formyl-phenylacetonitrile was boiled a short time with 15% KOH, the decomposition was rapid, the odor of phenylacetonitrile and ammonia being evident. Moist litmus paper turned blue indicating the presence of ammonia.

With 1% KOH: Alpha-formyl-phenylacetonitrile was placed in 1% potassium hydroxide solution and allowed to stand twelve days at room temperature. The starting material was recovered largely unchanged. A trace of floating oil suggested that small amounts of phenylacetonitrile were produced.

* * * * *

REACTION OF ALPHA-FORMYL-PHENYLACETONITRILE WITH PIPERIDINE:

Three grams (0.0206 moles) of alpha-formyl-phenylacetonitrile was placed in 7 ml. of absolute ethanol and 1.7 grams (0.020 moles) of piperidine (dried over potassium hydroxide) was added. The solution warmed and turned cherry red in color; it was warmed at 80° for one hour. Cooled and allowed to stand overnight in refrigerator. The crystals formed were filtered, washed with a little ethanol, and dried *in vacuo*, melting point 105-110°. The crystals were taken up in benzene and recrystallized. The resulting crystalline crop still showed a pale blue coloration in alcohol with ferric chloride solution probably due to the presence of some unreacted alpha-formyl-phenylacetonitrile. On recrystallization again from benzene, 3.1 grams of white prisms of melting point 122-123° were obtained. The product with ferric chloride in alcohol showed only a faint yellow coloration; with Fehling's solution no reducing action was observed, and bromine in carbon tetrachloride was readily taken up without the evolution of hydrogen bromide. In analogy with the reaction of aniline and methylamine hydrochloride with alpha-formyl-phenylacetonitrile, /39,48/, the product may have the structure $C_6H_5C(CN){:}CH\underbrace{N\text{-}(CH_2)_5}$.

Analysis: Cald. for $C_{14}H_{16}N_2$:N, 13.15%; Found: N, 12.84%.

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ACTION OF PHOSPHORUS PENTACHLORIDE ON PHENLYACETALDEHYDE:

27 grams (0.225 moles) of phenylacetaldehyde (residue from stripping of ethanol from 50% ethanol solution of phenylacetaldehyde (Eastman)) was placed in a round bottom flask fitted with reflux condenser and hydrogen chloride trap. 54 grams (0.260 moles) of phosphorus pentachloride was added in small portions under good cooling. The reaction is very vigorous. When the evolution of hydrogen chloride had ceased, the reaction mixture was slowly raised. Reflux was maintained at a bath temperature of 125-135° for twelve hours. On cooling, a dark brown, viscous, semi-solid material remained possessing the weak odor of unchanged phenylacetaldehyde.

One portion of the reaction mixture was repeatedly washed with hot benzene, and the combined benzene after washing with water and drying was concentrated, chilled, and diluted with petroleum ether, a viscous brown oil was obtained that set to a semi-solid consistency below 15°. No higher melting material could be isolated from this latter oil by attempted fractional precipitation from solvent mixtures.

One portion of the reaction mixture was washed with water repeatedly, and the residual oil distilled in vacuo. Considerable hydrogen chloride was evolved during a distillation, and most of the material could not be distilled below a bath temperature of 180° at 17 mms. pressure. A small portion

(1.5 of the distillate) was a dark yellow oil distilling at a bath temperature of 117-120° and is probably $C_6H_5CH_2CHCl_2$. (Literature: b.p. 110-119 at 25 mms. /23,3/).

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REACTION OF HYDRATROPIC ALDEHYDE AND PHOSPHORUS PENTACHLORIDE

20 grams (0.149 moles) of hydratropic aldehyde $C_6H_5CH(CH_3)CHO$ was placed in round bottom flask fitted with reflux condenser and hydrogen chloride trap. 34 grams (0.163 moles) of phosphorus pentachloride was added in small portions under good cooling. When the evolution of hydrogen chloride had ceased, the reaction mixture was slowly warmed. Reflux was established at a bath temperature of 125-130°. During the course of eight hours the bath temperature was slowly raised to about 140° to maintain reflux. The reaction mixture was cooled; water was added dropwise until foaming ceased, and then a large excess of water was added. The dark brown, viscous oil separating was taken up in benzene, dried over magnesium sulfate, and distilled under reduced pressure. After removal of the benzene, the oil began to come over at a bath temperature of 120°, 15 mms. pressure with the evolution of considerable hydrogen chloride. The distilled oil was yellow in color and contained chlorine as indicated by a positive silver nitrate test.

A small portion of the reaction mixture before addition of water was taken up in benzene, chilled, and petroleum ether added. A viscous oil separated that could not be crystallized.

One portion of the benzene solution of the undistilled oily product was stripped of benzene and stirred into concentrated sulfuric acid and allowed to stand at room temperature for two days. On drowning in water a chlorine containing viscous oil that could not be crystallized was obtained. A similar solution of the oily product in concentrated sulfuric acid was heated at 100° for one hour. On cooling and drowning in water a chlorine containing viscous oil was obtained that could not be crystallized.

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A BRIEF BIOGRAPHICAL RESUMÉ OF THE AUTHOR

A BRIEF BIOGRAPHICAL RESUME OF THE AUTHOR:

Parentage: Born January 5, 1920 in Hamilton, Ontario. Son of Rev. Alfred J. Barnard and Mary Gay Barnard of Quincy, Massachusetts and Prince Edward Island, Canada.

Education: Educated in the public school system of Boston, Massachusetts. Attended Tufts College, Medford, Massachusetts, 1938-1942, and received B. S. in Chemistry, magna cum laude, June 1942. Attended Graduate School of Arts and Sciences, Harvard University, Cambridge, Massachusetts, 1942-1944, and received M. A. degree (in chemistry), March 1944. Matriculated in the Graduate School, Lehigh University, Bethlehem, Pennsylvania, 1948-1950.

Professional Experience: 1942-1944, Austin Teaching Fellow, Department of Chemistry, Harvard University. Summers 1942, 1943, junior chemist, Godfrey L. Cabot Co., Boston, Mass.; properties of furnace blacks, decomposition of acyl peroxides. 1947-8, organized technical information service for the organic and antibiotic research divisions of J. T. Baker Chemical Company, Phillipsburg, N. J.

Military Service: Medical Department, U. S. Army; 1944-6. Served as T/3, Philippine Islands and Japan; surgical and medical laboratory technician, sanitation and tropical disease survey and control. Recipient of the Bronze Star, Combat Medical Award, and Combat Citation.

Professional Societies: Phi Beta Kappa (Tufts 1942); American Chemical Society, and its Division of Chemical Literature.

Publications: B. S. in Chemistry thesis, Tufts 1942, "Some Anomalous Salts of Glycine and Simple Amino Acids" (unpublished). Signed and unsigned technical information bulletins, published by J. T. Baker Chemical Company, 1947-1948.