THE REARRANGEMENT OF DISUBSTITUTED

DIAMINES

A thesis presented for the
degree of Doctor of Philosophy in Chemistry
in the University of Canterbury,
Christchurch, New Zealand.

by

G. B. RUSSELL

1963.
CONTENTS

ABSTRACT 1

I. INTRODUCTION 3

II. EXPERIMENTAL 13

(1) Introduction

Preparation of the Symmetrical N,N'-Diaryl-1,3-propanediamines 13

Preparation of Other Diamines 15

Preparation of N-(3-Bromopropyl)arylamines 17

Decomposition of the Diamines 18

Decomposition of the N-(3-Bromopropyl)arylamines 20

Examination of the Reaction Distillates 20

Examination of Reaction Residues 23

Identification of Components 24

Gas Chromatography 26

(2) Experimental Details 31

General 31

Preparation and Decomposition of:

N,N'-Diphenyl-1,3-propanediamine 31

N,N'-Di-β-tolyl-1,3-propanediamine 36

N,N'-Di-α-tolyl-1,3-propanediamine 41

N,N'-Di-α-m-tolyl-1,3-propanediamine 43

N,N'-Di-1-naphthyl-1,3-propanediamine 47

N,N'-Di-2-naphthyl-1,3-propanediamine 49

N,N'-Di-α-anisyl-1,3-propanediamine 50

N,N'-Di-α-m-anisyl-1,3-propanediamine 53
N,N'-Di-p-anisyl-1,3-propanediamine
N,N'-Di-o-chlorophenyl-1,3-propanediamine
N,N'-Di-m-chlorophenyl-1,3-propanediamine
N,N'-Di-3-bromophenyl-1,3-propanediamine
N,N'-Dianilinodimethyl ether
N,N'-Diphenyl-cis-1,3-propanediamine
N,N'-Diphenyl-1,3-butenediamine
N-(3-Bromopropyl)aniline
N-(3-Bromopropyl)-p-toluidine
N-(3-Bromopropyl)-m-chloroantline
N-(3-Bromopropyl)-p-anisidine
N-p-Toly1-N'-o-chlorophenyl-1,3-propanediamine

III. DISCUSSION

Conditions affecting Decomposition
The Scope and Synthetic Value of Diamine Breakdown
Extensions of Diamine Breakdown
Rearrangement Mechanism

APPENDIX

INTRODUCTION
EXPERIMENTAL
DISCUSSION
REFERENCES
ABSTRACT

The scope, mechanism and synthetic value of the acid-catalysed thermal decomposition of N,N'-diphenyl-1,3-propanediamine has been investigated. This diamine has been decomposed under a variety of acid conditions and the products have been analysed by gas chromatography. Using the optimum conditions found in these experiments, a number of other N,N'-diaryl-1,3-propanediamines have been decomposed with hydrogen bromide at elevated temperatures. The volatile products have been analysed by gas chromatography and have been separated chemically to give the expected anilines and 1,2,3,4-tetrahydroquinolines and also significant quantities of fulolidines in many cases where the formation of such tricyclic products is allowed. As well as these major components, a number of N-alkylanilines have also been isolated and some N-alkyltetrahydroquinolines have been provisionally identified. N,N'-Diphenyl-cis-1,3-cyclohexanediamine and sym-dianilino-dimethylether have been prepared and decomposed; examination of the reaction products has shown that 1,3-endomino-cyclohexane is probably produced in the first case while aniline and an intractible tar are obtained in the second case.

A number of N-(3-bromopropyl)-arylamines have been prepared and decomposed by heat. A comparison of the product ratios with those of the corresponding diamine decompositions has been made and the possibility that these compounds are intermediates in the diamine decomposition has been discussed. Comments have also been made of
other mechanistic aspects of the decomposition, in the light of
the experimental data.

During the course of this work, it was noted that no reports
could be found in the literature, of the application of the
Hofmann-Martius reaction to N-alkynaphthylamines. Consequently,
N-methylnaphthylamine hydrohalides have been prepared and decomposed.
With the hydrochlorides, only dibenzacridines were isolated, but
with the hydrobromides, normal Hofmann-Martius products were obtained
as well. The influence of the halogen on the course of such break-
down has been discussed.
INTRODUCTION

When N-alkylanilinium halides are heated in sealed tubes to about 300° they effectively undergo rearrangements in which one or more alkyl groups migrate from the nitrogen atom to the ring:

\[
\begin{align*}
\text{X}^+\text{NH}_2\text{R} & \xrightarrow{\Delta} \text{X}^+\text{NH}_3\text{R} + \text{X}^+\text{NH}_3
\end{align*}
\]

This reaction is known as the Hofmann-Martius rearrangement, and our knowledge of its scope and mechanism is based mainly on the extensive investigations of Hickinbottom. These have been reviewed in recent years 3,4.

The favoured position for entry of the alkyl group is the para position, if it is free; ortho substitution also occurs to some extent. For example, from the hydrobromide of N-methylaniline, are formed the salts of p-toluidine (main product) and o-toluidine 5. Polyalkylation has been stated to occur not only in the rearrangement of a tertiary amine, but also with a secondary amine 3,4.
However, the only example of this found in the literature, is the rearrangement of N-$n$-butylaniline hydrobromide. This is reported to give $p$-$n$-butylaniline as the major product, with aniline and $N_p$-$di$-$n$-butylaniline as by-products, together with a high boiling fraction suggested to contain $2,4$-$di$-$n$-butylaniline (the products from this decomposition contain unrearranged butyl groups and seem to be an exception to the generalizations made below). Hickinbottom has shown that alkyl halides and olefins are produced in the decomposition and can be drawn off, although with a reduced yield of ring alkylated anilines. He has also found that when the alkyl group is such that more branched isomers are possible, then these isomeric forms may be found in the ring-alkylated reaction products and in the olefins produced, but not in any alkyl halide drawn off from the reaction mixture. For example, N-$iso$amylaniline hydrobromide gives $iso$amylbromide, trimethylethylene and $p$-$tert$-amy laniline. Hickinbottom has further shown that olefins or easily ionised alkyl halides can be used to introduce alkyl groups into the aromatic ring of an aniline in the presence of its hydrohalide under the Hofmann-Martius reaction conditions.

Both intramolecular and intermolecular mechanisms were suggested by the early work on this reaction, and both have found supporters in recent years. Dewar, in supporting an intramolecular mechanism, assumes a $\bar{W}$-complex intermediate. His main argument against an intermolecular mechanism is that a formed alkylating agent would lead primarily to polyalkylation because of the activating effect of the
alkyl groups on the ring. Against this, however, is the fact that the most reactive position, the para position, is occupied first and the o-positions, possibly from steric causes, are considerably less reactive\(^4\). Also, olefin and alkyl halide formation, and the formation of products containing rearranged alkyl groups, are not readily explained on an intramolecular mechanism.

The generally accepted mechanism which has been proposed for the Hofmann-Martius rearrangement is the intermolecular mechanism of Hughes\(^3,4\), based on the earlier views of Michael\(^12\) and Hickinbottom\(^5\). Hughes considers the initial step to be a bimolecular displacement of the alkyl group from the anilinium ion by the nucleophilic halide ion. In the ionic solvent (molten anilinium salt) the halide may ionize, and the resulting carbonium ion may either lose a proton or attack the activated ring of an aniline molecule.

\[
\begin{align*}
\text{alkyl} + \text{halide} & \rightarrow \text{alkyl halide} + \text{olefin} \\
\text{alkyl} + \text{halide} & \rightarrow \text{carbonium ion} + \text{hydrogen}
\end{align*}
\]

It is to be noted that skeletal isomerisation cannot accompany the first step, which yields the alkyl halide; however production of a carbonium ion follows this step, and the appearance of isomeric alkyl groups in the C-alkyl-aniline, and in the olefin, is satisfactorily accounted for.
Hickinbottom suggested that the first step involved ionization:

\[
\begin{align*}
\text{NH}_2R & \quad \text{NH}_2^+ + R^- \\
\end{align*}
\]

and this has been suggested more recently to occur when the alkyl group is likely to produce a relatively stable carbonium ion.¹³

A recent report from this Department described an attempt to carry out a related rearrangement of N-phenylazetidine (I) to yield 1,2,3,4-tetrahydroquinoline (II).

At that time, the only recorded preparation of the required starting material (I) was that of Scholtz, who claimed to prepare it by the interaction of 1,3-dibromopropane and aniline. The preparation was of unusual interest, not only because it was the sole report of an azetidine being produced from the reaction of a dihalide with an amine, but also because the product was then the only reported N-ary lazetidine (N-ary lazetidines have since been prepared by the cyclization of N-(3-bromopropyl)-aryl amines under basic conditions¹⁶,¹⁷). Scholtz obtained the compound as a low-boiling fraction when distilling his main product, which was N,N'-diphenyl-1,3-propanediamine (III). Hanssen had previously prepared the diamine by this method, but failed to distil it owing to extensive decomposition. Veer later carried out the same preparation. He differed from Hanssen in
being able to distil his product, and from Scholtz in that the fraction distilling before the diamine contained only aniline. Sommers\textsuperscript{20} also prepared the diamine without signs of other products.

Fischer, Topsom and Vaughan\textsuperscript{14} found, in repeating Scholtz's preparation, that the low-boiling fraction could be separated into aniline and a compound answering to Scholtz's description of N-phenylazetidine. This description also fitted 1,2,3,4-tetrahydroquinoline (II) with which the compound was readily identified.

When the reaction mixture from the preparation was carefully freed from acid, N,N'-diphenyl-1,3-propanediamine (III) was the only product. However, the monohydrobromide of III was found to break down smoothly at 230°-250° to give II and aniline. With smaller amounts of acid present, the decomposition was less rapid but the same products were obtained. The yield of the reduced quinoline was about 50\%, and of aniline, slightly greater than quantitative on any of the simple reaction schemes described below.

A possible mechanism would be one based entirely on that for the normal Hofmann-Martius rearrangement, as is shown outlined in Fig. 1, opposite. However, it is possible that at the low acid, and therefore halide ion, concentrations used (usually a 10:1 molar ratio of III to HBr) the carbonium ion C might be produced by a direct unimolecular decomposition of A rather than via an alkyl halide intermediate B. As a further extension, the mechanism could involve a synchronous ring closure and aniline elimination, shown outlined in Fig. 2, opposite.
This was the mechanistic scheme favoured by Fischer, Topsom and Vaughan on the experimental evidence then available.

These authors also reported the preparation and decomposition of the \( \sigma \)-tolyl analogue of III; \( \sigma \)-toluidine and 3-methyl-1,2,3,4-tetrahydroquinoline were obtained in good yield (55\% for the latter compound). Substituted 1,2,3,4-tetrahydroquinolines are, in the main, prepared by chemical reduction of the corresponding quinoline. This method in some cases gives low yields and occasionally removes any nuclear halogen present. 1,2,3,4-Tetrahydroquinolines are also available by ring closure methods, for example 3-methyl-1,2,3,4-tetrahydroquinoline is obtained when \( \sigma \)-toluidine is heated with 1,3-chlorobromopropane and 1,2,3,4-tetrahydroquinoline is obtained by the reduction of \( \sigma \)-(\( \beta \)-acetylethyl)-nitrobenzene. From the work of Fischer et al. it seemed that the decomposition of suitable diamines might provide a useful additional route to substituted 1,2,3,4-tetrahydroquinolines, and one of the aims of the present work was to examine the scope of the reaction in the light of this possibility. For this purpose it was intended to prepare the ortho-, meta- and para-tolyl, the ortho-, meta- and para-anisyl, the ortho-, meta- and para-chlorophenyl, and the 1- and 2-naphthyl analogues of \( N,N' \)-diphenyl-1,3-propanediamine. It was hoped that the substituent range would prove sufficiently great to allow firm conclusions to be made concerning the effects of position and nature of substituent upon the product ratio and upon the ease of decomposition. It will be noted
that, from decomposition of the meta- substituted starting materials, two tetrahydroquinolines are possible:

\[
\text{HN - CH}_2\cdot \text{CH}_2\cdot \text{NH} \quad \xrightarrow[]{} \quad \text{HN} \quad + \quad \text{R} \quad + \quad \text{NH}_3
\]

The ratio of the 5- to the 7- substituted tetrahydroquinolines formed (IV and V) was expected to be of interest, especially to compare with similar data recently obtained by Palmer for the Skraup synthesis of quinolines.

In order to introduce fully the work undertaken, it is necessary to anticipate some of the results obtained in the present studies. Thus the diamine decompositions were found to yield not only tetrahydroquinolines, but also significant quantities of julolidines (VI) in cases where the aryl group of the diamine carried no ortho substituent.

These julolidines were obtained on further treatment of the residues left after simple distillation; in the earlier work of Fischer, Topsom and Vaughan these residues had not been further investigated. The
isolation of julolidine from simple diamine decompositions presented no great difficulty, and it became of further interest to see if the decomposition provided a useful route to substituted julolidines. The normal method for preparing julolidine is by refluxing 1,2,3,4-tetrahydroquinoline with 1,3-dichlorobromopropane but, apart from julolidine itself this method has only been recorded for the preparation of 8- and 9-methyljulolidines, and of 9-methoxy-julolidine; the method fails with other substituted tetrahydroquinolines. Smith and Tung Yin Yu, commenting on the scope of this method, concluded that the preparative route for julolidine via 1,2,3,4-tetrahydroquinoline was not always adaptable to the preparation of 9-substituted julolidines. In attempts to prepare a range of julolidines, these authors employed substitution reactions, assuming that the behaviour of julolidine towards electrophilic substitution should be similar to that of N,N-dimethylaniline. The 8-substituted julolidines, however, could not be prepared by direct substitution reactions which favour attack at the 9-carbon. The formation of julolidines in the diamine decompositions opened up the attractive possibility of a fresh route to the 8-substituted derivatives. It may be noted that while m-substituted arel diamines may be expected to give two isomeric tetrahydroquinolines, only one 8-substituted julolidine should be obtained.

During the course of these studies, it was hoped that a thorough analysis of products, in selected cases, might throw further light on the reaction mechanism. In particular, any intermediate halides and olefinic products would yield relevant information. It was intended also, to
compare the products from diamine decomposition, with those which
might be obtained by decomposing N-(3-bromopropyl)-arylamines (VII).

\[
\begin{align*}
&\text{ONH-CH₂-CH₂-CH₂-Br} \\
&\text{VII}
\end{align*}
\]

In particular, the \text{meta-} substituted N-(3-bromopropyl) anilines might
be expected to yield both 5- and 7- substituted tetrahydroquinolines
and the relative amounts of these obtained, could be compared with
those from the diamine decomposition. This comparison might indicate
if these bromo-compounds are likely intermediates.

All the diamines discussed above are symmetrical and cleavage of
either carbon-nitrogen bond leads to the same products. Hence, it was
intended to conduct further experimental work dealing with unsymmetrical
diamines, such as VIII and IX below:

\[
\begin{align*}
&\text{\text{CH₃}} \\
&\text{ONH-CH₂-CH₂-CH₃-HN-} \\
&\text{N,N'-Diphenyl-1,3-butanediimine} \\
&\text{VIII}
\end{align*}
\]

\[
\begin{align*}
&\text{\text{CH₃}} \\
&\text{ONH-CH₂-CH₂-CH₂-HN-Cl} \\
&\text{N-\text{p-Tolyl-}N'-\text{p-chlorophenyl-1,3-propenediamine}} \\
&\text{IX}
\end{align*}
\]
An examination of the products should reveal the comparative effects of substitution on the ease with which the carbon-nitrogen bond may be broken.

In all the proposed work so far outlined, the amine residues are linked by a simple trimethylene group. Of interest as a minor extension of the study was a proposal to prepare and decompose the further diamines N,N'-diphenyl-1,3-cyclohexane (X) and sym-dianilino-dimethylether (XI).

Of the geometrical isomers represented by X, the trans-isomer, it was thought, might readily give rise to the unknown 2,4-trimethylene-1,2,3,4-tetrahydroquinoline (XII), if the decomposition involved a synchronous one-step mechanism.

However, if a carbonium ion intermediate were involved, then the cis-isomer, which otherwise would have unfavourable geometry, might also give XII, on decomposition. Decomposition of the diamine XI, if it followed the pattern of the other diamine breakdowns, would be expected to result in the formation of 1,4-dihydro-2H-3,1-benzoxazine (XIII) in good yield.
Experimental

(1) Introduction

Preparation of the Symmetrical N,N'-Diaryl-1,3-propanediamines

Twelve N,N'-diaryl-1,3-propanediamines (aryl=phenyl, o-tolyl, m-tolyl, p-tolyl, o-anisyl, m-anisyl, p-anisyl, o-chlorophenyl, m-chlorophenyl, p-chlorophenyl, 1-naphthyl and 2-naphthyl) were prepared by the interaction, at elevated temperatures, of 1,3-dibromopropane with the appropriately substituted arylamine.

\[
\begin{align*}
2 \text{NH}_2 &\text{C}_6\text{H}_5 &\text{Br-CH}_2\text{-CH}_2\text{-CH}_2\text{-Br} &\rightarrow &\text{HN-CH}_2\text{-CH}_2\text{-CH}_2\text{-NH} \\
\end{align*}
\]

Veer\textsuperscript{19} carried out this preparation with a 4:1 molar ratio of aniline to 1,3-dibromopropane; the liberated hydrogen bromide reacted with the excess aniline to give the hydrobromide. This salt was then dissolved out of the reaction mixture with water and the base extracted with ether and distilled. Fischer, Topsom and Vaughan\textsuperscript{14} used this procedure but neutralized the reaction mixture with ammonia to eliminate the loss of product as its salt. They found that high yields proved possible when the ratio of aniline to 1,3-dibromopropane was 10:1. These conditions were followed in the present work for all diamines.
except those prepared from 1- and 2-naphthylamines. The reactions were exothermic, but were readily controlled, except in the case of p-anisidine where product decomposition occurred. For this particular preparation, the 1,3-dibromopropane was subsequently added dropwise with stirring. In general, the product was isolated by extraction and subsequent distillation.

In attempting a similar preparation for 1-naphthylamine, the exothermic reaction caused extensive decomposition even when the 1,3-dibromopropane was added dropwise. An attempt was made to carry out the reaction under milder conditions by refluxing a solution of 1-naphthylamine in benzene, with 1,3-dibromopropane. However, even on refluxing for several days, no appreciable reaction took place. Billman and Caswell have developed a method of preparing N,N'-diphenyl-α,ω-diaminoalkanes which involves the use of the sodio-derivative of acetenilide. This general scheme was:

\[
\begin{align*}
\text{NHCOC}_3 & \text{Na} \rightarrow \text{NOCOC}_3 \\
\text{COCH}_3 & \text{N} - (\text{CH}_2)_n - \text{N} \rightarrow \text{Cl}^-
\end{align*}
\]
This method was found by these authors to be particularly useful for those compounds where \( n = 4 \) or 5, but it also gave good yields for \( n = 3 \). This method was therefore followed in an attempt to prepare the diamine from 1-naphthylamine. Aceto-1-naphthalide was converted to the sodio-derivative by refluxing with sodium in toluene. The white solid obtained was in turn refluxed with 1,3-dibromopropane; the sodio-derivative dissolved and sodium bromide was precipitated. The product obtained on removal of the solvent was hydrolysed with concentrated hydrochloric acid but gave only 1-naphthylamine. However a further procedure, used by Trapesonzianz\(^{29}\) for the preparation of \( N,N'\)-di-1-naphthyl-1,2-propanediamine, was available. Following this method, 1,3-dibromopropane was added dropwise to a stirred mixture of 1-naphthylamine and anhydrous sodium carbonate. This proved successful, neutralization of the liberated acid by sodium carbonate effectively preventing decomposition. The procedure was then used, with similar success, for the conversion of 2-naphthylamine into the required diamine.

Preparation of Other Diamines

(a) \( N,N'\)-Diphenyl-1,3-butanediamine and \( \text{sym}-\text{dianilino-dimethylether} \) were prepared by the method above, the appropriate dihalide being heated with an excess of aniline.

(b) For the preparation of \( N,N'\)-diphenyl-\( \text{cis}-\text{1,3-cyclohexanediame} \) the general method was again used. It was originally intended to prepare both the \( \text{cis-} \) and \( \text{trans-} \) isomers from the respective dibromocyclohexanes and it seemed that both these starting materials could be obtained through a procedure reported by Lindeman and Helmut\(^{30}\). These workers claimed to
have prepared them from a mixture of cis- and trans-cyclohexane-1,3-diol, by refluxing with hydrobromic acid. They claimed that after they had distilled the reaction mixture the cis-1,3-dibromocyclohexane crystallized from the distillate and left the pure trans-isomer as a colourless liquid. The separation of the diols themselves, into cis- and trans-isomers, is known to be long and tedious, involving fractional recrystallization, and subsequent purification by derivatives. It was therefore, decided that the separation of the dibromo-compounds, as published by Lindeman and Helmut, would be quicker and easier. Accordingly the cis-dibromocyclohexane was prepared and isolated by their procedure. However the mother liquor, far from being pure trans-isomer, was shown by the analytical gas chromatograph to consist of a mixture of several components, in which the cis- and trans-isomers were present in almost equal amounts. Resolution of this mixture could not be effected by simple means.

In a recent paper, Cornubert, Rio and Sénechal have described the preparation of 1,3-dibromocyclohexane in which the trans-isomer predominates, from N-bromosuccinimide and cyclohexene.

\[
\begin{array}{c}
\text{Br} \\
\text{Br}
\end{array}
\rightarrow
\begin{array}{c}
\text{Br} \\
\text{Br}
\end{array}
\]

An attempt was made to prepare trans-1,3-dibromocyclohexane in this way. The 3-bromocyclohexene obtained in the first step was refluxed with 60% hydrobromic acid. The resulting dibromide answered the description given by Cornubert et al., but in this case also, gas chromatographic
analysis indicated a 1:1 mixture of cis- and trans-isomers. The reaction conditions were then modified, to see if a greater yield of trans-1,3-dibromocyclohexane could be obtained, by saturating the 3-bromocyclohexene with dry hydrogen bromide for several hours. However, little or no hydrogen bromide was added across the double bond. These results suggest that pure trans-cyclohexane-1,3-diol is required for the preparation of pure trans-1,3-dibromocyclohexane.

(c) N-α-tolyl-N-p-chlorophenyl-1,3-propanediamine was prepared as shown in the scheme below:

\[
\begin{align*}
\text{NH}_2 & \quad \text{Br}^- \quad \text{CH}_2 - \text{CH}_2 - \text{OH} \\
\text{CH}_3 & \quad \text{Br}^- \quad \text{NH}_2 - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{Br} \\
\text{NH} & \quad \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{OH} \quad \text{NH}_2 - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{H} - \text{N} - \text{Cl} \quad \text{Cl}
\end{align*}
\]

Preparation of N-(3-Bromopropyl)arylarnines

N-(3-Bromopropyl)aniline was prepared from aniline and 3-bromopropan-1-ol in the manner described by Deady, Leary, Topsom and Vaughan. N-(3-Bromopropyl)-m-toluidine and N-(3-bromopropyl)-m-chloroaniline were similarly prepared, but N-(3-bromopropyl)-p-anisidine was prepared by a method used by Deady for the preparation of the p-anisidine analogue.
In this method bromination of the \(\text{N-(3-hydroxypropyl)-m-anisidine}\) was carried out with phosphorus tribromide (bromination with hydrobromic acid would result in demethylation of the anisidine).

**Decomposition of the Diamines**

The Hofmann-Martius reaction is normally carried out in sealed tubes, and the products remain with the reactants. This would appear to be a necessary condition, because the initial products usually have boiling points close to those of the reactants, and therefore could not be separated by distillation during the reaction.

In the decomposition of \(\text{N,N'-diphenyl-1,3-propanediamine}\), most of the products were of lower molecular weight and boiling point than the reactant. Fischer, Topsom and Vaughan\(^{14}\) chose their conditions so that these products (aniline and tetrahydroquinoline) were distilled from the reaction mixture as they were formed. Similar conditions were chosen for the decompositions carried out in the present work. The Claisen flask containing the reactants was first evacuated to about 20 mm. by a water pump. This pressure proved to be sufficiently low for convenient distillation of products but not low enough to induce appreciable loss of hydrogen bromide from the reaction mixture. The Claisen flask was then heated slowly in an oil-bath and the temperature of decomposition taken when the first volatile products appeared. Subsequently the oil-bath was kept \(10^\circ\) to \(20^\circ\) above this critical temperature (ca. \(250^\circ\)). Reactions were in all cases continued until distillation had ceased and a small residue was left in the flask. All decompositions proceeded quite smoothly and quite rapidly except for the \(\text{p-anisidine, p-chloroaniline and p-chloroaniline analogues; in those cases, even with higher decomposition temperatures (230}\,^\circ\,\text{C - 300}\,^\circ\,\text{C),}\)
only slow breakdowns occurred.

Fischer et al. found it convenient to use 0.1 mole of hydrobromic acid for the bulk of their decompositions, and these were the conditions adopted for the early part of the present work. When a Pye analytical gas chromatograph became available, a number of decompositions of N,N'-diphenyl-1,3-propanediamine were carried out with varying amounts of acid. It was found that the ratio of components in the volatile fractions remained substantially unchanged, but that the more rapid decompositions accompanying the use of larger amounts of acid, led to greater residues. For example, two decompositions, each with 5g. of diamine gave:

(1) With 0.1 mole HBr, residue = 0.6g., time = 45 min.
(2) With 1 mole HBr, residue = 4.7g., time = 15 min.

These residues probably consist of unchanged diamine hydrobromide rather than salts of the products, and the experiments indicated that the most satisfactory amount of acid was indeed 0.1 mole. This proportion of acid allowed almost complete decomposition of the diamine in a reasonable time and the distillate usually accounted for about 90% (by weight) of the reactants.

From further experiments, employing sealed tubes and much the same conditions as for the normal Hofmann-Martius reaction, it was concluded that these conditions were less satisfactory for diamine decompositions; only half the diamine was decomposed to volatile components, and a large amount of intractible tar was left.

In other decomposition experiments, the nature of the acid was varied. Recent work in this department has shown that decomposition of
1,3-di(phenyloxy)propane (XIV) in the presence of aluminium chloride resulted in a high yield of chroman (XV).

Furthermore Hickinbottom has found that N-alkylanilines rearrange when heated with the Lewis acid, zinc chloride. However, two attempted diamine decompositions, using aluminium chloride, were unsuccessful and only unchanged diamine was obtained. Sulphuric acid also proved to be much less effective than hydrobromic acid; decomposition was slow and a large amount of residue was left.

**Decomposition of the N-(3-Bromopropyl)arylamines**

These bases were decomposed under conditions comparable with those for diamine breakdown. Thus the salts were neutralized and the bases heated under reduced pressure in a Claisen flask to about 200°. There was virtually no distillation of the volatile products, which effectively remained in the mixture as their hydrobromides. After heating for 15 minutes, the mixture was neutralized and distilled to give the volatile products.

**Examination of the Reaction Distillates**

In the early experiments, for which a gas chromatograph was not available, quantitative separation of the distillate components was attempted.
Chemical methods were employed, but a heavy reliance had to be placed on fractional distillation, for which a standard column (glass helices) or a modified Shorland column (nichrome coil) was used. The latter was highly efficient (20-30 theoretical plates) but with high-boiling fractions the procedure was slow and inconvenient. Later with the acquisition of an analytical gas chromatograph, analysis of a sample of the initial distillate preceded separation of components. After standardization of the instrument, a quantitative estimation of the components could be obtained and in subsequent treatment of the distillate, attention was focused mainly on identification. The normal separation procedure was then to obtain major fractions by distillation, to convert these into picrates, and to fractionally crystallize these from ethanol. A preparative gas chromatograph also became available and when a fraction contained more than one main component, (for example, isomeric tetrahydroquinolines with similar boiling points) this instrument was used to effect a separation.

Details of Chemical Methods of Separation: Three chemical methods of separation were used. In attempting quantitative separations two procedures, making use of the difference in properties of the primary, secondary and tertiary amines present, were available. These were the Hickinbottom method and the Hinsberg method. In the Hickinbottom method, the primary amines are separated from the mixture as ether- and water-insoluble zinc chloride complexes of the formula $B_2ZnCl_2$. This appeared to be more useful than the Hinsberg method both because the primary amine is easily removed and because the secondary amine is recovered as such and not as its benzenesulphonamide, which is sometimes difficult to hydrolyse. In preliminary experiments (with aniline and the
toluidines) some difficulty was experienced in a quantitative separation by this method, but this could partly be overcome by a slight modification, in which excess zinc chloride solution was added directly to the amine mixture rather than to an ether solution. However, washing the complex with water to remove excess zinc chloride always led to some hydrolysis and this reduced the accuracy of the method. Therefore, the complexes were deliberately hydrolysed and the arylamine subsequently obtained by distillation and weighed. Provided that these points were heeded, the Hickinbottom method was found to give good separations of the primary amines, except for the anisidines and for γ-chloroaniline.

The Hinsberg method of separation proved valuable in isolating a tertiary amine from a mixture containing secondary amines. Thus intermediate fractions from a distillation were often treated with benzenesulphonyl chloride and the julolidines were isolated in the pure state. The method proved especially useful in separating some of the products from the γ-anisyl-diamine decomposition. Use of this procedure was generally confined to the above purposes.

Fractional recrystallization of picrate mixtures also proved of great value in isolating many components, although the process was sometimes time-consuming. In general the least soluble tertiary amine picrates were first isolated while the more soluble secondary amine products were obtained from the mother liquors. The pure picrates were decomposed with sodium hydroxide solution. This separation was of particular use in isolating the products formed from the anisyl- and chlorophenyl-diamines.
Examination of the Reaction Residues

In general, the small tarry decomposition residues were not further examined. In some particular cases noted below, however, an attempt was made to isolate some of the components.

In the decomposition of $N,N'$-diphenyl-1,3-propanediamine, a small red residue was left in the flask. It was suspected that this residue could contain red salts of 9,9'-bijulolidyl (XVI), which has been shown by Smith and Tung Yin Yu\textsuperscript{27} to be an oxidation product of julolidine.

![Chemical Structures](image)

On neutralizing the residue, a brown sticky tar was obtained but further purification proved to be impracticable and no evidence for XVI could be found.

In the decomposition of $N,N'$-di-$o$-tolyl-1,3-propanediamine, juluolidine formation is excluded, but quite a large residue was left in the flask. Attempts made to neutralize and crystallize this residue failed. In a similar manner a large residue was obtained from $N,N'$-di-$o$-anisyl-1,3-propanediamine; in this case, extraction with sodium hydroxide solution and subsequent neutralization gave significant quantities of $o$-aminophenol. Similar treatment of the residue from the $m$-anisyl diamine gave $m$-aminophenol.
The decomposition of \textit{sym}-dianilino-dimethylether was unusual in that aniline was the only volatile product and 65% of the reaction product was a dark undistilled tar. As with other residues, its insolubility in organic solvents and its apparent high molecular weight suggested polymeric compounds.

Yellow crystals of 3,4,6,7-dibenzacridine(XVII) were obtained when the residue from the decomposition of \textit{N,N'}-di-2-naphthyl-1,3-propanediamine was stirred with acetone. This was the only residue to give a crystalline compound on treatment with a suitable solvent. An alcoholic solution of the residue gave 3,4,6,7-dibenzacridine picrate on the addition of picric acid.

\textbf{Identification of Components}

In most cases the components isolated were identified by comparing their melting points, and those of their derivatives, with published values. In cases of doubt, authentie samples were prepared by unambiguous methods. The most useful derivatives for the purpose were found to be hydrochlorides, picrates, benzoyl derivatives and methiodides.

The hydrochlorides were prepared by bubbling dry hydrogen chloride through a solution of the base in sodium-dried ether. The deposited derivative was recrystallized from alcohol. Picrates, easily prepared by adding an alcoholic picric acid solution to the base, were valuable in obtaining and characterising unknown bases. The benzoyl derivatives were formed under the conditions of the Schotten-Baumann reaction. They proved to be good specific derivatives for the characterisation of the secondary amines, particularly as only small samples were often collected...
from the preparative gas chromatograph. Methiodides, produced by the reaction of methyl iodide with the free base, were used to characterise tertiary amines.

Another procedure, which proved valuable in identifying tetrahydroquinolines, was dehydrogenation to the corresponding quinoline. The base was heated with an excess of sulphur until evolution of hydrogen sulphide had ceased. The mixture was then distilled to give the quinoline.

Infrared spectra were measured from a smear of the compound, using a Perkin-Elmer 221 spectrophotometer with sodium chloride optics. Two features of the spectra proved most useful for identification. These were: (a) The presence or absence of an N-H fundamental stretching vibration at about $2.95\mu$. This very clear peak was present in all spectra of the tetrahydroquinolines and of the N-alkylanilines but was absent in all spectra of the julolidines. (b) The C-H out of plane deformations of the aromatic ring. These vibrations occurred in the range $11\mu-15\mu$ and an analysis of the frequencies and the pattern allowed the positions of substitution in the benzene ring to be determined. This was valuable in identifying the N-alkylarylamines and in identifying the julolidines. The spectra were used as confirmatory evidence with the tetrahydroquinolines except with the 5- and 7-chloro-derivatives, where the structure of each isomer was assigned to the particular compound solely on the basis of the C-H out-of-plane deformations of the aromatic ring.

A number of compounds were provisionally identified by comparing their retention times on a Pye analytical gas chromatograph with those of authentic specimens. When analysing on the gas chromatograph the peaks in the mixture were assigned to a component by comparing their retention times with
samples isolated from the mixture itself. Such isolation was, in general possible when the amount of the component in the mixture was greater than 5%. A small quantity of the component was then added to the mixture and the affected peak was assigned to that component. In cases where such isolation was impracticable the authentic sample was synthesised and the retention time comparison was then always made on two different chromatographic columns, having liquid phases Apiezon L and polyethyleneglycol 4000 respectively. The Apiezon L column separated components according to their vapour pressures; polyethyleneglycol 4000 separated components according to their polarizability. The value of such a procedure may be seen in the case of N-ethyl-o-anisidine. This compound had the same retention time as N-iso-propyl-o-anisidine on the Apiezon L column but not on the polyethyleneglycol column. Certain other N-alkylanilines, quinolines and some N-alkyltetrahydroquinolines, all of which were present in very small amounts were identified in this manner, but it is appreciated that such identification, based on retention times and without isolation of the products themselves, cannot be conclusive.

Two other means of identification were used in particular cases. For quinoline, the ultraviolet spectrum could be compared with a published spectrum, and for 1,3-endoiminocyclohexane the nuclear magnetic resonance spectrum was analysed.

Gas Chromatography

(a) Analytical

Apparatus: The machine used for this purpose was a Pye Argon Gas Chromatograph incorporating a Brown Electronick strip-chart recorder, and an integrating amplifier. The instrument incorporates an ionization
detector, based on the principle described by Lovelock\textsuperscript{42}. The instrument handbook described the detector as being highly sensitive and very stable in that only slight changes in the ionization current occur for small changes in temperature, pressure and voltage. It also claimed the detector as having linearity-of-response (to concentration) at all voltages applied above a certain minimum. Ideally, the response of the detector should either be the same for different molecular species or be able to distinguish between them in some predictable manner. It has been claimed that, for most organic compounds with molecular weights above 100, the response is proportional to weight concentration\textsuperscript{43} and that, at a minimum detector voltage for a particular temperature, the peak area ratios should be reproducible to at least 3\%\textsuperscript{44}. During the course of this work these claims were, in the main, confirmed.

**Preparation of the Columns:** In order to achieve results commensurate with the capabilities of the chromatograph, care was taken in the preparation of the columns. The solid support chosen was Celite (a diatomaceous earth) and this was obtained in the correct particle size (between 154\( \mu \) and 152\( \mu \)) by grading 'Celite 545' between British Standard Sieves, Nos. 100 and 120. Since highly basic amines were to be used, the Celite was washed with alcoholic sodium hydroxide, to remove any active acid sites, before drying. This solid support was then impregnated with the hydrocarbon grease Apiezon L, as a liquid stationary phase. This was chosen because of its stability at high working temperatures. Following the manufacturer's recommendation that 10\% columns are of the most general application, 1g. of Apiezon L was dissolved in ether (40 mls.) and 9g. of the prepared Celite was added. After the ether had been removed on a water bath, the remaining material
was heated for 1 hour at 100° under reduced pressure. The material was then packed, with vibration, into a 4 mm. x 4 ft. glass column and was retained in place with plugs of glass yarn. The column was then preheated, in an auxiliary heater (224°) with argon passing through, for 24 hours to remove any low boiling materials. Tests showed that the liquid phase was stable and did not contain volatile impurities. All components used in this work showed peaks with a little or no "tailing" and, throughout the work, reproduction of retention times was good with this column. In general, the column temperature used was 150°-200° and the argon pressure was 101 lbs/in².

A polyethylene glycol 4000 column was prepared in a similar manner. Use of this column, however, was restricted to confirmatory identification because the necessarily lower operating temperature precluded analysis of high boiling components.

**Sampling Technique:** Samples were loaded into the column with a 0.05 μl. micropipette which was filled by capillary attraction. The gas line was disconnected for introduction of the sample, and the gas flow was restarted immediately afterwards. A negative baseline drift resulted from the flow stoppage and this was generally followed by a small negative air peak. Excellent reproducibility of analysis was obtained; in most cases the ratio of peak areas differed by less than the 5% limit imposed by the manufacturers. The mixtures were always diluted with ether to ensure that all the peaks were on scale and that the detector was not overloaded. Thus all quantitative measurements were relative.

**Carrier Gas:** The carrier gas used was commercial argon with a specified purity of 99.95%. No increase in sensitivity resulted in attempts to purify this further.
FIG. 3.

Tetrahydroquinoline : Aniline
(Chemical)

Tetrahydroquinoline : Aniline
(Peak Areas)
TABLE 1

Accuracy of Gas Chromatographic Analysis

This table shows some typical comparisons between the known weight ratios of mixtures of various amines with tetrahydroquinoline, as an internal standard, and the ratios determined from the peak areas.

<table>
<thead>
<tr>
<th>Amine</th>
<th>Weight Ratio</th>
<th>Peak Area Ratio</th>
<th>% Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aniline</td>
<td>0.812</td>
<td>0.780</td>
<td>11.8</td>
</tr>
<tr>
<td>o-Toluidine</td>
<td>1.831</td>
<td>1.792</td>
<td>2.2</td>
</tr>
<tr>
<td>p-Toluidine</td>
<td>1.412</td>
<td>1.063</td>
<td>33.0</td>
</tr>
<tr>
<td>m-Toluidine</td>
<td>0.642</td>
<td>0.660</td>
<td>2.7</td>
</tr>
<tr>
<td>o-Anisidine</td>
<td>0.823</td>
<td>0.760</td>
<td>6.8</td>
</tr>
<tr>
<td>p-Anisidine</td>
<td>0.758</td>
<td>0.812</td>
<td>6.8</td>
</tr>
<tr>
<td>m-Anisidine</td>
<td>1.232</td>
<td>1.293</td>
<td>4.7</td>
</tr>
<tr>
<td>o-Chloroaniline</td>
<td>0.810</td>
<td>0.714</td>
<td>11.3</td>
</tr>
<tr>
<td>p-Chloroaniline</td>
<td>1.062</td>
<td>1.020</td>
<td>3.1</td>
</tr>
<tr>
<td>m-Chloroaniline</td>
<td>0.755</td>
<td>0.800</td>
<td>3.5</td>
</tr>
<tr>
<td>N-Methyl-o-anisidine</td>
<td>0.437</td>
<td>0.438</td>
<td>3.3</td>
</tr>
<tr>
<td>6-Methyltetrahydroquinoline</td>
<td>0.925</td>
<td>1.000</td>
<td>7.5</td>
</tr>
<tr>
<td>8-Methyltetrahydroquinoline</td>
<td>0.495</td>
<td>0.548</td>
<td>11.5</td>
</tr>
<tr>
<td>7-Methoxytetrahydroquinoline</td>
<td>0.745</td>
<td>0.829</td>
<td>10.1</td>
</tr>
<tr>
<td>8-Methoxytetrahydroquinoline</td>
<td>0.630</td>
<td>0.645</td>
<td>2.5</td>
</tr>
<tr>
<td>6-Chlorotetrahydroquinoline</td>
<td>0.756</td>
<td>0.571</td>
<td>32.4</td>
</tr>
<tr>
<td>8-Chlorotetrahydroquinoline</td>
<td>0.848</td>
<td>0.635</td>
<td>23.8</td>
</tr>
<tr>
<td>Julolidine</td>
<td>0.848</td>
<td>0.898</td>
<td>5.4</td>
</tr>
<tr>
<td>9-Methyljulolidine</td>
<td>1.098</td>
<td>0.969</td>
<td>13.3</td>
</tr>
<tr>
<td>9-Chlorojulolidine</td>
<td>1.110</td>
<td>0.704</td>
<td>58.0</td>
</tr>
</tbody>
</table>
Linearity Check: This was carried out with a series of aniline-tetrahydroquinoline mixtures, and the results are shown graphically in Fig. 3. For the three points that show marked deviations from linearity, the tetrahydroquinoline peak heights were more than 60-70% of the full scale; this loss of linearity at large peak heights has also been noted by Creamer. For identification purposes peak heights were, within limits, unimportant but for analyses the mixtures were diluted till the peak heights of the more abundant components were not greater than 60-70% full-scale.

Response to Different Components: Checks on response were made, as required, during the course of the work. Tetrahydroquinoline was used as an internal standard, and the results are given in Table 1. These ratios show that for most compounds the response of the detector is proportional to weight concentrations, within a limit of 10% but with some compounds the variation was much greater. Most of these major deviations could be partly related to difficulties in purification and partly related to the chloro-substituent. Thus the chloro-tetrahydroquinolines and chlorojulolidine showed greatest deviations. However, the 9-chlorojulolidine, which was available only in small quantity, was difficult to purify at the time of the determination. Julolidine on the other hand presented far fewer difficulties in purification and gave a satisfactory analytical figure.

The determinations were repeated two or three times, with good agreement, with the primary arylamines. However, observations with aniline indicated that the analysis became less reliable if the column temperature was close to the boiling point of the amine. Repeat determinations were not made with the tetrahydroquinolines and julolidines as sufficient quantities of these bases were not available.
(b) Preparative

In some cases close boiling components, such as N-methyl- and N-ethyl- o- and p-toluidines, and the 5- and 7- substituted 1,2,3,4-tetrahydroquinolines were separated on the Beckman Megachrom Preparative Gas Chromatograph. This machine had four 4 foot columns, packed with C22 firebrick coated with 35% w/w Apiezon J as liquid phase. The operating temperature was 180° and the carrier gas was helium. The detector was a Katharometer and the peak areas obtained allowed the relative amounts of the components to be determined. Separations with the Megachrom were difficult with most of the compounds dealt with in this work. This arose firstly, because the long retention times of the components reduced the efficiency of separation; the Megachrom is of greatest use for more volatile components. Secondly, although the collection efficiency of the Megachrom column traps is high for a component in excess of 2ml., the efficiency declines markedly below this amount due to the decreased surface area available for condensation of the component. Since the sample volumes available in the present work were usually not more than 2-3ml., efficiency of recovery was often low, and a component present in small amount was liable to be lost.
**General**

Melting points and boiling points are uncorrected.

Reference melting points are given in brackets after the measured figures and, unless otherwise stated, they are the highest given in Beilstein's "Handbuch der Organischen Chemie", or Heilbron and Bunbury's "Dictionary of Organic Compounds".

Analyses were carried out at the Microanalytical Laboratory of the University of Otago.

Refractive indices were measured on a Hilger Abbé refractometer. The indices given are for the D line of sodium.

**Preparation and Decomposition of N,N'-Diphenyl-1,3-propanediamine**

**Preparation**

Redistilled aniline (400g.; b.p.66°/7mm.) and redistilled 1,3-dibromopropane (80g.; b.p.82°/60mm.) were heated together, with occasional swirling, on a water bath. After 30 min., solid aniline hydrobromide suddenly appeared in mass. After the mixture had been heated for a further 30 min., it was cooled and then shaken with a mixture of ether (500 ml.) and ammonia (200 ml.; s.g. 0.880). The ethereal extract was washed with water and was then dried over anhydrous sodium carbonate; the ether was removed by distillation. Distillation under reduced pressure allowed recovery of excess aniline (268g.; b.p.96°-100°/25mm.) and gave the required compound as a light yellow oil (70g.; 77% theory; b.p.192°-194°/1mm.); \( \eta_0^2 1.6188 \) (\( \eta_0 1.6257 \))\(^1\); dihydrochloride, m.p.192°-193° (193°-194°)\(^2\).
FIG. 4.
Decomposition

(a) N,N'-Diphenyl-1,3-propanediamine (32g.) and AnalaR hydrobromic acid (1.5ml.; 48%) were placed together in a simple Claisen distillation apparatus, and heated (silicone oil-bath) at a pressure of 20mm. Between 230°-240° (oil-bath temperature) nearly all the reaction material decomposed to give a distillate (26.4g.) and a red residue (5.9g.).

The distillate was carefully fractionated through an 18 inch column, packed with glass helices, to give aniline [13.5g.; b.p.64°-65°/7mm.; hydrochloride, m.p.200° (200°)] and 1,2,3,4-tetrahydroquinoline [4g.; b.p.104°-105°/7mm.; benzoyl derivative, m.p.76° (76°)]. The column was washed down into the distilling flask with ether and the ether was subsequently removed. Distillation of the residue from a Claisen flask gave julolidine (4.5g.; b.p.130°-138°/1mm.) as a light yellow oil. This oil soon solidified and gave, after two recrystallizations from acetone, white crystals, m.p.37°(40°).

Analysis:

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>33.23</td>
<td>8.49</td>
<td>3.17</td>
</tr>
<tr>
<td>% Calculated</td>
<td>33.23</td>
<td>8.67</td>
<td>3.07</td>
</tr>
</tbody>
</table>

It gave a picrate, m.p.173°(174°)27, and a methiodide, m.p.213°(186°). The infrared spectrum (Fig.4 opposite) showed peaks characteristic of 1,2,3-trisubstitution in benzene (13.3μ, 15.7μ), but no peak characteristic of an N-H bond.

An attempt was made to purify the red residue left in the decomposition flask but this was unsuccessful.

The amounts of each component, expressed as percentages by weight of
the original diamine, were:

<table>
<thead>
<tr>
<th>Amine</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aniline</td>
<td>42%</td>
</tr>
<tr>
<td>1,2,3,4-Tetrahydroquinoline</td>
<td>15%</td>
</tr>
<tr>
<td>Julolidine</td>
<td>14%</td>
</tr>
</tbody>
</table>

(b) In a second decomposition, N,N'-diphenyl-1,3-propanediamine (36g.) and AnalaR hydrobromic acid (1.5ml.; 48%) were decomposed under the same conditions to give a distillate (34.3g.) and a residue (2.5g.).

In this case the distillate was treated with zinc chloride solution (150ml.; 50% aqueous) to give, on stirring, a thick white paste of the zinc chloride-aniline complex. This complex was collected by filtration. It was washed with dilute zinc chloride solution and pressed down to squeeze out excess solution. The complex was then washed with ether several times, to remove adhering secondary and tertiary amines. This ether solution was used to extract further amines from the excess zinc chloride solution and from the aqueous washings. The dried zinc chloride-aniline complex (32.7g., corresponding to 18.9g. of aniline) was hydrolysed with hydrochloric acid (50ml.; 4N). This solution was then made alkaline with enough sodium hydroxide solution (10% aqueous) to dissolve the precipitated zinc hydroxide first formed. The liberated aniline was extracted with ether (100ml.) and the extract was washed with water and dried with anhydrous magnesium sulphate. The ether was then removed and distillation of the residue afforded aniline (15.3g.; b.p. 80°-84°/15mm.). The other ether solution containing the secondary and tertiary amines, was also washed with water and was dried with anhydrous magnesium sulphate. Distillation of the residue after removal of the ether, gave 1,2,3,4-tetrahydroquinoline (6.4g.; b.p. 126°-130°/15mm.) and
### Decomposition of N,N'-Diphenyl-1,3-Propanediamine

**1. Solvent**
- 2
- 3
- 4

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

### Decomposition of N,N'-Di-p-Tolyl-1,3-Propanediamine

**1. Solvent**
- 2
- 3
- 4
- 5

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FIG. 5.**
julolidine (2·9g.; b.p. 150°-155°/15mm.), m.p. 37° (40°) after two recrystallizations from acetone. The intermediate fraction (4·4g.; b.p. 130°-150°/15mm.) was shaken with a mixture of benzenesulphonyl chloride (30g.) and sodium hydroxide solution (50ml.; 10% aqueous). After cooling it was extracted with ether. This ether layer was extracted twice with 5% hydrochloric acid (to remove julolidine), then it was washed with water and dried over anhydrous magnesium sulphate. The ether was removed to leave 1,2,3,4-tetrahydroquinoline benzenesulphonamide (4·6g. equivalent to 2·3g. of base), m.p. 67° (67°) after two recrystallizations from alcohol. The hydrochloric acid extract was made alkaline and extracted with ether. This ether solution was washed and dried, and the ether was removed by distillation to leave julolidine (1·8g.), m.p. 38° (40°) after two recrystallizations from acetone.

Amounts of each component expressed as percentages by weight of the original diamine were:

- Aniline 42%
- 1,2,3,4-Tetrahydroquinoline 24%
- Julolidine 13%

(c) In a further decomposition, N,N'-diphenyl-1,3-propanediamine (5·1g.) and AnalaR hydrobromic acid (0·3ml.; 48%) were decomposed under the same conditions to give a distillate (4·5g.) and a residue (0·5g.).

The components of the distillate were analysed on the analytical gas chromatograph. Three peaks corresponding to aniline, 1,2,3,4-tetrahydroquinoline and julolidine were obtained on the strip recorder (identification trace is shown in Fig.5 opposite). With the integrating
amplifier, the relative amounts of each component were determined. The percentage amounts of each with respect to the original diamine were:

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aniline</td>
<td>45%</td>
</tr>
<tr>
<td>1,2,3,4-Tetrahydroquinoline</td>
<td>20%</td>
</tr>
<tr>
<td>Julolidine</td>
<td>17%</td>
</tr>
</tbody>
</table>

(d,e,f,g,h,i) In six further decompositions, N,N'-diphenyl-1,3-propanediamine (5g.) was heated in a Claisen distillation apparatus, under a pressure of 10mm., with six different amounts of AnalaR hydrobromic acid

(d) 0.27ml., (e) 0.30ml., (f) 0.12ml., (g) 0.51ml., (h) 1.28ml., (i) 2.65ml.

representing 0.05 moles (f), 0.1 moles (d,e), 0.2 moles (g), 0.5 moles (h) and 1 mole (i). Between 240° and 250°, decomposition occurred to give a distillate in all cases. The residue, which increased with the amount of acid, was neutralized in each case and the liberated bases were extracted with ether and combined with the respective distillates. These solutions were analysed on the analytical gas chromatograph and the relative amounts of each component were determined. The mixtures were then distilled to determine the amount of the volatile components. The results are tabulated on p.89, (Table 2).

(j,k) In two further decompositions, samples of N,N'-diphenyl-1,3-propanediamine 3.1g. (j), 2.7g. (k) were sealed in hard glass tubes with AnalaR hydrobromic acid 0.15ml., 0.1 moles (j); 1.35 ml., 1 mole (k).

The tubes were heated in a furnace at 250° for 1 hour, during which time the mixtures darkened. When cold, the reaction mixtures were neutralized with sodium hydroxide solution and the bases were taken up with ether. Evaporation of the ether and distillation of the residues gave distillates of 1.1g. (j)
and 0·9g. (k). The relative amounts of components in the distillates, determined by the analytical gas chromatograph, are tabulated on p.89, (Table 2).

(1) N,N'-Diphenyl-1,3-propanediamine (5·1g.) was heated in a Claisen distillation apparatus, under a pressure of 14mm., with concentrated sulphuric acid (0·12ml.). Between 260° and 270° a slow decomposition occurred which effectively stopped after 30 min. There was 1·8g. of residue and 2·9g. of distillate, the latter was subjected to gas chromatographic analysis. The results are given on p.89, (Table 2).

(m) N,N'-Diphenyl-1,3-propanediamine (5·3g.) was heated with anhydrous aluminium chloride (3g.) under the conditions above for 1 hour. There being no distillate, the residue was poured into water and the base was extracted with ether. After removal of the ether, distillation gave only unchanged diamine (4·4g.; b.p.192°-195°/1mm.), n^D 1·6195 (n^D 1·6185).

(n) N,N'-Diphenyl-1,3-propanediamine (5·4g.) was refluxed in xylene with anhydrous aluminium chloride (4·8g.) for 2-5 hours. The solution, together with undissolved aluminium chloride, was poured into water and the xylene solution separated. The xylene was removed by distillation and further distillation of the residue gave only unchanged diamine (4·9g.; b.p.192°-195°/1mm.), n^D 1·6130 (n^D 1·6138).

Preparation and Decomposition of N,N'-Di-p-tolyl-1,3-propanediamine

Preparation

Redistilled 1,3-dibromopropane (120g.; b.p.84°/80mm.) was added slowly to molten, redistilled p-toluidine (400g.; b.p.84°/10mm.) on a water bath. The remainder of the procedure was analogous to that used for the preparation of N,N'-diphenyl-1,3-propanediamine (p.31) and gave, after distillation, the
required compound (82g.; 56% theory; b.p.192°-194°/1mm.) as a thick liquid that soon solidified. Two recrystallizations from alcohol gave white crystals, m.p.70° (70°) 19; diacetyl derivative, m.p.119.5°-120°(120°) 19.

Decomposition:

\(\text{(a)}\) N,N' Di-p-tolyl-1,3-propanediamine (55g.) and AnaleR hydrobromic acid (2ml.; 48%) were heated (oil-bath) together in a Claisen distillation apparatus under a pressure of 20mm. A trap cooled by liquid air was interposed between the filter pump and the distillation apparatus. Decomposition commenced when the oil-bath reached 240° and the temperature was maintained at 250° until all the volatile products (51.7g.) had distilled over. A red glassy residue of 3.7g. was obtained. No trace of any organic material was found in the cold trap.

The distillate was fractionated through the modified Shorland column to give four main fractions.

**Fraction 1** (22.7g.; b.p.75°/10mm.) proved to be \(\text{\textregistered}\)-toluidine. The compound was obtained as a white solid after recrystallization from alcohol, m.p.45° (45°).

**Fraction 2** (2.5g.; b.p.94°-100°/10mm.), which had a characteristic odour, was N-ethyl-\(\text{\textregistered}\)-toluidine. It gave a hydrochloride, m.p.161° (162°), and a \(p\)-toluenesulphonamide, m.p.70° (71°).

Analysis for hydrochloride:

\[
\begin{array}{c|c}
\text{% Found} & 8.70 \\
\text{% Calculated} & 8.20 \\
\end{array}
\]

The infrared spectrum showed peaks characteristic of 1,4-disubstitution in benzene (12.4\(\mu\)), and of an N-H bond (2.95\(\mu\)).
Fraction 3 (6.6g.; 124°-125°/10mm.), which was collected as a light green liquid, soon solidified to give 6-methyl-1,2,3,4-tetrahydroquinoline, m.p. 35° (36°) after recrystallization from pentane.

Analysis:

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Found</td>
<td>81.41</td>
<td>8.78</td>
<td>9.52</td>
</tr>
<tr>
<td>Calc.</td>
<td>81.63</td>
<td>8.64</td>
<td>9.51</td>
</tr>
</tbody>
</table>

It gave a hydrochloride, m.p. 188° (189°), and a benzoyl derivative, m.p. 78.5° (78°). The infrared spectrum showed peaks characteristic of 1,2,4-trisubstitution in benzene (11.25, 12.40µm), and of an N-H bond (2.95µm).

Fraction 4 (5.6g.; b.p. 153°-160°/10mm.), which was obtained as a colourless liquid, nD 1.5799, proved to be 9-methyldulolidine. It gradually turned red on exposure to air.

Analysis:

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Found</td>
<td>83.15</td>
<td>9.04</td>
<td>7.51</td>
</tr>
<tr>
<td>Calc.</td>
<td>83.42</td>
<td>9.04</td>
<td>7.49</td>
</tr>
</tbody>
</table>

Equivalent weight (conductometric titration) 188.5 (187); pикрэт, m.p. 167°; methiodide, m.p. 229°-230°; hydrochloride, m.p. 250°.

An authentic sample of 9-methyldulolidine was prepared by refluxing 6-methyl-1,2,3,4-tetrahydroquinoline (1g.) with 1,3-dibromopropane (4g.) for 4 hrs. The solid hydrobromide salt was filtered off, washed with ether and neutralized with sodium hydroxide solution (10% aqueous); the liberated base was extracted with ether. Removal of the ether, and subsequent distillation, gave 9-methyldulolidine as a light yellow oil (b.p. 156°-160°/11mm.); pикрэт, m.p. 167° (unchanged when mixed with a sample of the picrate above); methiodide, m.p. 228°-229° (unchanged when mixed with the methiodide above).
The infrared spectrum of 9-methyljulolidine (Fig. 4 p. 32) showed a peak characteristic of 1,2,3,5-tetrasubstitution in benzene (11.7 μ) but no peak characteristic of amN-H bond.

After the fraction had been collected, the column was washed down with ether, to give, on removal of the ether, unchanged N,N'-di-p-tolyl-1,3-propanediamine (6.9 g.), m.p. 70° after two recrystallizations from alcohol. The melting point was unchanged when mixed with an authentic sample.

The amounts of each component, expressed as a percentage by weight of the original diamine, were:

- p-Toluidine 47%
- N-Ethyl-p-toluidine 5%
- 6-Methyl-1,2,3,4-tetrahydroquinoline 14%
- 9-Methyljulolidine 12%

(b) In a second decomposition under the same conditions, N,N'-di-p-tolyl-1,3-propanediamine (34.4 g.) and Analytical hydrobromic acid (1 ml.; 45%) gave a distillate of 32.2 g. and a residue of 2.6 g.

The distillate was treated with zinc chloride solution (50% aqueous) to give, by a method analogous to that for aniline (p. 33), p-toluidine (16.3 g.; b.p. 78°-80°/10 mm.), m.p. 45° (43°). The ether solution containing the secondary and tertiary amines was distilled to remove the ether, and further distillation from a Claisen flask with a Vigreux side arm gave 3 main fractions.

Fraction 1 (3.3 g.; b.p. 80°-110°/10 mm.) was passed through the preparative gas chromatograph to give N-methyl-p-toluidine [hydrochloride, m.p. 120° (120°) unchanged when mixed with an authentic sample] and N-ethyl-p-toluidine [hydrochloride, m.p. 161° (162°) unchanged when mixed with an authentic sample].
The peak areas on the recorder graph showed that the ratio of the 2 components was approximately 1:1.5 respectively.

**Fraction 2** (5·5g.; b.p.110°-150°/10mm.) was redistilled to give 6-methyl-1,2,3,4-tetrahydroquinoline (b.p.124°-125°/10mm.) as a light green liquid that soon solidified. After recrystallization from n-pentane it had m.p.36° (38°); benzoyl derivative m.p.78° (78°).

**Fraction 3** (5·3g.; b.p.130°-160°/1mm.) was redistilled to give 9-methyljulolidine (b.p.156°-160°/10mm.). It gave a picrate, m.p.167° unchanged when mixed with a authentic sample.

The percentage amounts of each component with respect to the original diamine were:

- p-Toluidine 47%
- N-Methyl-p-toluidine 4%
- N-Ethyl-p-toluidine 6%
- 6-Methyl-1,2,3,4-tetrahydroquinoline 16%
- 9-Methyljulolidine 16%

(c) In a further decomposition, N,N′-di-p-tolyl-1,3-propanediamine (11·5g.) and AnalaR hydrobromic acid (0·6ml.; 43%) gave 11·0g. of distillate and 0·5g. of residue.

The distillate was analysed on the analytical gas chromatograph and eight peaks were recorded (Fig. 5, p.34). These peaks were identified by comparing their retention times with pure samples, except those of 1,6-dimethyl-1,2,3,4-tetrahydroquinoline and N-ethyl-6-methyl-1,2,3,4-tetrahydroquinoline which were identified by comparing their retention times with samples made by refluxing 6-methyl-1,2,3,4-tetrahydroquinoline with
methyl bromide and with ethyl bromide respectively. (The prepared samples were not isolated but were used mixed with unreacted 6-methyl-1,2,3,4-tetrahydroquinoline). The areas under the peaks were measured with the integrating amplifier and relative amounts of each, with respect to the original diamine were:

<table>
<thead>
<tr>
<th>Compound</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>p-Toluidine</td>
<td>44%</td>
</tr>
<tr>
<td>N-Methyl-p-toluidine</td>
<td>4%</td>
</tr>
<tr>
<td>N-Ethyl-p-toluidine</td>
<td>6%</td>
</tr>
<tr>
<td>6-Methylquinoline</td>
<td>2%</td>
</tr>
<tr>
<td>6-Methyl-1,2,3,4-tetrahydroquinoline</td>
<td>15%</td>
</tr>
<tr>
<td>1,6-Dimethyl-1,2,3,4-tetrahydroquinoline</td>
<td>2%</td>
</tr>
<tr>
<td>N-Ethyl-6-methyl-1,2,3,4-tetrahydroquinoline</td>
<td>4%</td>
</tr>
<tr>
<td>9-Methyljulolidine</td>
<td>17%</td>
</tr>
</tbody>
</table>

**Preparation and Decomposition of N,N'-Di-o-tolyl-1,3-propanediamine**

**Preparation**

By a method analogous to that used to prepare N,N'-diphenyl-1,3-propanediamine (p.31), redistilled o-toluidine (200g.; b.p.90°/15mm.) and redistilled 1,3-dibromopropane (60g.) gave, after distillation, N,N'-di-o-tolyl-1,3-propanediamine (53g.; 72% theory; b.p. 205°-210/1mm.), as a thick liquid that soon solidified. Recrystallization from alcohol gave white crystals, m.p.50° (50°-51°).

**Decomposition**

(a) N,N'-Di-o-tolyl-1,3-propanediamine (39.8g.) was decomposed (240°-250°/15mm.) with AnalAr hydrobromic acid (1.5ml., 48%). The distillate weighed 34g. while 5.8g. of a light brown tarry residue remained.
The distillate was fractionated through the modified Shorland column to give three main fractions.

**Fraction 1** (15.1g.; b.p. 60°-64°/5mm.) was ω-toluidine, n\textsuperscript{o} 1.5701; hydrochloride, m.p. 215° (215°).

**Fraction 2** (2.9g.; b.p. 64°-110°/5mm.) was treated with zinc chloride solution (see p.33) to give ω-toluidine (1g.; b.p. 64°/5mm.). The ether solution containing the secondary amines was distilled, first to remove ether, and then to give a mixture found to be inseparable by chemical means.

**Fraction 3** (12.3g.; b.p. 110°-114°/5mm.) was 8-methyl-1,2,3,4-tetrahydroquinoline; n\textsuperscript{o} 1.5871; benzoyl derivative, m.p. 107° (108°); hydrochloride, m.p. 215° (215°). The base (2g.) was mixed with sulphur (1g.) and heated (oil-bath) at 250° for 30 min. Distillation afforded 8-methylquinoline (1.1g.; b.p. 174°/10mm.) as a yellow oil; picrate, m.p. 204° (205°)\textsuperscript{14}, unchanged when mixed with an authentic sample.

The amounts of each component, expressed as percentages by weight of the original diamine, were:

- ω-Toluidine 40%
- 8-Methyl-1,2,3,4-tetrahydroquinoline 31%

(b) In a second decomposition, N,N'-di-ω-tolyl-1,3-propanediamine (10.6g.) and Anslar hydrobromic acid (0.5ml.; 48%) were decomposed, as above, to give a distillate of 9.7g. and a residue of 0.7g.

On the analytical gas chromatograph, the distillate gave four major peaks which were identified by retention time comparisons. The distillate was treated with zinc chloride solution (see p.33) to give ω-toluidine
The ether solution containing the secondary amines was distilled from a Claisen flask with a Vigreux side-arm to give, first ether, and then 2 fractions.

**Fraction 1** (1.3g.; b.p.93°-132°/15mm.) was passed through the preparative gas chromatograph to give samples of N-methyl-α-toluidine benzoyl derivative, m.p.65° (66°)47 and N-ethyl-α-toluidine benzoyl derivative, m.p.72° (72°)47.

**Fraction 2** (5.0g.; b.p.132°-138°/15mm.) was 8-methyl-1,2,3,4-tetrahydroquinoline; benzoyl derivative, m.p.108° (108°), unchanged when mixed with an authentic sample.

The relative amounts of components, obtained and defined as before, were:

- α-Toluidine 32%
- N-Methyl-α-toluidine 4%
- N-Ethyl-α-toluidine 6%
- 8-Methyl-1,2,3,4-tetrahydroquinoline 46%

**Preparation and Decomposition of N,N'-Di-m-tolyl-1,3-propanediamine**

**Preparation**

The reaction between redistilled m-toluidine (500g.; b.p.90°/10mm.) and redistilled 1,3-dibromopropane (100g.) gave N,N'-di-m-tolyl-1,3-propanediamine (80g.; 65% theory; b.p.210°-220°/1mm.) as a light yellow oil, nD 1.6012

**Analysis:**

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>30.43</td>
<td>8.43</td>
<td>10.94</td>
</tr>
<tr>
<td>% Calculated</td>
<td>30.40</td>
<td>8.56</td>
<td>10.61</td>
</tr>
</tbody>
</table>

It gave a hydrochloride, m.p.214°-216° (215°-216°).
Decomposition

\( N,N'\text{-Di-}m\text{-}toly1\text{-}1,3\text{-propanediamine (41.8 g.) and AnalaR hydrobromic acid (1 ml.; 48\%) were heated together (200°-210°) in a Claisen distillation apparatus under a pressure of 20 mm. The distillate weighed 37.9 g. and the residue 3.1 g.} \)

The distillate was fractionated under reduced pressure through an 18 inch column packed with glass helices to give 3 main fractions; the residue (3.7 g.) was \( N,N'\text{-Di-}m\text{-}toly1\text{-}1,3\text{-propanediamine (hydrochloride, m.p. 210°-212°, unchanged when mixed with an authentic sample).} \)

**Fraction 1** (17.1 g.; b.p. 100°-110°/13 mm.) was \( m\text{-toluidine, m.p. 1.5656; hydrochloride, m.p. 227°-229° (228°).} \)

**Fraction 2** (3.4 g.; b.p. 144°-156°/18 mm.) was a mixture of 5- and 7-methyl-1,2,3,4-tetrahydroquinolines.

**Analysis:**

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>81.80</td>
<td>8.43</td>
<td>9.31</td>
</tr>
<tr>
<td>% Calculated</td>
<td>81.60</td>
<td>8.35</td>
<td>9.52</td>
</tr>
</tbody>
</table>

The mixture gave the following derivatives: benzoyl derivative, m.p. 121° (5-methyl-, 121°; 7-methyl-, 77°-78°)\(^4\) after four recrystallizations from alcohol; hydrochloride, m.p. 233°-240° (5-methyl-, 238°-240°; 7-methyl-, 204°-205°)\(^4\) after six recrystallizations from alcohol-ether. A sample of the mixture (2 g.) was mixed with sulphur (1 g.) and heated (oil-bath) at 240° for 1 hour. Distillation gave a mixture of 5- and 7-methylquinolines (1.2 g.; b.p. 129°-134°/16 mm.); one picrate was isolated, m.p. 238° (5-methyl-, 215°-221°23; 7-methyl-, 265°)\(^23\) after four recrystallizations from alcohol.

**Fraction 3** (4.4 g.; 172°-180°/18 mm.) was redistilled to give 8-methyljulolidine.
(b.p. 130°-132°/lmm.) as a light yellow oil, n° 1.5877.

**Analysis:**

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>83.28</td>
<td>9.30</td>
<td>7.60</td>
</tr>
<tr>
<td>% Calculated</td>
<td>83.42</td>
<td>9.09</td>
<td>7.43</td>
</tr>
</tbody>
</table>

It gave a picrate, m.p. 158° and a methiodide, m.p. 209°-210°.

**Analysis for Methiodide:**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>4.07</td>
</tr>
<tr>
<td>% Calculated</td>
<td>4.25</td>
</tr>
</tbody>
</table>

The infrared spectrum (Fig. 6, p. 67) showed a peak characteristic of, 1,2,3,4-tetrasubstitution in benzene (12.68 μ) but no peak characteristic of an N-H bond.

The amounts of each component expressed as percentages by weight of the original diamine were:

- m-Toluidine 45%
- 5- and 7-Methyl-1,2,3,4-tetrahydroquinoline 23%
- 8-Methyljulolidine 13%

(b) In a second decomposition, N,N'-di-m-tolyl-1,3-propanediamine (30.5 g.) and AnalR hydrobromic acid (1 ml.; 45%) gave 28.0 g. of distillate and 2.8 g. of residue.

Four peaks were obtained on the analytical gas chromatograph. These peaks were identified by comparing their retention times with isolated samples.

The distillate was treated with zinc chloride solution (see p. 33) to give m-toluidine (13.5 g.; b.p. 60°-70°/lmm.). Solvent was removed from the ether solution containing the secondary and tertiary amines and distillation of the residue gave two fractions.
Fraction 1 (5.5g.; b.p.93°-96°/1mm.) was passed through the preparative gas chromatograph to give samples of 5- and 7-methyl-1,2,3,4-tetrahydroquinolines. From the peak areas on the recorder graph, the ratio of the two components was 2:3. The 5-isomer had m.p. 27°, after recrystallisation from n-pentane; it gave a benzoyl derivative, m.p. 124°-125° (121°) and a hydrochloride, m.p. 239°-240° (238°-240°). The 7-isomer remained as a light green oil, m.p. 1-5302; it gave a benzoyl derivative, m.p. 77°-78° (77°-78°) and a hydrochloride, m.p. 205°-207° (204°-205°).

Fraction 2 (5.5g.; 114°-120°/1mm.) was 8-methyljulolidine; picrate, m.p. 157°-158°; methiodide, m.p. 209°-210°.

The relative amounts of the components were obtained with the analytical gas chromatograph. With respect to the weight of original diamine the percentages were:

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>m-Toluidine</td>
<td>42%</td>
</tr>
<tr>
<td>7-Methyl-1,2,3,4-tetrahydroquinoline</td>
<td>20%</td>
</tr>
<tr>
<td>5-Methyl-1,2,3,4-tetrahydroquinoline</td>
<td>14%</td>
</tr>
<tr>
<td>8-Methyljulolidine</td>
<td>14%</td>
</tr>
</tbody>
</table>

(c.d) In two further decompositions, samples of N,N'-di-m-tolyl-1,3-propanediamine (7.13g., 5.03g.) were heated (200°-210°/20mm.) with 1 mole of Analal hydrobromic acid (3.2ml., 2.3ml.).

Small distillates were obtained and decomposition was accompanied by the loss of hydrogen bromide. The residues were neutralized with sodium hydroxide solution and the liberated bases extracted with ether. These ether solutions were combined with the distillates and the mixtures analysed on the gas chromatograph. The mixtures were then distilled at 1mm. to give the volatile
components (5.0g.; 2.8g.). The weights of these, taken in conjunction with
the gas chromatographic analysis allowed the moles of components to be
calculated. The results are tabulated on p.92; (Table 4).

Preparation and Decomposition of \(\text{N,N'}-\text{Di-l-naphthyl-1,3-propanediamine}\).

Preparation

Redistilled l-naphthylamine (130g.; b.p.130\(^0\)-132\(^0\)/1mm.) was placed
in a flask fitted with a stirrer, condenser, dropping funnel and thermometer, and
heated on a water-bath. Anhydrous sodium carbonate (90g.) was added to the
molten base and the mixture was stirred. Redistilled 1,3-dibromopropane
(70g.) was added slowly at such a rate that the temperature of the mixture was
maintained at 150\(^0\)-130\(^0\). After 2 hours, when all the dibromopropane had been
added and the effervescence had ceased, the mixture was poured into water and
the bases were extracted with chloroform. The chloroform solution was washed
with water, and was dried with anhydrous sodium carbonate; the chloroform was
removed by distillation. Distillation of the residue gave previously unprepared
\(\text{N,N'}-\text{di-l-naphthyl-1,3-propanediamine}\) (32g.; 23\% theory; b.p.230\(^0\)-300\(^0\)/1mm.)
as a thick yellow liquid. On washing the product with ether white crystals
were obtained and were recrystallized from chloroform-ether, m.p.102\(^0\)-103\(^0\).

Analysis:

\[
\begin{array}{ccc}
& C & H \\
% Found & 34.36 & 6.66 \\
% Calculated & 34.86 & 6.74 \\
\end{array}
\]

It gave a dihydrochloride, m.p.237\(^0\)-250\(^0\).

Analysis:

\[
\begin{array}{c}
% Found \\
5.93 \\
% Calculated \\
6.20 \\
\end{array}
\]
Decomposition.

N,N'-Di-1-naphthyl-1,3-propanediamine (14·6g.) was decomposed with AnalAr hydrobromic acid (0·5ml.; 43%) at 250°-260° under a pressure of 15mm. The distillate weighed 13·9g. and the residue weighed 0·8g. The distillate was redistilled from a flask fitted with a fractionating side-arm to give two main fractions.

Fraction 1 (5·9g.; b.p.123°-134°/1mm.), which solidified, was 1-naphthylamine, m.p.49°-50° (50°) after recrystallization from petroleum ether (b.p.50°-70°). It gave an acetyl derivative, m.p.160°-162° (161°-162°).

Fraction 2 (5·6g.; b.p.182°-183°/1mm.) solidified and was recrystallised twice from petroleum ether (b.p.50°-70°) to give white crystals of 7,8-benzo-1,2,3,4-tetrahydroquinoline, m.p.44°-45° (45°), hydrochloride, m.p. 258°-260° (260°-262°). A small sample of the base was heated with sulphur to give, on distillation, a sample of 7,8-benzoquinoline, m.p.49°-50° (50°-51°). After recrystallization from petroleum ether (b.p.50°-70°). This gave a picrate, m.p.190°-191° (192°-193°).

Amounts of each component, expressed as percentages by weight of the original diamine were:

1-Naphthylamine 40%
7,8-Benzol-1,2,3,4-tetrahydroquinoline 33%

Preparation and Decomposition of N,N'-Di-2-naphthyl-1,3-propanediamine.

Preparation.

2-Naphthylamine (160g.), recrystallised twice from alcohol-water, and anhydrous sodium carbonate (80g.) were heated together to 130° in a flask
fitted with a stirrer, condenser, dropping funnel and thermometer. Redistilled 1,3-dibromopropane (100 g.) was added with stirring at a rate just sufficient to maintain the temperature at 160°-170°. When effervescence had ceased (2 hrs.) the mixture was poured into water and the bases were extracted with ether. The ether solution was washed with water and dried with anhydrous magnesium sulphate and the ether was removed by distillation. Distillation of the residue gave the previously unprepared N,N'-di-2-naphthyl-1,3-propanediamine (60 g.; 37% theory; b.p. 290°-300°/1mm.) as an orange glass.

Analysis:

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>34.29</td>
<td>6.57</td>
<td>8.15</td>
</tr>
<tr>
<td>% Calculated</td>
<td>34.68</td>
<td>6.74</td>
<td>8.59</td>
</tr>
</tbody>
</table>

It gave a dihydrochloride, m.p. 235°-237°.

Decomposition.

N,N'-Di-2-naphthyl-1,3-propanediamine (55.7 g.) on heating with AnalyR hydrobromic acid (2 ml.; 45%), decomposed slowly to give 47 g. of distillate; 7.5 g. of residue was left. The distillate was fractionated through a column (10 in.) packed with helices. There were two main fractions.

Fraction 1 (19.9 g.; b.p. 140°-148°/1 mm.) gave, after two recrystallizations from ligroin, white crystals of 3-naphthylamine, m.p. 110° (112°-113°), unchanged when mixed with an authentic sample.

Fraction 2 (17.4 g.; b.p. 160°-164°/1 mm.) gave, after two recrystallizations from ligroin, white crystals of 5,6-benzo-1,2,3,4-tetrahydroquinoline, m.p. 92°-93° (92°-93°). It gave an acetyl derivative, m.p. 31°-32° (77°), a benzoyl derivative, m.p. 156°-157° (153°-154°)50, and a hydrochloride, m.p. 246°-249° (246°-249°)50.
In addition to these two fractions a small higher boiling fraction 
(2·1g.; b.p.164°-180°/1mm.) was obtained as a thick oil. On the basis of 
itss infrared spectrum it seemed to consist mainly of 5,6-benzo-1,2,3,4-
tetrahydroquinoline. Addition of alcoholic picric acid solution gave a small 
quantity of finely divided, very insoluble, 3,4,6,7-dibenzacridine picrate, 
m.p.330°-335° (332°-334°)51. The presence of this base in the decomposition 
mixture was confirmed when the decomposition residue was washed with acetone to 
leave yellow crystals of 3,4,6,7-dibenzacridine, m.p.213°-218° (220°-221°)51; 
picrate, m.p.330°-335° (332°-334°)51.

Amounts of each component expressed as percentages by weight of the 
original diamine were:

2-Naphthylamine 36%
5,6-Benzo-1,2,3,4-tetrahydroquinoline 31%
3,4,6,7-Dibenzacridine Trace.

Preparation and Decomposition of N,N'-Di-o-anisyl-1,3-propanediamine

Preparation

Reaction of redistilled o-anisidine (250g.; b.p.90/1mm.) and redistilled 
1,3-dibromopropane (60g.) gave, after distillation, N,N'-di-o-anisyl-1,3-
propanediamine (60g.; 72% theory; b.p.230°-240°/1mm.) as a thick yellow oil.

Analysis:

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>71.0</td>
<td>7.61</td>
<td>9.37</td>
</tr>
<tr>
<td>% Calculated</td>
<td>71.32</td>
<td>7.59</td>
<td>9.78</td>
</tr>
</tbody>
</table>

Decomposition

N,N'-Di-o-anisyl-1,3-propanediamine (28g.) decomposed very slowly with
AnalR hydrobromic acid (1.2ml.; 43%) at 270°-280°, under a pressure of 20mm. The distillate obtained weighed 21.3g, leaving a dark red residue (6.4g.).

The distillate was analysed on the gas chromatograph and the four major peaks found were identified by retention time comparison, using both Apiezon L and Polyethyleneglycol 4000 liquid phase columns.

The distillate, on treatment with zinc chloride solution, gave only a sticky gum. It was therefore redistilled under reduced pressure, through a short fractionating column packed with glass helices, to give 3 fractions.

**Fraction 1 and Fraction 2** (3.2g.; b.p.32°-98°/1mm. and 1.6g.; b.p.98°-115°/1mm.) were shown by the gas chromatograph to each contain the same three components. Virtually no separation had thus occurred in the boiling range 92°-115°.

**Fraction 3** (3.2g.; b.p.115°-125°/1mm.) was 8-methoxy-1,2,3,4-tetrahydroquinoline. The fraction was converted to the hydrochloride salt and recrystallized three times from alcohol-ether, m.p.226° (220°)53. The salt was then neutralized to give a pure sample of the base; benzoyl derivative, m.p.151°-132° (132°)52; picrate, m.p.163°-164°. The infrared spectrum showed peaks characteristic of 1,2,3-trisubstitution in benzenes (13.2μ, 13.3μ) and of an N-H bond (2.9μ). A red residue (3.9g.) was left in the flask.

The first two fractions were mixed and treated with a saturated solution of picric acid in alcohol. Fractional recrystallization of the resulting picrate allowed separation of fine yellow needles of the less soluble o-anisidine picrate, m.p.209° (200°), from the light orange plates of N-methyl-α-anisidine picrate, m.p.140.5°-141° (141°-142°)55.
Analysis of N-methyl-α-anisidine picrate:  

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>46.13</td>
<td>4.26</td>
<td>15.82</td>
</tr>
<tr>
<td>% Calculated</td>
<td>45.90</td>
<td>3.83</td>
<td>15.30</td>
</tr>
</tbody>
</table>

No further picrates could be obtained from the mother liquors.

The α-anisidine picrate was decomposed with hot sodium hydroxide solution (10% aqueous) and the α-anisidine was recovered by steam distillation. The base was extracted with ether and distilled (n_20 = 1.5035; b.p. 65°-67°/1 mm.). The N-methyl-α-anisidine picrate was treated in a similar manner to yield, on distillation, a solid sample of N-methyl-α-anisidine (b.p. 65°/1 mm.), m.p. 30°-31° (33°).

Analysis:

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>70.22</td>
<td>8.31</td>
<td>10.09</td>
</tr>
<tr>
<td>% Calculated</td>
<td>70.07</td>
<td>8.03</td>
<td>10.22</td>
</tr>
</tbody>
</table>

It gave a hydrochloride, m.p. 115°-116° (115°-120°)\(^5\). The infrared spectrum showed peaks characteristic of 1,2-disubstitution in benzene (13.6\(\mu\)) and of an N-H bond (3.2\(\mu\)).

The large residue left in the flask after the main fractionation was dissolved in ether and shaken with sodium hydroxide solution (30% aqueous). The aqueous layer was neutralized with hydrochloric acid to precipitate a sticky gum. This gum was extracted with ether and the ether was removed to leave a residue that was dissolved in hot benzene. On cooling, white crystals of α-aminophenol were obtained, m.p. 173°-174° (174°) after a further recrystallization from benzene. The melting point was unchanged when mixed with an authentic sample.

Gas chromatographic analysis gave the following percentage amounts of
components with respect to the original diamine:

<table>
<thead>
<tr>
<th>Compound</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\alpha)-Anisidine</td>
<td>15%</td>
</tr>
<tr>
<td>N-Methyl-(\alpha)-anisidine</td>
<td>14%</td>
</tr>
<tr>
<td>N-Ethyl-(\alpha)-anisidine</td>
<td>1%</td>
</tr>
<tr>
<td>8-Methoxy-1,2,3,4-tetrahydroquinolone</td>
<td>3%</td>
</tr>
<tr>
<td>(\alpha)-Aminophenol</td>
<td>3%</td>
</tr>
</tbody>
</table>

1. N-Ethyl-\(\alpha\)-anisidine was only identified in the mixture by comparing its retention time, on both Apiezon L and Polyethylene glycol 4000 liquid phase columns, with a synthetic sample of N-ethyl-\(\alpha\)-anisidine. This was prepared by refluxing \(\alpha\)-anisidine (10g.) with ethyl bromide (5g.). After 60 min., the solid mixture was neutralized with sodium hydroxide solution (10% aqueous) and the liberated bases were extracted with ether. The ether solution was treated with zinc chloride solution (50% aqueous) and the precipitated \(\alpha\)-anisidine complex was removed by filtration. The ether extract containing the secondary amine was washed with water and was dried with anhydrous magnesium sulphate before being saturated with dry hydrogen chloride to give N-ethyl-\(\alpha\)-anisidine hydrochloride; on filtration and recrystallization from alcohol-ether, this salt had m.p. 195°-194°. The salt was neutralized with sodium hydroxide solution and the base was extracted with ether. Distillation gave N-ethyl-\(\alpha\)-anisidine (b.p. 84°-86°/1mm.) as a colourless oil.

2. Based on the weight of material actually isolated.

Preparation and Decomposition of N,N'-Di-\(\mu\)-anisyl-1,3-propanediamine

Preparation

Reaction between redistilled \(\mu\)-anisidine (100g.; b.p. 132°-134°/20mm.) and
redistilled 1,3-dibromopropane (40g.), gave the hitherto unknown N,N'-di-m-anisyl-1,3-propanediamine (41g.; 72% theory; b.p.220°-230°/1mm.) as a light orange oil.

Analysis:

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Found</td>
<td>71.40</td>
<td>7.42</td>
<td>9.21</td>
</tr>
<tr>
<td>Calc.</td>
<td>71.32</td>
<td>7.69</td>
<td>9.78</td>
</tr>
</tbody>
</table>

Decomposition

(a) The decomposition of N,N'-di-m-anisyl-1,3-propanediamine (15.4g.) in the presence of AnalaR hydrobromic acid (0.5ml.; 48%), at 200°-210° and under a pressure of 20mm, gave a distillate weighing 13.2g. and a residue of 3.1g.

The distillate was redistilled from a Claisen flask with a Vigreux side-arm to give two main fractions. A small amount of material then continued to distil but the temperature increased steadily with no obvious fraction.

- **Fraction 1** (5.2g.; b.p.104°-108°/10mm.) was m-anisidine; picrate, m.p. 175° (175°).
- **Fraction 2** (4.9g.; b.p.130°-140°/10mm.) was a mixture of 5- and 7-methoxy-1,2,3,4-tetrahydroquinolines. The preparation of a benzoyl derivative from the fraction was attempted but only an oil was obtained. A picrate from the fraction gave, on four recrystallizations from alcohol, fine yellow needles of 7-methoxy-1,2,3,4-tetrahydroquinoline picrate, m.p.154°-155° (7-isomer, m.p.156°; 5-isomer unknown), while a hydrochloride had m.p.196°-197° after four recrystallizations from alcohol-ether (7-isomer, m.p.181° 55; 5-isomer unknown). A sample of the mixture (2.5g.) was heated with sulphur (1.5g.) for 2 hours and gave on distillation a mixture of 5- and 7-methoxyquinolines (1.5g.; b.p.
120°-124°/10mm.). The quinoline mixture was treated with a saturated alcoholic picric acid solution and the bulk of the resulting picrate, collected by filtration, could be redissolved in ethanol. The small amount of insoluble picrate was recrystallized from a large excess of alcohol-acetone to give a small sample of 5-methoxyquinoline picrate, m.p. 230° (7-isomer, m.p. 235° 48; 5-isomer m.p. 230° 56) as fine yellow needles. The alcohol solution of the bulk of the picrate was boiled down to give fine yellow needles of 7-methoxyquinoline picrate, m.p. 235°-236° (235° 48) after a further recrystallization from alcohol. When this picrate was mixed with the previous picrate, the melting point was depressed.

The amounts of each component, expressed as percentages by weight of the original diamine, were:

- m-Anisidine 34%
- 5- and 7-Methoxy-1,2,3,4-tetrahydroquinolines 33%

(b) In a second decomposition, N,N'-di-m-anisyl-1,5-propanediamine (25g.) and AnalR hydrobromic acid (1ml.; 43%) were decomposed to give a distillate (21.1g.) and a residue (4.1g.).

The distillate was analysed on the Pye gas chromatograph and four major peaks found on the strip recorder were identified by comparing their retention times with those of authentic samples.

The distillate was fractionated through a short column, packed with glass helices, to give three main fractions.

Fraction 1 (9.1g.; b.p. 100°-110°/3mm.), which was shown by the analytical gas chromatograph to consist of two components, was treated with a saturated
solution of picric acid in alcohol. Fractional recrystallization of the precipitated picrate gave mainly m-anisidine picrate, m.p.175° (175°) unchanged when mixed with an authentic sample. A small sample of the more soluble N-methyl-m-anisidine picrate was obtained, m.p.147° (147°)57. The sample was too small to allow hydrolysis to the free base. The m-anisidine picrate was hydrolysed with hot sodium hydroxide solution (10% aqueous) and the base was obtained by steam distillation. It was extracted with ether and distilled (b.p.97°/1mm.).

Fraction 2 (7.5g.; b.p.120°-130°/3mm.), which was shown by the analytical gas chromatograph to consist of two components, was treated with a saturated solution of picric acid in alcohol. Fractional recrystallization from alcohol of the precipitated picrate gave only 7-methoxy-1,2,3,4-tetrahydroquinoline picrate, m.p.156° (156°)46. This picrate was hydrolysed with sodium hydroxide solution (10% aqueous) to give 7-methoxy-1,2,3,4-tetrahydroquinoline (b.p. 124°-126°/1mm.); benzoyl derivative, m.p.31° (31°)46. Its infrared spectrum showed peaks characteristic of 1,3,4-trisubstitution in benzene (12.1μ, 12.9μ) and of an N-H bond (2.9μ).

Fraction 3 (1.6g.; b.p.140°-160°/3mm.) was dissolved in ether and washed with sodium hydroxide solution (10% aqueous) to extract any phenols formed in the decomposition. The aqueous layer was separated and neutralized with hydrochloric acid (4N) to give a sticky gum. This was extracted with ether, the ether was removed, and the residue was recrystallized from toluene to give white crystals of m-aminophenol, m.p.123° (123°) unchanged when mixed with an authentic sample. Evaporation of the original ether extract from this fraction gave the previously unknown 8-methoxyjulolidine (0.5g.), as a dark liquid. This gave a picrate, m.p.147°-148° after recrystallization from alcohol.
FIG. 6.
Analysis:

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>52.50</td>
<td>4.91</td>
<td>12.96</td>
</tr>
<tr>
<td>% Calculated</td>
<td>52.73</td>
<td>4.63</td>
<td>12.96</td>
</tr>
</tbody>
</table>

The picrate was hydrolysed with sodium hydroxide solution to give a pure sample of the base.

Analysis:

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>76.96</td>
<td>3.36</td>
<td>6.73</td>
</tr>
<tr>
<td>% Calculated</td>
<td>76.85</td>
<td>3.37</td>
<td>6.90</td>
</tr>
</tbody>
</table>

The infrared spectrum showed (Fig. 6, opposite) a peak characteristic of 1,2,3,4-tetrasubstitution in benzene (13 μ) but no peak characteristic of an N-H bond.

With respect to the original diamine relative amounts, of the components determined with the gas chromatograph were:

- m-Anisidine 36%
- N-Methyl-m-anisidine 7%
- 5-Methoxy-1,2,3,4-tetrahydroquinoline 6%
- 7-Methoxy-1,2,3,4-tetrahydroquinoline 24%
- 3-Methoxyjulolidine 2% 2*
- m-Aminophenol 4% 2*

1.* Since 5-methoxy-1,2,3,4-tetrahydroquinoline was not isolated, although it was shown from the first decomposition to be present, it was assigned to the peak close to 7-methoxy-1,2,3,4-tetrahydroquinoline.

2.* These components were isolated from the high boiling fraction and the figure is the percentage calculated from the weights of the isolated samples.
Preparation and Decomposition of $N,N'$-Di-$p$-anisyl-1,3-propanediamine

**Preparation**

Redistilled 1,3-dibromopropane (120g.) was added dropwise to stirred redistilled $p$-anisidine (300g.; b.p.$115^\circ$-$120^\circ/1$mm.) heated on a water bath. After 60 min., solid $p$-anisidine hydrobromide had formed and the reaction mixture was cooled before being shaken with a mixture of ether (100ml.) and ammonia (200ml.; s.g.$0.380$). White crystals of the ether insoluble $N,N'$-di-$p$-anisyl-1,3-propanediamine were collected by filtration. The crude product (75g.; 44% theory) was recrystallized from alcohol to give pure material, m.p.$99^\circ$ ($96^\circ$)[16].

<table>
<thead>
<tr>
<th>Analysis</th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>70.30</td>
<td>7.56</td>
<td>9.52</td>
</tr>
<tr>
<td>% Calculated</td>
<td>71.32</td>
<td>7.69</td>
<td>9.79</td>
</tr>
</tbody>
</table>

It gave a hydrochloride, m.p.$203^\circ$-$209^\circ$.

**Decomposition**

(a) The decomposition of $N,N'$-di-$p$-anisyl-1,3-propanediamine (15g.) with AnalyR hydrobromic acid (0.5ml.; 48%) at $250^\circ$-$260^\circ$ under a pressure of 25mm. gave 12·1g. of distillate and left a red residue (2·3g.). The distillate was redistilled from a Cleisen flask fitted with a fractionating side arm, to give three main fractions.

**Fraction 1** (3·2g.; b.p.$96^\circ$-$99^\circ/1$mm.) contained mainly $p$-anisidine as three recrystallizations from $p$-pentane gave white crystals, m.p.$56^\circ$-$57^\circ$ ($56^\circ$).

**Fraction 2** (1·7g.; b.p.$116^\circ$-$125^\circ/1$mm.), a mixture of several components was treated with an alcoholic solution of picric acid. The resulting
picrate was filtered off and was then fractionally recrystallized from ethanol to give two products. The first was 8-methoxyquinoline picrate, m.p. 217°.

<table>
<thead>
<tr>
<th>Analysis</th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>49.35</td>
<td>3.29</td>
<td>13.96</td>
</tr>
<tr>
<td>% Calculated</td>
<td>49.50</td>
<td>3.09</td>
<td>14.45</td>
</tr>
</tbody>
</table>

The second was N-methyl-6-methoxy-1,2,3,4-tetrahydroquinoline picrate (or N-thallinethalline picrate, thalline being the trivial name for 8-methoxy-1,2,3,4-tetrahydroquinoline), m.p. 164°-165° (164°). No further picrates could be obtained. Another sample of this fraction was treated with methyl iodide to give, on recrystallization from alcohol-ether, white crystals of N-methylthallinethallide, m.p. 204°-305° (223°-224°).

<table>
<thead>
<tr>
<th>Analysis</th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>45.30</td>
<td>5.33</td>
<td>4.16</td>
</tr>
<tr>
<td>% Calculated</td>
<td>45.14</td>
<td>5.64</td>
<td>4.39</td>
</tr>
</tbody>
</table>

Fraction 3 (1.9g.; b.p. 120°-133°), containing several components, was also treated with an alcoholic picric acid solution. The resulting picrate was filtered off and fractionally recrystallized from ethanol to give thalline picrate, m.p. 164° (164°-165°) suppressed when mixed with previous picrate of N-methylthalline. Thalline picrate was hydrolysed with sodium hydroxide solution (10% aqueous) and a sample of the base obtained by steam-distillation, m.p. 38° (42°-43°) after recrystallization from p-pentane.

(b) N,N'-Di-p-anisyl-1,3-propanediamine (39g.) and AnalR hydrobromic
acid (1ml.; 48%) were decomposed, as in (a) above, to give a distillate (35-g.) and a residue (3·0g.).

Analysis of the distillate on the gas chromatograph gave ten peaks. Some of these peaks were identified by comparing retention times with authentic samples, but the isolation of components from the mixture was difficult and some of the components remained unidentified.

The distillate was fractionated through a column packed with glass helices. A continuous boiling range from 103° to 150° was observed at a pressure of 1mm., and six arbitrary cuts were taken. Analysis on the gas chromatograph showed that each fraction consisted of several components:

Fraction 1 (34g.; b.p.103°-116°/1mm.) consisting of 4 components, solidified and, after three recrystallizations from n-pentane, gave white crystals of p-anisidine, m.p.56°-57° (57°). The other fractions were mixed and shaken with benzenesulphonyl chloride (20ml.) and sodium hydroxide solution (30ml., 1% aqueous). After being cooled the mixture was extracted with ether. The ether solution was washed twice with 5% aqueous hydrochloric acid (to remove tertiary amines), then washed with water and dried over anhydrous magnesium sulphate. The ether was removed by distillation to leave the sulphonamides of the secondary amines. However, no free amines were obtained in an attempt to hydrolyse these sulphonamides. The hydrochloric acid extract was made alkaline and extracted with ether. This ether solution was washed and dried, and the ether removed. Distillation gave, according to the gas chromatograph, a mixture of five components (3·7g.; b.p.120°-140°/1mm.). A sample of this mixture, in ether, was saturated with dry hydrogen chloride to give, after two
recrystallizations from ethanol, 6-methoxyquinoline hydrochloride, m.p. 204°. This hydrochloride was neutralized and the liberated base was extracted and distilled to give 6-methoxyquinoline.

Analysis:

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Found</td>
<td>75.16</td>
<td>5.61</td>
<td>8.60</td>
</tr>
<tr>
<td>Calc.</td>
<td>75.50</td>
<td>5.65</td>
<td>8.80</td>
</tr>
</tbody>
</table>

Methyl iodide was added to a sample of the mixture and on recrystallization from ethanol-ether, white crystals of N-methylthalline methiodide were obtained, m.p. 204°-205° unchanged when mixed with the methiodide previously obtained.

Picric acid solution was added to a further sample of the mixture and gave, after fractional recrystallization of the picrate mixture, 6-methoxyquinoline picrate, m.p. 217° (unchanged when mixed with authentic sample) and N-methylthalline picrate m.p. 164° (164°). A small sample of N-methylthalline was obtained by hydrolysing the picrate with sodium hydroxide solution (10% aqueous).

The other components of the mixture could not be isolated.

Analysis on the gas chromatograph showed that the percentage amounts of each component with respect to the original diamine were:

1. \( p \)-Anisidine 31%
2. N-Methyl-\( p \)-anisidine 10%
3. N,N-Dimethyl-\( p \)-anisidine 10%
4. N-Ethyl-\( p \)-anisidine 20%
5. 6-Methoxyquinoline 3%
6. Thalline 3.5%
7. N-Methylthalline 3%
These components were identified by comparing their retention times with samples isolated from the decomposition mixture, except for components 2, 3 and 4, which were identified by comparing the retention times with samples made by refluxing p-anisidine with either methyl bromide (1:0.5 molar ratio for component 2; 1:2 molar ratio for component 3) or ethyl bromide (for component 4). The prepared samples were used while still mixed with unreacted p-anisidine. Two further peaks on the strip-recorder were, from their retention times and by inference from other decompositions, tentatively assigned to N-ethylthalline (3.5%) and 2-methoxyjulolidine (4%).

Preparation and Decomposition of N,N'-Di-o-chlorophenyl-1,3-propanediamine.

Preparation.

Redistilled p-chloroaniline (200g.; b.p.70°-72°/1mm.) and redistilled 1,3-dibromopropane (60g.) reacted to give, after distillation, the required compound (75g.; 86% theory; b.p.220°-225°/1mm.), previously unprepared. Recrystallization from alcohol of the solid product gave white crystals, m.p.77°-78°.

Analysis:

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>60.98</td>
<td>5.64</td>
<td>9.47</td>
</tr>
<tr>
<td>% Calculated</td>
<td>61.10</td>
<td>5.43</td>
<td>9.49</td>
</tr>
</tbody>
</table>

Decomposition.

N,N'-Di-o-chlorophenyl-1,3-propanediamine (50g.) decomposed slowly (300°) (20mm.) in the presence of Analar hydrobromic acid (2ml.; 48%); the distillate weighed 45.2g. and the residue weighed 5.2g.

Addition of ether to the distillate precipitated white crystals of
$\alpha$-chloroaniline hydrochloride (1g.). After recrystallization from alcohol-ether, the m.p. was $250^\circ-253^\circ$ ($239^\circ-260^\circ$) unchanged when mixed with an authentic sample. The ether-soluble distillate was analysed on the gas chromatograph and the four major peaks found were identified by comparing their retention times with those of authentic samples.

The distillate was redistilled through a short column (glass helices) to give three main fractions.

**Fraction 1** (16.8g.; b.p.64°-70°/mm.) was treated with an alcoholic picric acid solution. The picrate obtained was fractionally recrystallised from alcohol to give only $\alpha$-chloroaniline picrate, m.p.$136^\circ-137^\circ$ ($136^\circ$) unchanged when mixed with an authentic sample. The picrate was hydrolysed with sodium hydroxide solution (10% aqueous) to give $\alpha$-chloroaniline (15g.; b.p.$70^\circ$/1mm.).

**Fraction 2** (8.2g.; b.p.$80^\circ-90^\circ$/1mm.) was also treated with an alcoholic picric acid solution, to give more $\alpha$-chloroaniline picrate, m.p.$136^\circ-137^\circ$, unchanged when mixed with an authentic sample. On boiling down the mother liquor, bright yellow crystals of N-allyl-$\alpha$-chloroaniline picrate were obtained. After recrystallization from alcohol this had m.p.$87^\circ-68^\circ$, unchanged when mixed with an authentic sample.

**Analysis:**

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>45.23</td>
<td>3.73</td>
<td>14.07</td>
</tr>
<tr>
<td>% Calculated</td>
<td>45.40</td>
<td>3.23</td>
<td>14.12</td>
</tr>
</tbody>
</table>

N-Allen-$\alpha$-chloroaniline picrate was hydrolysed with sodium hydroxide solution to give, on steam distillation, a sample of the base.
The infrared spectrum was similar to that obtained from a synthetic sample. This was prepared by warming together allyl bromide (6 g.) and o-chloroaniline (12 g.). The precipitated salts were neutralized and the bases were extracted with ether. After the ether was removed, the residue was treated with an alcoholic picric acid solution to give o-chloroaniline picrate, m.p. 136°-137°. On boiling down the mother liquor N-allyl-o-chloroaniline picrate was obtained as a bright yellow solid m.p. 168°-169°. When hydrolysed this picrate gave a pure sample of the base.

Fraction 3 (10 g.; b.p. 105°-110°/1 mm.) was also treated with an alcoholic picric acid solution. The picrates were fractionally recrystallized from alcohol to give, as the least soluble component, a small quantity (0.5 g.) of quinoline picrate, m.p. 204°-205° (204°) unchanged when mixed with an authentic sample. The quinoline picrate was hydrolysed to give a trace of the base. Infrared and ultraviolet spectra of the free base compared favourably with the spectra of an authentic sample.

The only other picrate isolated was 8-chloro-1,2,3,4-tetrahydroquinoline picrate, obtained as orange-yellow crystals, m.p. 130°-131°.

Analysis:

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>45.58</td>
<td>3.40</td>
<td>14.07</td>
</tr>
<tr>
<td>% Calculated</td>
<td>45.54</td>
<td>3.28</td>
<td>14.14</td>
</tr>
</tbody>
</table>

This picrate was hydrolysed in the usual way to give the hitherto unprepared 8-chloro-1,2,3,4-tetrahydroquinoline as a light green liquid.
Analysis:

<table>
<thead>
<tr>
<th></th>
<th>C (%)</th>
<th>H (%)</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Found</td>
<td>64.71</td>
<td>5.82</td>
<td>8.01</td>
</tr>
<tr>
<td>Calculated</td>
<td>64.48</td>
<td>5.97</td>
<td>8.31</td>
</tr>
</tbody>
</table>

It gave a benzoyl derivative, m.p. 154°. A small sample of the base was dehydrogenated by heating with sulphur to give, on distillation, 3-chloroquinoline (b.p. 110°/1mm.); methiodide, m.p. 165°(165°). The infrared spectrum of the 3-chloro-1,2,3,4-tetrahydroquinoline showed peaks characteristic of 1,2,3-trisubstitution in benzene (13.3μ, 12.1μ) and of an N-H bond (2.95μ).

Analytical gas chromatography indicated that the amounts of each component with respect to the original diamine were:

- p-Chloroaniline 33%
- N- Allyl-p-chloroaniline 21%
- 3-Chloro-1,2,3,4-tetrahydroquinoline 29%
- Quinoline trace
- N-Ethyl-3-chloro-1,2,3,4-tetrahydroquinoline 5%

(This last component was only identified by comparing its retention time with a sample made by refluxing p-chloro-1,2,3,4-tetrahydroquinoline with ethyl bromide. The small amount of prepared sample was not isolated but used mixed with unreacted starting material.)

**Preparation and Decomposition of N,N'-Di-p-chlorophenyl-1,3-propanediamine**

**Preparation**

Redistilled p-chloroaniline (200g.; b.p. 107°-110°/2mm.) and redistilled 1,3-dibromopropane (60g.) gave, after distillation, N,N'-di-p-chlorophenyl-1,3-propanediamine (51g.; 58% theory; b.p. 280°-290°/1mm.) as a thick
orange liquid that soon solidified. Recrystallization from alcohol gave white crystals, m.p. 85°-86° (75°).19.

### Analysis

<table>
<thead>
<tr>
<th>% Found</th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>61.31</td>
<td>5.67</td>
<td>9.80</td>
</tr>
<tr>
<td>% Calculated</td>
<td>61.10</td>
<td>5.43</td>
<td>9.49</td>
</tr>
</tbody>
</table>

### Decomposition

51 Grams of N,N'-di-p-chlorophenyl-1,3-propanediamine, heated in the presence of hydrobromic acid (2 ml.; 48%), decomposed only slowly at 230°-290° (18 mm.) to give 43.8 g. of distillate and 6 g. of residue.

Addition of ether to the distillate precipitated p-chloroaniline hydrochloride, m.p. 265°-269°. This salt was neutralized to give p-chloroaniline (0.5 g.); recrystallization from ligroin gave material of m.p. 67°-68° (71°) unchanged when mixed with an authentic sample. The distillate was analysed on the gas chromatograph and seven major and three minor peaks were recorded. The latter were not identified since isolation from the mixture proved difficult.

Since redistillation through a short fractionating column gave no obvious fractions, the distillate was separated chemically. It was treated with zinc chloride solution (see p.33) to give p-chloroaniline (21.9 g.; b.p. 88°-90°/1 mm.; m.p. 68°-69°). The ether solution containing the secondary and tertiary amines was washed with water and dried, and the ether was removed. An unsuccessful attempt was made to separate the residue into components by fractional recrystallization of the picrates. However, on steam distillation, 9-chlorojulolidine remained as an oil in the still-pot. Subsequent extraction with ether and distillation gave a
pure sample of this hitherto unknown, compound (2.3g.; b.p.145°-149°/10mm.) as a white solid, m.p.45-50°-46° after recrystallization from petroleum ether (b.p.40°-50°).

Analysis:

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>69.49</td>
<td>7.01</td>
<td>6.42</td>
</tr>
<tr>
<td>% Calculated</td>
<td>69.39</td>
<td>6.75</td>
<td>6.75</td>
</tr>
</tbody>
</table>

It gave a picrate, m.p.152°-153°.

Analysis:

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>49.52</td>
<td>4.24</td>
<td>12.43</td>
</tr>
<tr>
<td>% Calculated</td>
<td>49.54</td>
<td>3.89</td>
<td>12.33</td>
</tr>
</tbody>
</table>

It also gave a hydrochloride, m.p.240°-241°. The infrared spectrum (Fig.6, p.57) showed a peak characteristic of 1,2,3,5-tetrasubstitution in benzene (11.7μ).

The steam-volatile bases obtained above were treated with an alcoholic picric acid solution and the picrates obtained were fractionally recrystallized to give, as the least soluble component, 6-chloroquinoline picrate. This recrystallized from alcohol as fine needles, m.p.220°.

Analysis:

<table>
<thead>
<tr>
<th></th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>12.90</td>
</tr>
<tr>
<td>% Calculated</td>
<td>12.39</td>
</tr>
</tbody>
</table>

Subsequent hydrolysis of this picrate with sodium hydroxide solution (10% aqueous) gave 6-chloroquinoline as a white solid, m.p.39°-40° (41°). It gave a methiodide, m.p.248°-250° (249°). The second picrate obtained from the fractional recrystallization was that of 5-chloro-1,2,3,4-tetrahydroquinoline, m.p.150° (150°). Hydrolysis of this picrate gave the
free base as a white solid, m.p. 40°-41° (42°); benzoyl derivative, m.p. 84° (84°). A small amount of the base was heated with sulphur to give, on distillation, 6-chloroquinoline, m.p. 39° (41°) unchanged when mixed with an authentic sample. This quinoline gave a picrate, m.p. 320° unchanged when mixed with an authentic sample. On boiling down the mother-liquor, a small sample of N-ethyl-p-chloroaniline picrate was obtained. After four recrystallizations from alcohol, it had m.p. 150°-151° (152°) unchanged when mixed with an authentic sample (prepared by refluxing p-chloroaniline with ethyl bromide and isolating the N-ethyl-derivative as the picrate). The picrate was hydrolysed to give N-ethyl-p-chloroaniline, nω 1·5631 (1·5629)59.

The relative amounts of each component determined on the gas chromatograph and expressed with respect to the original diamine were:

<table>
<thead>
<tr>
<th>Component</th>
<th>Relative Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>p-Chloroaniline</td>
<td>37%</td>
</tr>
<tr>
<td>N-Methyl-p-chloroaniline</td>
<td>5%</td>
</tr>
<tr>
<td>N-Ethyl-p-chloroaniline</td>
<td>10%</td>
</tr>
<tr>
<td>6-Chloroquinoline</td>
<td>2·5%</td>
</tr>
<tr>
<td>6-Chloro-1,2,3,4-tetrahydroquinoline</td>
<td>11%</td>
</tr>
<tr>
<td>N-Ethyl-6-chloro-1,2,3,4-tetrahydroquinoline</td>
<td>3%</td>
</tr>
<tr>
<td>9-Chlorojulolidine</td>
<td>14%</td>
</tr>
</tbody>
</table>

N-Ethyl-6-chloro-1,2,3,4-tetrahydroquinoline was identified by comparing its retention time, on two columns, with a sample made by refluxing 6-chloro-1,2,3,4-tetrahydroquinoline with ethyl bromide. The small amount of derivative was not isolated but used mixed with unreacted base.
Preparation and Decomposition of N,N'-Di-m-chlorophenyl-1,3-propanediamine

Preparation

Redistilled m-chloroaniline (200g.; b.p. 35°-38°/1mm.) and redistilled 1,3-dibromopropane (60g.) gave, after distillation, 52g. of hitherto unprepared, N,N'-di-m-chlorophenyl-1,3-propanediamine (60% theory; b.p. 260°-270°/1mm.) as a thick orange liquid, ν₉ 1.6415.

Analysis:

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>60.91</td>
<td>5.55</td>
<td>9.23</td>
</tr>
<tr>
<td>% Calculated</td>
<td>60.10</td>
<td>5.43</td>
<td>9.49</td>
</tr>
</tbody>
</table>

Decomposition

(a) N,N'-Di-m-chlorophenyl-1,3-propanediamine (43.6g.) and Anal R hydrobromic acid (1.7ml.; 48%) were heated (oil-bath) together under a pressure of 15 mm. The material decomposed slowly at 230°-240° to give 41g. of distillate, leaving a residue of 2.2g.

The distillate was analysed on the gas chromatograph and the four peaks found were identified by comparing their retention times with isolated samples.

The distillate was redistilled through a column (glass helices) to give three main fractions.

Fraction 1 (20.1g.; b.p. 74°-80°/1mm.) was m-chloroaniline, ν₉ 1.5931.

Fraction 2 (11.9g.; b.p. 110°-130°/1mm.) was shown by the Pye gas chromatograph to consist of two close-boiling components. Fractional recrystallisation of the picrates, prepared from a sample of the fraction, failed to effect separation. Close retention times of the two components
made separation difficult on the preparative gas chromatograph and only small samples of the hitherto unknown 5- and 7-chloro-1,2,3,4-
tetrahydroquinolines were obtained.

The respective identity of the two fractions was deduced from their infrared spectra (Fig. 7, opposite). The spectrum containing a peak of medium intensity at 11.95 \( \mu \) and one of strong intensity at 12.80 \( \mu \) was assigned to the 7-isomer; these frequencies being characteristic of the deformation of 1 isolated aromatic hydrogen and 2 adjacent aromatic hydrogens respectively. Moreover, the spectrum of 6-chloro-1,2,3,4-tetrahydroquinoline, which should contain analogous peaks, compared favourably with the spectrum of the unknown compound (Fig. 7). In a similar manner, the spectrum containing a peak of strong intensity at 15.10 \( \mu \) and a peak of medium intensity at 14.20 \( \mu \) was assigned to the 5-isomer; these frequencies being characteristic of the deformation of 3 adjacent aromatic hydrogens. The spectrum of 8-chloro-1,2,3,4-tetrahydroquinoline which should also contain these peaks, compared favourably with the unknown compound (Fig. 7).

5-Chloro-1,2,3,4-tetrahydroquinoline was a light green liquid, \( n^\circ_\text{D} 1.6137 \).

**Analysis:**

\[
\begin{array}{ccc}
\text{C} & \text{H} & \text{N} \\
\% \text{Found} & 64.53 & 6.31 & 8.00 \\
\% \text{Calculated} & 64.48 & 5.97 & 8.31 \\
\end{array}
\]

It gave a hydrochloride, m.p. 120°-122°.

**Analysis:**

\[
\begin{array}{c}
\% \text{Found} \\
\% \text{Calculated} \\
\end{array}
\]

7-Chloro-1,2,3,4-tetrahydroquinoline was a white solid after recrystallization.
from petroleum ether (b.p.30°-40°), m.p.63°-65.5°.

Analysis:

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>64.31</td>
<td>8.13</td>
<td>3.51</td>
</tr>
<tr>
<td>% Calculated</td>
<td>64.43</td>
<td>8.31</td>
<td>8.31</td>
</tr>
</tbody>
</table>

It gave a hydrochloride, m.p.208°-209°.

Analysis:

<table>
<thead>
<tr>
<th></th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>6.94</td>
</tr>
<tr>
<td>% Calculated</td>
<td>6.86</td>
</tr>
</tbody>
</table>

Fraction 3 (6.5g.; b.p.133°-140°/1mm.), obtained as an oil, was the hitherto unknown 8-chlorojulolidine.

Analysis:

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>69.39</td>
<td>6.77</td>
<td>7.12</td>
</tr>
<tr>
<td>% Calculated</td>
<td>69.39</td>
<td>6.75</td>
<td>6.75</td>
</tr>
</tbody>
</table>

It gave a picrate, m.p.161°-162° after recrystallization from alcohol.

Analysis:

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>49.78</td>
<td>4.20</td>
<td>12.75</td>
</tr>
<tr>
<td>% Calculated</td>
<td>49.54</td>
<td>3.39</td>
<td>12.83</td>
</tr>
</tbody>
</table>

It also gave a hydrochloride, m.p.162°-163° after recrystallization from alcohol-ether. Its infrared spectrum (Fig.6, p.57) showed a peak characteristic of 1,2,3,4-tetrasubstitution in benzene (12.8μ).

Gas chromatography showed that the relative amounts of each component with respect to the original diamine were:
<table>
<thead>
<tr>
<th>Chemical Compound</th>
<th>Yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>m-Chloroaniline</td>
<td>47%</td>
</tr>
<tr>
<td>5-Chloro-1,2,3,4-tetrahydroquino 16/o</td>
<td>13%</td>
</tr>
<tr>
<td>7-Chloro-1,2,3,4-tetrahydroquinoline</td>
<td>13%</td>
</tr>
<tr>
<td>3-Chlorojulolidine</td>
<td>13%</td>
</tr>
</tbody>
</table>

(b,c) In two further decompositions, samples of N,N'-di-m-chlorophenyl-1,3-propanediamine (9.1g., 5.7g.) were heated with 1 mole of AnalR hydrobromic acid (3.5ml., 2.2ml. respectively). Between 230°-240° decomposition occurred to give, with the loss of hydrogen bromide, a small distillate. After distillation had effectively ceased, the residue was neutralized with sodium hydroxide solution and the liberated bases were extracted with ether. This ether solution was combined with the distillate and the mixture was analysed on the gas chromatograph. The relative amounts of the components were determined and are tabulated on p. 92. The mixture was then distilled at 1mm. to give the volatile components (5.3g., 4.0g., respectively).

Preparation and Decomposition of sym-Dianilinodimethyl ether.

Preparation

sym-Dichlorodimethyl ether (50g.) was added dropwise, with stirring, to redistilled aniline (200g.) heated to 50° on a water-bath. A violent reaction, which occurred after the addition, resulted in the formation of a dark tar. After cooling, this tar was shaken with a mixture of sodium hydroxide solution benzene and ether. The organic layer was washed with water and dried with anhydrous magnesium sulphate; the solvent was removed by distillation. Distillation of the residue gave the hitherto unprepared
sym-dianilinodimethyl ether as a yellow oil (31g.; 38% theory; b.p. 214°-220°/1mm.), nD 1.6399.

Analysis:

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>73.53</td>
<td>7.63</td>
<td>12.03</td>
</tr>
<tr>
<td>% Calculated</td>
<td>73.63</td>
<td>7.02</td>
<td>12.23</td>
</tr>
</tbody>
</table>

Decomposition

sym-Dianilinodimethyl ether (26.7g.) was decomposed at 260°-270° (20mm.) in the presence of AnaB hydrobromic acid (1ml.; 48%) to give a distillate (9.0g.); leaving 16.5g. of residue.

The distillate, which was shown by the gas chromatograph to contain only one compound, was redistilled to give aniline [b.p. 75°-78°/10mm.; nD 1.5336 (nD 1.5325); hydrochloride, m.p. 200° (200°)].

An attempt was made to isolate a crystalline compound from the residue but even after neutralization it remained as an intractible tar and resisted separation.

Preparation and Decomposition of N,N'-Diphenyl-1,3-cyclohexanediame

Preparation

cis-1,3-Dibromocyclohexane. 1,3-Cyclohexanediol (90g.) was heated on a water-bath for 3 hrs. with a mixture of AnaB hydrobromic acid (500g.; 48%) and concentrated sulphuric acid (140g.). On cooling, 1,3-dibromocyclohexane separated out as a dark liquid. This was washed with dilute sodium hydroxide solution and then with water and was dried over anhydrous magnesium sulphate. Distillation gave a fraction (84g.; b.p. 115°-120°/20mm.) from which cis-1,3-dibromocyclohexane crystallized out as
a white solid. Cooling gave further product which was recrystallized from ether, m.p. 112°-113° (112°30'), (16g.).

The mother liquor was analysed on the Pye gas chromatograph and of the four peaks which occurred, those of the cis- and trans-1,3-dibromocyclohexanes were present in almost equal area. No further attempt was therefore made to isolate the trans-1,3-dibromocyclohexane.

N,N'-Diphenyl-cis-1,3-cyclohexanadiamine: cis-1,3-Dibromocyclohexane (15g.) was added to redistilled aniline (100g.) heated on a water-bath. After 4 hrs. crystals of aniline hydrobromide had appeared and the mixture was cooled. The solid reaction product was stirred as a slurry with ether (50ml.) and ammonia (50ml.) to give white crystals of the required compound which were collected by filtration. The crude product (5g.; 33% theory) was recrystallized from methanol to give the previously unprepared diamine, m.p. 204°-205°.

Analysis:

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>81.43</td>
<td>8.32</td>
<td>10.15</td>
</tr>
<tr>
<td>% Calculated</td>
<td>81.20</td>
<td>8.27</td>
<td>10.53</td>
</tr>
</tbody>
</table>

Attempted preparation of trans-1,3-dibromocyclohexane: Cyclohexene (40g.), dissolved in carbon tetrachloride (100ml.), was refluxed with N-bromosuccinimide (50g.) for 60 min. The solution was cooled and the succinimide filtered off. Distillation removed the carbon tetrachloride and gave 3-bromocyclohexene (40g.; 89% theory; b.p. 70°/17mm.). This was cooled to 0° and added slowly, with stirring, to hydrobromic acid (150ml.; 60%) at 0° in an ice-bath. After the mixture had been refluxed...
for 1.5 hrs., it was cooled and was poured into water. The separated 1,3-dibromocyclohexane was dried with anhydrous magnesium sulphate and was then distilled under reduced pressure to give a colourless fraction (40g.; 54% theory; b.p. 108°-109°/14mm.0, n_d^21 1.5474 (n_d^21 1.5480)\(^2\). When this fraction was analysed on the gas chromatograph it was found to be almost a 1:1 mixture of cis- and trans-1,3-dibromocyclohexanes. The retention times of the two components were too close to allow separation with the preparative gas chromatograph.

**Decomposition**

N,N'-Diphenyl-cis-1,3-cyclohexanediimine (4.9g.) and AnalR hydrobromic acid (0.2ml.; 48%) were heated together (100mm.). Between 290° and 300°, the material decomposed slowly to give a distillate (3.2g.) and leave a light grey residue which proved to be unchanged N,N'-Diphenyl-cis-1,3-cyclohexanediimine (on recrystallization from methanol it had m.p. 201° unchanged when mixed with an authentic sample).

The distillate, which was shown by the analytical gas chromatograph to consist of 2 components, was treated with zinc chloride solution (see p.33) to give aniline (1.2g.; b.p. 75°/10mm.). The other solution containing the secondary or tertiary amine was saturated with dry hydrogen chloride to give white crystals, assumed to be N-phenyl-1,3-iminocyclohexane hydrochloride. After recrystallization it had m.p. 200°-202°.

**Analysis:**

\[
\begin{align*}
\% \text{ Found} & \quad 6.30 \\
\% \text{ Calculated for C}_2\text{H}_4\text{NCl} & \quad 6.60
\end{align*}
\]

The hydrochloride was neutralized with sodium hydroxide solution (10%
FIG. 8.

1,3-endo-MINOCYCLOHEXANE

N-PHENYLZETIDINE.
N-PHENYLPIPERIDINE.
N-PHENYLPYRROLIDINE.
aqueous) and the base extracted with ether. Evaporation of the ether gave a colourless oil, assumed to be N-phenyl-1,3-endomimocyclohexane (1.2g.; \(n^\circ 1.5748\)).

Analysis:

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>83.19</td>
<td>8.67</td>
<td>3.16</td>
</tr>
<tr>
<td>% Calculated for (\text{C}_9\text{H}_8\text{N})</td>
<td>85.25</td>
<td>8.67</td>
<td>3.10</td>
</tr>
</tbody>
</table>

It gave a picrate, m.p. 143°, a methiodide, m.p. 193°-194° and a hydrobromide, 195°-200°. The infrared spectrum (Fig.3, opposite) showed peaks characteristic of monosubstitution in benzene (13.25\(\mu\), 14.5\(\mu\)) but no peak characteristic of an N-H bond. The spectrum closely resembled those of N-phenylazetidine, N-phenylpyrrolidine and N-phenylpiperidine (Fig.3, opposite). The peaks occurring in the range 10\(\mu\)-11.5\(\mu\) are very similar to those of the spectrum of N-phenylpyrrolidine while those in the range 8\(\mu\)-9\(\mu\) have similarities to both N-phenylazetidine and N-phenylpiperidine.

A nuclear magnetic resonance spectrum (Fig.9, p.71) showed three groups of protons were present in the compound. The low-field group (A) (2.62\(\tau\)-3.15\(\tau\)) is equivalent to 5 aromatic protons, confirming the presence of an unsubstituted aniline and the chemical shift is consistent with a dimethylaniline type. The mid-field group (B) (5.73\(\tau\)-5.83\(\tau\)) is consistent with 2 methinyl protons adjacent to a nitrogen atom. Thus the structure XVIII is suggested by this spectrum.

![XVIII](image-url)
N.M.R. SPECTRUM OF 1,3-ENDOIMINOCYCLOHEXANE.

FIG. 9.
The high field group (C), (δ 8.07-3.72) corresponds to 3.6 methylene protons and in the absence of a terminal methyl peak at 203 c.p.s. these are assigned to a cyclic structure. Further analysis of the N.M.R. spectrum indicates it to be most consistent with the assigned structure of 1,3-endogino-cyclohexane (XIX) rather than the two alternative structures XX or XXI.

![Structures](image)

**Preparation and Decomposition of N,N'-Diphenyl-1,3-butanediamine**

**Preparation**

1,3-Dibromobutane: Butane-1,3-diol was refluxed for 2 hrs. with a mixture of hydrobromic acid (250 g.; 43%) and concentrated sulphuric acid (70 g.). The crude dibromide, which separated to the bottom of the flask, was washed with sodium hydroxide solution (10% aqueous) and then with water and was dried with anhydrous magnesium sulphate. Fractionation gave 1,3-dibromobutane (43 g.; b.p. 81°/10 mm.), n_D 1.5103 (n_D 1.507).

N,N'-Diphenyl-1,3-butanediamine: Reaction between redistilled aniline (200 g.) and redistilled 1,3-dibromobutane (40 g.; b.p. 82°/60 mm.) gave, after distillation, the previously unreported compound (39 g.; 89% theory; b.p. 210°-220/1 mm.; n_D 1.6060).

**Analysis:**

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>80.28</td>
<td>8.61</td>
<td>11.62</td>
</tr>
<tr>
<td>% Calculated</td>
<td>80.00</td>
<td>8.33</td>
<td>11.67</td>
</tr>
</tbody>
</table>
Decomposition

Decomposition of N,N'-diphenyl-1,3-butanediamine (19g.) at 250°-260° (1ml. of 48% AnalR hydrobromic acid; 20mm.) gave 18.5g. of distillate; the residue weighed 2.7g.

The distillate was analysed on the Pye gas chromatograph to give eleven peaks; the six major ones were assigned to components by comparing their retention times with authentic samples.

The distillate was treated with zinc chloride solution (see p. ) to give aniline (4.5g.; 77°/10mm.). Three of the secondary amines were separated by the preparative gas chromatograph. These were:

N-Ethyl-aniline; hydrochloride, m.p. 175°-176° (176°) unchanged when mixed with an authentic sample; benzoyl derivative, m.p. 60° (60°).

2-Methyl-1,2,3,4-tetrahydroquinoline; benzoyl derivative, m.p. 117°-118° (119°). 4-Methyl-1,2,3,4-tetrahydroquinoline; benzoyl derivative, m.p. 133°-135° (136°)61.

The relative amounts of each component, determined by the Pye gas chromatograph, with respect to the original diamine were: -

<table>
<thead>
<tr>
<th>Component</th>
<th>Relative Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aniline</td>
<td>25%</td>
</tr>
<tr>
<td>N-Methylaniline</td>
<td>2%</td>
</tr>
<tr>
<td>N-Ethylaniline</td>
<td>19%</td>
</tr>
<tr>
<td>2-Methylquinoline</td>
<td>7%</td>
</tr>
<tr>
<td>2-Methyl-1,2,3,4-tetrahydroquinoline</td>
<td>10%</td>
</tr>
<tr>
<td>4-Methyl-1,2,3,4-tetrahydroquinoline</td>
<td>15%</td>
</tr>
</tbody>
</table>
Preparation and Decomposition of N-(3-Bromopropyl)aniline

Preparation

3-Bromopropan-1-ol: Redistilled trimethylene glycol (100mL; 157g.; b.p. 126°/20mm.) was cooled in an ice-salt-bath and dry hydrogen bromide gas, from a tetralin-bromine generator, was bubbled through it for 5 hrs. The white complex which gradually formed dissolved on warming. Fractionation gave 3-bromopropan-1-ol (94g.; 23% theory; b.p. 84°-86°/20mm.).

N-(3-Bromopropyl)aniline Hydrobromide: Redistilled aniline (200g.) and 3-bromopropan-1-ol (30g.) were heated together, with occasional shaking, for 2 hrs. on a water bath. After cooling, the mixture was shaken with ether (100mL.) and ammonia (100mL.; s.g. 0.880). The ether extract was washed with water and was dried with anhydrous magnesium sulphate; the ether was removed by distillation. Distillation of the residue allowed recovery of the excess aniline (b.p. 76°/30mm.). The crude product remaining in the flask was cooled in an ice-salt bath and hydrobromic acid (100mL.; 45%; pre-cooled below 0°) was added slowly with shaking. After standing for 1.5 hrs., the mixture was fractionated until constant boiling hydrobromic acid passed over (124°) and was then left for 2 hrs. The product crystallized out and was recrystallized from alcohol-ether, m.p. 131°-132° (131°); (36g.; 57% theory).

Decomposition

(a) N-(3-Bromopropyl)anilinium bromide (16.6g.) was neutralized with sodium hydroxide solution (10% aqueous) and the liberated base was extracted with ether. The ether was evaporated off, leaving N-(3-bromopropyl)aniline as a dark coloured oil which was then heated (oil-bath) in a small flask
under reduced pressure (20mm.). Between 180° and 200° the base suddenly decomposed with the loss of hydrogen bromide but no distillate was obtained. After further heating (15 min.), the mixture was cooled and was then neutralized with hot sodium hydroxide solution. The bases were extracted with ether and this solution was analysed on the Pye gas chromatograph. Three peaks were recorded corresponding in retention times to aniline, 1,2,3,4-tetrahydroquinoline and julolidine. The relative amounts of these three components were:

- Aniline: 10%
- 1,2,3,4-Tetrahydroquinoline: 46%
- Julolidine: 44%

The ether solution was then distilled under reduced pressure (10mm.) to give, after removal of the ether, the volatile products (4·2g.) and a red oily residue (2·4g.) which proved impossible to identify.

(b) In a similar decomposition, N-(3-bromopropyl)anilinium bromide (7·5g.) was neutralized and the liberated base was heated at 200° (20mm.) for 15 min. The residue was neutralized and the bases were extracted with ether. This ether solution was analysed on the Pye gas chromatograph to give the three peaks corresponding to aniline, 1,2,3,4-tetrahydroquinoline and julolidine. The relative amounts of the three components were 92, 53% and 56% respectively. After removal of ether the decomposition products were distilled under reduced pressure (10mm.) to give a distillate (2·3g.) and a residue (1·4g.).

(c) In a further decomposition N-(3-bromopropyl)anilinium bromide (10·4g.) was neutralized and the base heated with anhydrous sodium carbonate (6g.) at
200° for 15 min. (20mm.). Decomposition occurred, with accompanying
effervescence, and the volatile components distilled off. The residue
was neutralized and the liberated bases were extracted with ether and
combined with the distillate. This ether solution was analysed on the
Pye gas chromatograph to give the three peaks corresponding to aniline,
1,2,3,4-tetrahydroquinoline and julolidine. The relative amounts
of these were 14%, 40% and 47% respectively. The ether solution was
distilled under reduced pressure (10mm.) to remove the ether; further
distillation gave 30.8g. of distillate while the residue weighed 1.1g.

Preparation and Decomposition of N-(3-Bromopropyl)-m-toluidine

Preparation

In a method analogous to that used to prepare N-(3-bromopropyl) anilinium
bromide, 3-bromopropyl-1-ol (30g.) and redistilled m-toluidine (150g.;
boiling point 30°-32°/1mm.) gave N-(3-bromopropyl)-m-toluidine hydrobromide (17g.;
24% theory). This previously unprepared salt had m.p. 113°-119.5° after
two recrystallizations from alcohol-ether.

Analysis:

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>Br</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>38.51</td>
<td>5.19</td>
<td>51.35</td>
</tr>
<tr>
<td>% Calculated</td>
<td>39.83</td>
<td>4.83</td>
<td>51.78</td>
</tr>
</tbody>
</table>

Decomposition

(a) N-(3-Bromopropyl)-m-toluidine hydrobromide (8.0g.) was neutralized
with sodium hydroxide solution and the liberated base was extracted and
heated (200°) in a small flask, under reduced pressure. After 15 min., the
residue was neutralized and the bases were extracted with ether. This ether
solution was analysed on the Pye gas chromatograph and four peaks were
identified. With the integrating amplifier, the relative amounts of each component were determined.

\[
\begin{align*}
\text{m-Toluidine} & \quad 11\% \\
5\text{-Methyl-1,2,3,4-tetrahydroquinoline} & \quad 26\% \\
7\text{-Methyl-1,2,3,4-tetrahydroquinoline} & \quad 30\% \\
8\text{-Methyljulolidine} & \quad 33\%
\end{align*}
\]

After removal of the ether, the mixture was distilled to give a distillate (1.8g.) and a residue (0.4g.).

(b) In a second decomposition N-(3-bromopropyl)-m-toluidine hydrobromide (5.8g.) was neutralised and the base decomposed. The products were neutralised and the mixture was analysed on the gas chromatograph as before. The relative amounts of each component were:

\[
\begin{align*}
\text{m-Toluidine} & \quad 11\% \\
5\text{-Methyl-1,2,3,4-tetrahydroquinoline} & \quad 25\% \\
7\text{-Methyl-1,2,3,4-tetrahydroquinoline} & \quad 23\% \\
8\text{-Methyljulolidine} & \quad 33\%
\end{align*}
\]

The ether solution containing these components was distilled to give, after removal of the ether, 1.7g. of distillate and 0.6g. of residue.

**Preparation and Decomposition of N-(3-Bromopropyl)-m-chloroaniline**

**Preparation**

3-Bromopropan-1-ol (30g.) and redistilled m-chloroaniline gave the hitherto unprepared N-(3-bromopropyl)-m-chloroaniline hydrobromide (10g.; 13% theory). The salt had m.p. 94°-95° after two recrystallisations from
alcohol-ether.

Analysis:

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>Br</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>33.04</td>
<td>3.71</td>
<td>49.90</td>
</tr>
<tr>
<td>% Calculated</td>
<td>32.78</td>
<td>3.64</td>
<td>43.63</td>
</tr>
</tbody>
</table>

Decomposition

N-(3-Bromopropyl)-m-chloroaniline hydrobromide (7.0g.) was neutralized with sodium hydroxide solution and the liberated base was extracted and decomposed under reduced pressure as above (200°; 15 min.) The mixture was then neutralized and the bases were extracted with ether. This ether solution was analysed on the gas chromatograph and four peaks were identified; the relative amounts of the components were:

- m-Chloroaniline: 13%
- 5-Chloro-1,2,3,4-tetrahydroquinoline: 22%
- 7-Chloro-1,2,3,4-tetrahydroquinoline: 22%
- 3-Chlorojulolidine: 33%

After removal of the ether, distillation under reduced pressure gave a distillate (2.1g.) and a residue (1.1g.).

Preparation and Decomposition of N-(3-Bromopropyl)-m-anisidine

Preparation

N-(3-Hydroxypropyl)-m-anisidine: 5-Bromopropan-1-ol (10g.) was added slowly and with stirring to redistilled m-anisidine (17g.; b.p. 132°-134°/20mm.) heated on a water bath. After heating for a further hour, the products were cooled and treated with a mixture of ammonia (s.g. 0.830) and ether. The ether extract was washed with water and then dried with anhydrous magnesium
sulphate; the ether was removed by distillation. Distillation of the residue gave the hitherto unprepared N-(3-hydroxypropyl)-m-anisidine as a yellow oil (3.2g.; 33% theory; b.p. 160°-166°/1mm.), ρ 1.5656.

Analysis:

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>66.30</td>
<td>3.75</td>
<td>7.26</td>
</tr>
<tr>
<td>% Calculated</td>
<td>66.29</td>
<td>3.29</td>
<td>7.73</td>
</tr>
</tbody>
</table>

N-(3-Bromopropyl)-m-anisidine Hydrochloride: Phosphorus tribromide (5g.), in benzene (30ml.) was added dropwise and with stirring to N-(3-hydroxypropyl)-m-anisidine (3g.) cooled in an ice-bath. Stirring was continued at 0° for 30 min. after completion of the addition, and then continued for 30 min. at room temperature (during which time a cream tar formed in the bottom of the flask). The mixture was then heated on a water-bath for 5 hours. After cooling, the mixture was shaken with a dilute sodium hydroxide solution and the benzene solution was extracted. This was washed with water and was then dried over anhydrous magnesium sulphate. The solution was then saturated with dry hydrogen chloride to give a sticky gum. This was dissolved in hot alcohol to give, on cooling, white crystals of N-(3-bromopropyl)-m-anisidine hydrochloride (5g.; 33% theory), m.p. 120°-122° after two recrystallizations from alcohol-ether.

Analysis:

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>Halogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>42.01</td>
<td>5.41</td>
<td>40.61</td>
</tr>
<tr>
<td>% Calculated</td>
<td>42.78</td>
<td>5.35</td>
<td>41.18</td>
</tr>
</tbody>
</table>

Decomposition

N-(3-Bromopropyl)-m-anisidine hydrochloride (4g.) was neutralized with
sodium hydroxide solution (10% aqueous) and the liberated base was extracted with ether. After removal of the ether, the base was heated (15 min.) under a pressure of 10 mm. at 220°. After cooling, the reaction mixture was neutralised with sodium hydroxide solution and the reaction products extracted with ether. Five peaks were found on passage of this solution through the Pye gas chromatograph. The relative amounts of each component were:

- m-Anisidine 9%
- N-Methyl-m-anisidine 10%
- 5-Methoxy-1,2,3,4-tetrahydroquinoline 10%
- 7-Methoxy-1,2,3,4-tetrahydroquinoline 33%
- 3-Methoxyjugolidine 31%

The ether solution containing these components was distilled to remove the ether and then to give a distillate (0.5 g.) and a residue (0.6 g.).

**Preparation and Decomposition of N-p-Tolyl-N'-p-chlorophenyl-1,3-propanediamine**

**Preparation**

N-(3-Bromopropyl)-p-toluidine hydrobromide: By a method analogous to that used to prepare N-(3-bromopropyl)aniline hydrobromide, 3-bromopropan-1-ol (40 g.) and redistilled p-toluidine (130 g.; b.p. 84°/1 mm.) gave N-(3-bromopropyl)-p-toluidine hydrobromide (20 g.; 21% theory). This had m.p. 152°-153° (151°) after two recrystallizations from alcohol-ether.

N-p-Tolyl-N'-p-chlorophenyl-1,3-propanediamine: N-(3-Bromopropyl)-p-toluidine hydrobromide (18 g.) was neutralized with sodium hydroxide solution (10% aqueous) and the base extracted with ether. The ether solution was dried with anhydrous magnesium sulphate. It was then added dropwise over 1.5 hrs. to
stirred, molten, redistilled p-chloroaniline (100g.; b.p.107°-110°/2mm.),
heated over a water-bath. The mixture was heated for a further hour; it
was then neutralized and the bases were extracted with ether. Distillation
gave the required compound, hitherto unprepared, as a thick yellow liquid
(15g.; 91% theory; b.p.245°-250°/1mm.; nD 1.6415).

Analysis:

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>70.37</td>
<td>7.23</td>
<td>10.06</td>
</tr>
<tr>
<td>% Calculated</td>
<td>69.95</td>
<td>6.92</td>
<td>10.20</td>
</tr>
</tbody>
</table>

Decomposition

N-p-Tolyl-N'p-chlorophenyl-1,3-propanediamine (9.8g.) was smoothly
decomposed by heating (260°-270°; 20mm.) with AnaLaR hydrobromic acid
(0.5ml.; 48%) to give a distillate (8.8g.) and 1g. of residue.

The Pye gas chromatograph indicated that there were fifteen components
in the distillate and most of these were identified by comparing their
retention times with authentic samples. The large number of components
made other methods of separation or analysis impossible. The relative
amounts of each component, determined by gas chromatograph, with respect
to the original diamine were:

- p-Toluidine 19%
- p-Chloroaniline 31%
- N-Methyl-p-toluidine 1%
- N-Ethyl-p-toluidine 4%
- N-Methyl-p-chloroaniline 3%
- N-Ethyl-p-chloroaniline 3%
- 6-Methylquinolone 1%
37.

6-Methyl-1,2,3,4-tetrahydroquinoline 6.5%
N-Ethyl-3-methyl-1,2,3,4-tetrahydroquinoline 3%
6-Chloro-1,2,3,4-tetrahydroquinoline 3%
9-Methyljulolidine 10%
9-Chloro-julolidine 3%

Decomposition of N-(3-Bromopropyl)aniline with 1,2,3,4-Tetrahydroquinoline

(a) N-(3-Bromopropyl)aniline hydrobromide (3g.) was neutralized and the base was extracted with ether. To this solution was added 1,2,3,4-tetrahydroquinoline (1.3g.; 0.0098 moles). The ether was removed and the mixture was heated to 250° for 20 min. at atmospheric pressure. After cooling the residue was neutralized and the bases were extracted with ether. This ether solution gave peaks corresponding to aniline, 1,2,3,4-tetrahydroquinoline and julolidine on the gas chromatograph and the relative amounts were 3%, 65% and 35% respectively. After removal of the ether the components were distilled to give 2.2g., of distillate. The moles of components in the mixture were thus 0.0007, 0.0106 and 0.0042 respectively.

(b) In a second decomposition N-(3-bromopropyl)aniline hydrobromide (2.5g.) and 1,2,3,4-tetrahydroquinoline (1.32g.; 0.0092 moles) gave, according to the gas chromatograph, aniline (5%), 1,2,3,4-tetrahydroquinoline (58%) and julolidine (57%). Distillation of the decomposition mixture gave a distillate containing these components (2.0g.) and hence the moles of components in the mixture were 0.0018, 0.0087 and 0.0043 respectively.
Decomposition of N,N'-Diphenyl-1,3-propanediamine with 1,2,3,4-
Tetrahydroquinoline

N,N'-Diphenyl-1,3-propanediamine (2·5g.), 1,2,3,4-tetrahydroquinoline
(1·55g.; 0·0008 moles) and anilin hydrobromic acid (1·1ml.; 43%) were mixed
and heated (250°) for 20 min. at atmospheric pressure. After cooling,
the residue was neutralized and the bases extracted with ether. Gas
chromatographic analysis gave the relative amounts of the following
components: aniline 31%, 1,2,3,4-tetrahydroquinoline 63%, jujubilide 17%.

Distillation of the ether solution containing these components gave,
after removal of the ether, 2·8g. of a distillate. The moles of each
component in the distillate were thus 0·0083, 0·0121 and 0·0023 respectively.
# Table 2

**Products from the Decomposition of N,N'-Diphenyl-1,3-propanediamine**
(as analysed by gas chromatography)

<table>
<thead>
<tr>
<th>Run</th>
<th>Diamine (Grams)</th>
<th>HBr (mole)</th>
<th>Distillate (grams)</th>
<th>Time (mins.)</th>
<th>Aniline (moles)</th>
<th>Tetrahydroquinoline (moles)</th>
<th>Julolidine (moles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a²</td>
<td>32.0</td>
<td>0.1</td>
<td>26.4</td>
<td>-</td>
<td>1.01</td>
<td>0.25</td>
<td>0.13</td>
</tr>
<tr>
<td>b²</td>
<td>36.0</td>
<td>0.1</td>
<td>34.3</td>
<td>-</td>
<td>1.01</td>
<td>0.40</td>
<td>0.17</td>
</tr>
<tr>
<td>c</td>
<td>5.1</td>
<td>0.1</td>
<td>4.5</td>
<td>42</td>
<td>1.08</td>
<td>0.47</td>
<td>0.22</td>
</tr>
<tr>
<td>d</td>
<td>5.4</td>
<td>0.1</td>
<td>4.9</td>
<td>50</td>
<td>1.16</td>
<td>0.47</td>
<td>0.19</td>
</tr>
<tr>
<td>e</td>
<td>5.9</td>
<td>0.1</td>
<td>5.4</td>
<td>46</td>
<td>1.08</td>
<td>0.49</td>
<td>0.22</td>
</tr>
<tr>
<td>f</td>
<td>5.1</td>
<td>0.02</td>
<td>4.8</td>
<td>90</td>
<td>1.23</td>
<td>0.47</td>
<td>0.19</td>
</tr>
<tr>
<td>g</td>
<td>5.1</td>
<td>0.2</td>
<td>4.0</td>
<td>25</td>
<td>0.87</td>
<td>0.49</td>
<td>0.17</td>
</tr>
<tr>
<td>h</td>
<td>5.1</td>
<td>0.5</td>
<td>3.5</td>
<td>15</td>
<td>0.37</td>
<td>0.44</td>
<td>0.09</td>
</tr>
<tr>
<td>i</td>
<td>5.3</td>
<td>1.0</td>
<td>3.0</td>
<td>15</td>
<td>0.63</td>
<td>0.37</td>
<td>0.12</td>
</tr>
<tr>
<td>j⁵</td>
<td>3.1</td>
<td>0.1</td>
<td>1.1</td>
<td>60</td>
<td>0.51</td>
<td>0.17</td>
<td>0.07</td>
</tr>
<tr>
<td>k⁵</td>
<td>2.7</td>
<td>1.0</td>
<td>0.9</td>
<td>60</td>
<td>0.60</td>
<td>0.08</td>
<td>-</td>
</tr>
<tr>
<td>l</td>
<td>5.1</td>
<td>0.1⁴</td>
<td>3.0</td>
<td>30</td>
<td>0.96</td>
<td>0.07</td>
<td>0.03</td>
</tr>
</tbody>
</table>

1. Moles with respect to 1 mole of diamine.
2. Chemical separations.
4. Concentrated sulphuric acid.
III

DISCUSSION

Conditions Affecting Decomposition

A careful investigation was made of the effect of various acid conditions on the breakdown of \( \text{N,N'}-\text{diphenyl-1,3-propanediamine} \) (Table 2). Using hydrobromic acid as a catalyst, it was found that the rate of decomposition increased with increase in acid amount; indeed for amounts less than about 0.05 moles the breakdown was very slow. On the other hand, increased amounts of acid led to greater quantities of inseparable residue. Table 2 shows that the variation of acid made no appreciable difference to the relative amounts of the volatile components. The optimum conditions for decomposition with hydrobromic acid therefore represent a compromise between the two factors mentioned above. Thus the use of a tenth molar amount of hydrogen bromide was found to give volatile products, representing about 90% of the decomposition mixture, within a reasonable time.

Decompositions carried out in sealed tubes \( (j \text{ and } k) \) gave large residues irrespective of the amount of acid. These residues probably consisted mainly of polymeric compounds. The relatively high yields of aniline, compared to the other amine products, suggest that breakdown has taken place and that the residue is not mainly unchanged diamine. It is likely that decompositions in sealed tubes or at high acid concentrations would give rise to Hofmann-Martius-like reactions because volatile products are not being removed. Thus \( \text{aminopropyl} \) units would have a chance to substitute in the ortho and para positions of
Decompositions of N,N'-Diaryl-1,3-propanediamines

The amounts of each component determined by gas chromatography are expressed in moles per mole of diamine decomposed with 0.1 molar amounts of HBr.

<table>
<thead>
<tr>
<th>Compound</th>
<th>p-tolyl-</th>
<th>o-tolyl-</th>
<th>m-tolyl-</th>
<th>o-anisyl-</th>
<th>m-anisyl-</th>
<th>p-anisyl-</th>
<th>o-chloro-phenyl-</th>
<th>p-chloro-phenyl-</th>
<th>p-chloro-phenyl-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arylamine</td>
<td>1.04</td>
<td>0.78</td>
<td>1.00</td>
<td>0.36</td>
<td>0.22</td>
<td>0.70</td>
<td>0.61</td>
<td>1.03</td>
<td>0.35</td>
</tr>
<tr>
<td>N-Methylarylamine</td>
<td>0.03</td>
<td>0.09</td>
<td>-</td>
<td>0.23</td>
<td>0.14</td>
<td>0.20</td>
<td>0.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N-Ethylarylamine</td>
<td>0.11</td>
<td>0.11</td>
<td>0.13</td>
<td>0.11</td>
<td>0.37</td>
<td></td>
<td></td>
<td></td>
<td>0.19</td>
</tr>
<tr>
<td>Tetrahydroquinoline</td>
<td>0.26</td>
<td>0.32</td>
<td>0.39</td>
<td>0.15</td>
<td>0.41</td>
<td>0.08</td>
<td>0.35</td>
<td>0.53</td>
<td>0.19</td>
</tr>
<tr>
<td>Jugolidine</td>
<td>0.23</td>
<td>0.19</td>
<td>0.05</td>
<td></td>
<td></td>
<td></td>
<td>0.23</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>N-Alkyltetrahydroquinoline</td>
<td>0.06</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.05</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>N-Allylarylamine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.37</td>
<td></td>
</tr>
<tr>
<td>Phenol</td>
<td>0.20</td>
<td>0.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N,N-Dimethylarylamine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.19</td>
<td></td>
</tr>
</tbody>
</table>
the arylamine-molecules and subsequent reactions could then lead to a large number of high molecular-weight compounds.

Hickinbottom decomposed N-alkylanilines using certain metal halides as catalysts (for example, cobalt and zinc chlorides). A slow diamine decomposition has been observed using cobaltous chloride as a catalyst but mostly aniline and a resinous residue were obtained. Aluminium chloride failed to promote decomposition at all. The use of sulphuric acid as a catalyst (1) did cause breakdown; the yield of aniline was about that obtained using hydrogen bromide. However, the amounts of tetrahydroquinoline and julolidine obtained were relatively low. Thus hydrogen bromide was the most suitable catalyst tried.

The Scope and Synthetic Value of Diamine Breakdown

As was pointed out in the introduction, it was hoped that the diamine decomposition would provide a useful method of synthesis for substituted tetrahydroquinolines and julolidines. However, in extending the decomposition of N,N'-diphenyl-1,3-propanediamine to other aryl-substituted diamines, two limiting factors concerning the nature of the aryl group became apparent. (1) The required products should be reasonably volatile. Thus experience with the naphthaleneamine compounds indicated that aryl groups such as nitrophenyl- would make the method unattractive. (2) Deactivating substituents in the aryl group must be avoided. The decomposition of chlorophenyl-diamines required high temperatures, and was accompanied by significant cleavage of the propane chain (see Table 3). With substituents of greater deactivating power than chlorine, yields of julolidines and tetrahydroquinolines might be
expected to be lower. Conversely, activating groups appear, in general, to facilitate cyclization. Other complications may arise however. Thus, although the electronic effect of the methoxy group allowed the anisyl diamines to decompose with relative ease, the concurrent demethylation led to such a variety of other products that isolation of the expected tetrahydroquinolines and jujolidines was almost impossible. The amine decomposition is therefore limited to a narrow choice of substituents on the aromatic ring.

The position of the substituent also had a marked effect on the ease and nature of the breakdown. Para-substituted diamines decomposed with greater difficulty than their ortho- and meta- isomers. Furthermore, and to a lesser extent ortho, substituted diamines gave significant quantities of minor components with a corresponding reduction in the yield of tetrahydroquinolines. This is clearly shown in Table 3. It might be expected that ortho-substituted diamines would give enhanced yields of tetrahydroquinolines as jujolidine formation is excluded but, except with the methyl substituent, the amount formed was lower than with the meta-substituted diamines. The large number of minor components in the decompositions made clean separation of the major products difficult. To be a good synthetic method, the difference in boiling points of the components would need to be sufficiently great to allow a simple separation of products. This condition is only really fulfilled for the decomposition of the unsubstituted or m-substituted diamines. Low yields and isolation difficulties thus made the preparation of 6- and 8-substituted tetrahydroquinolines unpractical by this method. The
### TABLE 4

**Decomposition of N,N'-Diaryl-1,3-oxazolidines**

*(A) The amounts of each component determined chemically are expressed as moles per mole of diamine decomposed.*

<table>
<thead>
<tr>
<th>Decomposition</th>
<th>Run</th>
<th>Arylamine</th>
<th>Tetrahydroquinoline</th>
<th>Julolidine</th>
</tr>
</thead>
<tbody>
<tr>
<td>p-Tolyl</td>
<td>b</td>
<td>1·10</td>
<td>0·24</td>
<td>0·22</td>
</tr>
<tr>
<td>o-Tolyl</td>
<td>a</td>
<td>0·94</td>
<td>0·53</td>
<td></td>
</tr>
<tr>
<td>o-Tolyl</td>
<td>b</td>
<td>0·67</td>
<td>0·84</td>
<td></td>
</tr>
<tr>
<td>m-Tolyl</td>
<td>a</td>
<td>1·08</td>
<td>0·33</td>
<td>0·16</td>
</tr>
<tr>
<td>m-Tolyl</td>
<td>b</td>
<td>1·05</td>
<td>0·29</td>
<td>0·23</td>
</tr>
<tr>
<td>1-Naphthyl</td>
<td></td>
<td>0·91</td>
<td>0·68</td>
<td></td>
</tr>
<tr>
<td>2-Naphthyl</td>
<td></td>
<td>0·62</td>
<td>0·55</td>
<td></td>
</tr>
</tbody>
</table>

*(B) The amounts of each component determined by gas chromatography are expressed as moles per mole of diamine decomposed with 1 mole of HBr.*

| m-Tolyl       | c   | 0·82      | 0·45                | 0·13       |
| m-Tolyl       | d   | 0·80      | 0·41                | 0·07       |
| m-Chlorophenyl| b   | 0·68      | 0·51                | 0·09       |
| m-Chlorophenyl| c   | 0·72      | 0·46                | 0·17       |
naphthyl-diamines (Table 4) however, gave good yields of the corresponding benzotetrahydroquinolines (XXII and XXIII).

With the 1-naphthyl-diamine no other products were expected nor were any found but fractionation of the 2-naphthyl-diamine decomposition mixture indicated that small amounts of other compounds were present in the distillate. The possible products 6,7-benzotetrahydroquinoline and the corresponding julolidine would not be expected by analogy with the known reactivity to electrophilic attack of the 1-position in 2-naphthylamine (compared to the 3-position). Acridine formation in the decomposition of the 2-naphthyl-diamine was not altogether surprising; it was noticed also in decompositions involving N-methyl-2-naphthylamine (see appendix), the inference being that N-alkyl-3-naphthylamines (particularly the N-methyl-compound) were also formed in the reaction.

Tables 3 and 4 show that the meta-substituted diamine breakdowns gave only major products. This allowed the mixed 5- and 7-substituted tetrahydroquinolines to be easily separated from other components. However the usefulness of the method as a preparative route to these little known compounds depends on the ease with which such 5- and 7-isomers may be separated. Gas chromatography gave a good separation
of the methyl-isomers and a fair separation of the chloro-isomers.
For the methoxy-isomers, the gas chromatograph was not available and
other means of separation were attempted. That the small amount of
5-methoxy tetrahydroquinoline was lost and only the 7-isomer obtained is
indicative of the limitation of the rearrangement as a preparative method
for these compounds if a preparative gas chromatograph is not available.
Although the 5-methoxy-compound was not isolated its presence was
confirmed when the tetrahydroquinolines were converted to the quinolines
and the mixture was treated with picric acid; the more insoluble 5-
methoxyquinoline picrate could be isolated.

The presence of N-methyl- and N-ethylarylamines in the decomposition
products was unexpected. It is clear from Table 3 that this cleavage of
the trimethylene chain is the rule rather than the exception. Formation
of these N-alkyl-products indicates that some reduction is occurring in
the decomposition and this is in accord with the identification of oxidised
tetrahydroquinolines, such as 6-methylquinoline and 6-chloroquinoline, in
the distillates. Failure to find C-alkylanilines among the products may
be attributed to the rapid removal of the N-alkylanilines from the reaction
mixture as they are formed. N-Alkyltetrahydroquinolines were also
 provisionally identified in the mixtures.

One of the most important and interesting features of this work was
the separation and identification of the julolidines as major components
of the diamine breakdowns. This explained why the yields of anilines
formed was somewhat greater than theoretical on the simple reaction schemes
first suggested (p.7). These schemes formulated the decomposition of
one molecule of diamine into one of arylamine and one of tetrahydroquinoline. However, on any reasonable reaction scheme for the production of julolidine, two molecules of diamine give three of aniline and one of julolidine. In cases where the aryl group is ortho-substituted julolidine formation is excluded but in these cases larger residues of unidentified high molecular-weight materials are produced in addition to the reduced quinolines. Breakdown of the m-substituted aryl-diamines is attractive as a route to 8-substituted julolidines. These compounds, which were easily isolated from the decomposition products, are not always available by reaction with the appropriate tetrahydroquinoline or by direct substitution. The small yield of 8-methoxyjulolidine taken in conjunction with the small yield of the 5-methoxytetrahydroquinoline (compared to the 7-methoxy-isomer) indicates that substitution is relatively difficult in the position ortho to the methoxy group. The decompositions of the para-substituted arylamines also gave reasonable yields of 9-substituted julolidines but the difficulty in decomposing these amines makes unattractive the preparation of such julolidines by this method.

In many respects therefore, the results from diamine decompositions fall into a recognizable pattern. However as a general preparative tool, such breakdown appears to be limited to the synthesis of a few selected julolidines and tetrahydroquinolines.

Extensions of Diamine Breakdown

(a) N,N'-diphenyl-1,3-butanediamine on decomposition gave the expected 2- and 4-methyl-1,3,5,4-tetrahydroquinolines but the presence of many
other components made separation difficult. The apparent absence of
the expected methyljulolidines may be a reflection of the instability
of such compounds under the decomposition conditions.

(b) With \( N,N' \)-diphenyl-pig-1,3-cyclohexanediarnine, the expected
tetrahydroquinoline was not obtained. What was isolated was a compound
 provisionally identified as \( N \)-phenyl-1,3-endoiminocyclohexane. However
confirmation of this identification is still needed because it is the
only instance of an azetidine ring being formed and isolated in these
decompositions. Another puzzling feature is the apparent stability of
this strained azetidine ring toward acid. The compound was isolated
and purified via its hydrochloride salt and this is in direct contrast to
the behaviour of \( N \)-phenylazetidine, or azetidine itself, where the ring
opens immediately hydrogen bromide or hydrogen chloride are bubbled into
an ether solution of the base.

(c) 3,3'-Dianilinodimethyl ether gave aniline as the only volatile product.
A dark resinous residue, which could not be purified, formed the bulk of
the product. Cleavage of the trimethylene chain is well established in
these breakdowns and it might be expected that cleavage of the ether
would be even more facile. Thus a fragment of canonical structure
XXIV is mesomeric with the structure XXV and such a fragment might readily
decompose to give formaldehyde and a charged residue, both of which could
lead to high molecular-weight compounds.

\[
\begin{align*}
\text{XXIV} & \quad \text{XXV} \\
\end{align*}
\]
FIG. 10.

Ar-NH-CH$_2$-CH$_2$-CH$_2$-HN-Ar

$\xrightarrow{HBr}$

Ar-NH$_2$-CH$_2$-CH$_2$-CH$_2$-HN-Ar

$\xrightarrow{Br}$

Ar-NH$_2$, Ar-NH-CH$_2$-CH$_2$-CH$_2$-Br

Ar-NH$_2$, Ar-NH-CH$_2$-CH=CH$_2$

Ar-NH$_2$, Ar-NH-CH$_2$-CH$_2$CH$_2$

Ar-NH$_2$, Ar-NH-CH$_2$-CH$_2$-CH$_2$-Br

FIG. 11.

$\xrightarrow{Br}$

Ar-NH$_2$, Ar-NH-CH$_2$-CH=CH$_2$

Ar-NH$_2$, Ar-NH-CH$_2$-CH$_2$CH$_2$

$+ C_6H$_5$ - NH$_2$

$+ H^+$
These last two decompositions (b and c) serve to show that the diamine decomposition is unpredictable and hence limited in synthetic value.

Rearrangement Mechanism.

There are several reaction paths by which tetrahydroquinoline may be formed in diamine decomposition. It is convenient to divide these into two categories, namely the synchronous mechanism (Fig. II) on the one hand and all mechanisms involving reactive intermediates on the other. Figure 10 shows possible reaction paths involving intermediates which may lead directly, or via other intermediates, to the tetrahydroquinoline. For all schemes in this figure the rate-determining step is presumably the initial splitting off of the arylamine molecule. Thus the rate is determined and affected only by factors influencing the ease of breaking of the relevant bond. In contrast, the synchronous mechanism will be affected by the ease of ring closure (that is, of bond formation between the aromatic ring and the alkyl chain). The schemes in figure 10 correspond broadly to the accepted mechanism of the Hofmann-Martius reaction but for N-alkylanilines there can be no mechanism corresponding to Fig. II. It should thus be possible to place the present decomposition into one of the mechanistic categories by seeing if factors affecting the new bond formation do influence the ease of reaction and also by seeking evidence for reactive intermediates.

In any of the possible mechanisms, the nitrogen atom of the leaving arylamine molecule has considerable positive charge. This is fairly obvious for the synchronous mechanism and is shown below for the formation
of a carbonium ion and of an alkyl halide.

Thus any substituent stabilizing the positive charge on the nitrogen atom should increase the ease of the reaction. On these grounds, therefore, the ease of decomposition (on any of the proposed mechanistic schemes) should increase in the order chlorophenyl $<$ phenyl $<$ tolyl $<$ anisyl. Although no rate studies have been carried out, a qualitative comparison of decomposition rates could readily be made; the order found was precisely that predicted above.

It is worthwhile to also consider the relative effects of ortho, meta or para substituents. Each of the substituents mentioned above is capable of conjugative electron release (on the assumption of hyperconjugation in the case of the methyl group). It is therefore clear that, should bond breaking be the only important process in determining rate, then such a substituent should aid reaction more from a para or ortho position than from a meta position. In practice, and for each of the groups, it is the meta substituent that is by far the most effective in this respect. The only scheme in which this sequence is explicable is the synchronous mechanism and then only if bond-formation (that is, cyclization) is a major consideration. Such bond making involves electrophilic attack on the
aromatic ring and will be aided by electron release from suitably orientated substituents. This aid will be more effective from a methyl-, methoxy- or chloro- substituent which is meta to the amino group (that is, ortho or para to the point of closure). Furthermore, acceptance of bond formation as being of greater importance (than bond-breaking), still requires the general order for different substituents, which was in fact found.

On this evidence alone, the synchronous mechanism would seem to be the only one acceptable. However, other results from this study appear explicable only in terms of this mechanism. When \( N,N' \)-diphenyl-1,3-butanediamine is decomposed, a greater yield of 4-methyltetrahydroquinolines (than the 3-methyl isomer) is obtained. This is in accord with the inductive effect of the additional methyl group aiding bond-breaking and this fits in with either mechanistic category. However, the other unsymmetrical diamine (XXVI) gives a greater amount of 6-methyltetrahydroquinoline than 3-chlorotetrahydroquinoline. If simple bond-breaking were the rate-determining step the transition state involving fission of the \( \beta \)-toluidine would be of lower energy than the one involving fission of \( \beta \)-chloroaniline and hence the bond a-a would cleave preferentially to give a greater yield of 6-chlorotetrahydroquinoline.

\[
\begin{align*}
\text{CH}_3&-\text{NH}^+\text{CH}_2\text{-CH}_2\text{-CH}_2\text{-HN}-\text{Cl} \\
\text{XXVI}
\end{align*}
\]
That the reverse order was noted is indicative of the synchronous mechanism.

Further evidence is seen in the decomposition of the cyclohexane diamine XXVII.

\[
\text{NHAr} \quad \text{NHAr}
\]

As was pointed out in the introduction, the cis- isomer has two axial anilino-groups (the alternative conformer with two equatorial groups is not suited to reaction). Thus the stereo-electronic requirement for synchronous ring closure to the tetrahydroquinoline cannot be fulfilled. If, however, the decomposition followed a non-synchronous path, aniline would be split off as the first step and ring closure to the tetrahydroquinoline would be possible. The fact that no tetrahydroquinoline was isolated, again points to a synchronous mechanism.

The non-synchronous mechanisms correspond closely to that suggested for the Hoffmann-Martius rearrangement. It might be expected that the synchronous mechanism found here provides a lower energy path to the products. This seems to be so, in general, Hickinbottom found it necessary to heat the N-alkylanilinium salts to 300° for several hours to produce rearrangement. However it would be expected that where ring closure is difficult and higher temperatures are employed, some reaction would occur by non-synchronous paths. Indeed small yields of
N-alkylanilines were obtained with the *para-* and *ortho-*substituted diamines. Further, in the decomposition of the *o*-chlorophenyl dismine, which required high temperatures, a relatively high yield of N-allyl-*o*-chloroaniline was obtained.

In the Hofmann-Martius rearrangement, Hughes was able to propose a mechanism from the intermediates (alkyl bromides and olefins) isolated, while the isomerization of the alkyl groups supported the theory. However evidence of a similar sort is not expected in the dismine breakdowns. The corresponding alkyl halides are the N-(3-bromopropyl)arylamines which were found to be unstable under the reaction conditions (see following) and hence would not be expected to be isolated even if present. The corresponding olefin, the N-allylaniline was isolated only in the instance mentioned above and reaction here may have partly occurred by a nonsynchronous process. Isomerisation would be difficult to prove in the dismine decomposition. The isomerisation would be expected to give 3-methylindoline XXVIII and 1,4-diphenyl-3,5,6-trimethylpiperazin XXIX.

![Chemical structures](image)

However, it has been shown\(^3\) that in the decomposition of N,N'-diphenyl-1,2-ethanediisamine, no indoline is obtained at all. Thus ring closure to give XXVIII is unlikely. The complexity of the residues prevented any evidence being found for the presence of XXIX.

**Decomposition of N-(3-Bromopropyl)arylamines:** These compounds were synthesised
### TABLE 5.

**Decomposition of N-(3-Bromopropyl)arylamines**

The amounts of products determined by gas chromatography are given in moles per mole of N-(3-bromopropyl)arylamine salt.

<table>
<thead>
<tr>
<th>Bromo-compound</th>
<th>Arylamine</th>
<th>Tetrahydroquinoline</th>
<th>Julolidine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aniline (a)</td>
<td>0.031</td>
<td>0.290</td>
<td>0.189</td>
</tr>
<tr>
<td>Aniline (b)</td>
<td>0.071</td>
<td>0.236</td>
<td>0.135</td>
</tr>
<tr>
<td>Aniline (Na$_2$CO$_3$)</td>
<td>0.129</td>
<td>0.357</td>
<td>0.335</td>
</tr>
<tr>
<td>m-Toluidine (a)</td>
<td>0.129</td>
<td>0.492</td>
<td>0.223</td>
</tr>
<tr>
<td>m-Toluidine (b)</td>
<td>0.121</td>
<td>0.435</td>
<td>0.250</td>
</tr>
<tr>
<td>m-Chloroaniline</td>
<td>0.132</td>
<td>0.334</td>
<td>0.236</td>
</tr>
<tr>
<td>m-Anisidine</td>
<td>0.056</td>
<td>0.136</td>
<td>0.073</td>
</tr>
</tbody>
</table>
TABLE 6

Comparison of the 3- and 7- substituted Tetrahydroquinolines from the Bromopropylarylamine and Diamine Decompositions.

<table>
<thead>
<tr>
<th>Aryl-group</th>
<th>Diamine</th>
<th>Bromopropylamine</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% 5-isomer</td>
<td>% 7-isomer</td>
</tr>
<tr>
<td>m-Tolyl&lt;sup&gt;1&lt;/sup&gt;</td>
<td>43</td>
<td>57</td>
</tr>
<tr>
<td>m-Tolyl&lt;sup&gt;1&lt;/sup&gt;</td>
<td>43</td>
<td>57</td>
</tr>
<tr>
<td>m-Tolyl&lt;sup&gt;2&lt;/sup&gt;</td>
<td>41</td>
<td>59</td>
</tr>
<tr>
<td>m-Chlorophenyl&lt;sup&gt;1&lt;/sup&gt;</td>
<td>51</td>
<td>49</td>
</tr>
<tr>
<td>m-Chlorophenyl&lt;sup&gt;1&lt;/sup&gt;</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>m-Chlorophenyl&lt;sup&gt;2&lt;/sup&gt;</td>
<td>49</td>
<td>51</td>
</tr>
<tr>
<td>m-Anisyl&lt;sup&gt;2&lt;/sup&gt;</td>
<td>21</td>
<td>79</td>
</tr>
</tbody>
</table>

1. 1 mole of HBr added for 1 mole of diamine decomposed.
2. 0.1 mole of HBr for 1 mole of diamine decomposed.
as they were thought to be possible intermediates. In fact they were found to decompose vigorously and completely at temperatures (300°) lower than of the diamine decompositions. Results are shown in Table 5. Considerable quantities of residues were obtained in these decompositions but this is not altogether surprising as the alkyl part of one molecule could condense with the nitrogen of another. Because of this and of the different reaction conditions (1 mole of acid with the bromo-compounds) no useful purpose can be gained by comparing the relative amounts of arylamine, tetrahydroquinoline and julolidine from the decomposition of the bromo-compounds with these amounts obtained from the diamine decompositions. However the relative amounts of 5- and 7-substituted tetrahydroquinolines obtained, when the meta-substituted bromoanilarylamines were decomposed, are of interest (Table 8). These relative amounts are in remarkably close agreement with those from the diamines and this suggests that both decompose by a similar reaction path. Since it has been shown that bond-making is of major importance in the rate-determining step for diamine decomposition it seems probable that the bromoanilarylamines also decompose by a synchronous mechanism and not via a carbonium ion.

The Skraup Synthesis of Quinolines: Recently Palmer has reinvestigated the Skraup reaction, using various m-substituted anilines. This reaction is generally considered to proceed with the intermediate formation of o-arylaminocarboxaldehyde (XXX) or a Schiff's base derived from it (XXXI), followed by cyclization, elimination and oxidation.

\[ \text{NH}_2 \quad + \quad \text{CH}_2=\text{CH}-\text{CHO} \quad \rightarrow \quad \text{XXX} \]
Palmer has suggested that the ring closure actually proceeds via the protonated amil (XXXI) shown below:

![Chemical Structure](image)

This intermediate (XXXI) is very similar to that in the disamine decompositions:

![Chemical Structure](image)

It is therefore of interest to note that the ratio of 5- to 7-substituted quinoline isomers, determined by gas chromatography, are almost exactly those obtained for the tetrahydroquinoline isomers in the present work.

<table>
<thead>
<tr>
<th>Arylamine</th>
<th>Ratio of 5:7 quinolines (Palmer)</th>
<th>Ratio of 5:7 tetrahydroquinolines (Diamine Decomp.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>m-Toluidine</td>
<td>40% 60%</td>
<td>41% 59%</td>
</tr>
<tr>
<td>o-Antipyrine</td>
<td>22% 78%</td>
<td>21% 79%</td>
</tr>
<tr>
<td>m-Chloroaniline</td>
<td>47% 53%</td>
<td>49% 51%</td>
</tr>
</tbody>
</table>

**Formation of Julolidine:** Although cyclization to julolidine would involve synchronous ring closure and anilines elimination as for tetrahydroquinoline,
formation of julolidines could follow two routes. (a) By the interaction of two diamine molecules or (b) by the interaction of a diamine molecule with tetrahydroquinoline.

(a) \[ \text{Ar-NH-CH}_2-\text{CH}_2-\text{NH}_2-\text{Ar} \] + \[ \text{Ar-NH-CH}_2-\text{CH}_2-\text{NH-Ar} \] \[ \rightarrow \] \[ \text{XXXII} \]

(b) \[ \text{Ar-NH-CH}_2-\text{CH}_2-\text{CH}_2-\text{NH}_2-\text{Ar} \] \[ \rightarrow \] \[ \text{XXXIII} \]

Of these schemes, (a) is the more likely since, under the reaction conditions, tetrahydroquinoline formed in the reaction should be distilled off before it could react to any great extent, with a diamine molecule. It might be expected that the \( \alpha \)-substituted aryldiamines, which cannot give rise to julolidines, would give greater yields of the N-alkyltetrahydroquinolines arising from compounds similar to XXIII. However, this was found to be so only in the \( \alpha \)-chlorenamine case; in the other decompositions the para-substituted diamine gave greater amounts of the N-alkyltetrahydroquinolines and the reason for this is not clear.

The yields of julolidines were much greater in the decompositions of the N-(3-bromopropyl)arylamines than the diamine decompositions and this difference was particularly marked with the \( \alpha \)-methoxy-compound. While this increased yield of julolidine could mean that the bromo-compound is a
precursor to jujolidine formation in the diamine decomposition, it is more likely to be a reflection of the decomposition conditions of the bromo-compounds. As the products are not being removed as they are formed in the decomposition of the bromo-compounds, the greater yield of jujolidine would arise through reaction of tetrahydroquinoline and N-(3-bromopropyl) arylamine. However, in this respect two further experimental results are relevant. When bromopropylaniline was decomposed in the presence of tetrahydroquinoline, some of the latter was used up presumably by reaction with the bromopropylaniline. However, when N,N'-diphenylpropanediamine was decomposed (at atmospheric pressure) with an added amount of tetrahydroquinoline, the amount of this base recovered implied that little of the added tetrahydroquinoline had been used. Conditions were not strictly comparable with those of normal diamine decomposition, but it does seem unlikely that, in the latter reaction, jujolidine formation is dependent on the prior formation of tetrahydroquinoline.
APPENDIX

THE REARRANGEMENT OF N-METHYL-NAPHTHYLAMINES
INTRODUCTION

A survey of the literature reveals that although the Hofmann-Martius rearrangement has been well established with hydrohalide salts of N-alkylanilines, only one attempt has been made to rearrange a simple N-alkynaphthylamine salt. Hey heated 2-naphthyldi(propylamine hydrochloride at 300°-320° for six hours, but found only propylene and 2-naphthylamine in his products with no evidence of ring-alkylated naphthyamines. The only other examples of nuclear alkylation in the naphthalene series by analogous rearrangements are the reactions carried out by Hey with methanol and naphthylamine salts. Hey's studies were mainly concerned with showing that the Hofmann-Martius rearrangement can lead to meta-alkylation of anilines and in these experiments Hey heated o- and p-toluidine hydrochlorides with excess methanal in an autoclave. Such reactions were called Hofmann-Martius rearrangements by Hey, because he considered that a N-methylated amine was first formed and that rearrangement proceeded via an alkyl halide intermediate. From the reaction Hey isolated isoquinine (XXXIV) thus showing that meta-substitution does indeed occur when the ortho and para positions have been occupied.

\[
\text{XXXIV}
\]

By-products in the reactions were hydrocarbons, acridines and phenols. Hey extended his reaction to the naphthylamine hydrochlorides but, although nuclear alkylation did occur, the ring-alkylated products were naphthols.
Both 1- and 2-naphthylamine gave the N-methylated arylamine and a methyl-naphthol while 2-naphthylamine gave, in addition, di-2-naphthylamine and dibenzacridine bases.

The work of Heap and of Hey suggested that the Hoffmann-Martius rearrangement might not occur with simple N-alkynaphthylamines. However, the decompositions of N,N'-dinaphthyl-1,3-propanediamine, reported earlier, gave products analogous to those obtained from the decomposition of the phenyl-diamines and it seems probable that both decompositions occur by the same reaction path. It was therefore of interest to heat salts of N-methyl-1- and N-methyl-2-naphthylamines under the Hoffmann-Martius conditions.

N-Methyl-1- and N-methyl-2-naphthylamine hydrochlorides were prepared via the amino-derivative of aceto-1- and aceto-2-naphthalides. This scheme adapted from Billman and Caswell's synthesis of disubstituted-α,ω-diaminoalkanes is outlined below:
The decompositions were carried out in sealed tubes at about 250°. The hydrochloride salts were first decomposed but, as no C-alkyl products could be isolated, the hydrobromide salts were made and decomposed. The volatile components from these decompositions were separated by the preparative gas chromatograph but the quantities available for injection were small and some of the minor components could not be isolated. Difficulty was also found in the separation of the tarry residues until it was realized that the dibenzacridines (XXXV and XXXVI) had been formed in the two decompositions.

XXXV

XXXVI
EXPERIMENTAL

Preparation and Decomposition of Salts of N-Methyl-1-naphthylamine.

Preparation

**Aceto-1-naphthalide**: Redistilled 1-naphthylamine (100g.; b.p. 130°-132°/1mm.; m.p. 50°) was added to a mixture of acetic anhydride (90ml.) and acetic acid (600ml.) in a 2l. beaker. After warming at 100° for 5 min., the mixture was cooled and water was added to precipitate aceto-1-naphthalide, which was collected by filtration. The white flaky crystals were washed with cold alcohol and dried, (150g.; 95% theory), m.p. 180°-181° (181°).

**N-Methyl-aceto-1-naphthalide**: Aceto-1-naphthalide (125g.) was dissolved in hot, sodium-dried, xylene (300ml.) and clean sodium (15g.) was added slowly with stirring to the refluxing solution. Vigorous evolution of hydrogen commenced and continued till all the sodium had dissolved. The mixture was heated at 80°-100° for 1.5 hrs, at the end of which sodium-aceto-1-naphthalide had formed as a solid white cake. Methyl iodide (100g.) in xylene (50ml.) was added dropwise to the mixture. After 10-15 min, the mass of sodium-aceto-1-naphthalide broke up and the mixture effervesced vigorously and sodium iodide precipitated. The mixture was refluxed for 2 hrs. After cooling, the sodium iodide was filtered off and the xylene was removed by distillation. Distillation under reduced pressure gave the required compound (48g.; 60% theory; b.p. 193°-200°/1mm.) as a white solid, m.p. 93°-94°.

**N-Methyl-1-naphthylamine Hydrochloride**: The N-methyl-aceto-1-naphthalide (48g.) was dissolved in concentrated hydrochloric acid (200ml.) and water added till the solid just began to precipitate. After refluxing for 16 hrs.
the mixture was concentrated to half volume and then cooled. The deposited hydrochloride (13g; 36% theory) had m.p.174°-175° after recrystallization from alcohol-ether.

**N-Methyl-1-naphthylamine-Hydrobromide:** N-Methyl-1-naphthylamine hydrochloride (4g.) was neutralized with sodium hydroxide solution (10% aqueous) and the base extracted with ether. Evaporation of the ether gave N-methyl-1-naphthylamine as an oil; benzoyl derivative, m.p.121°-122° (121°)56. Hydrogen bromide from a bromine/tetralin generator, was bubbled through an ethereal solution of N-methyl-1-naphthylamine to give white crystals of N-methyl-1-naphthylamine hydrobromide m.p.189°-190° after recrystallization from alcohol-ether.

**Decomposition of N-Methyl-1-naphthylamine Hydrochloride**

N-Methyl-1-naphthylamine hydrochloride (5.1g.) was sealed into a hard glass tube (lin.diameter) and heated at 250° for 2 hours in a furnace. The orange glassy solid obtained was washed with sodium hydroxide solution, when a strong fishlike odour characteristic of methylamines was noticed, and the liberated bases extracted with chloroform. The chloroform solution was washed with water and dried over anhydrous magnesium sulphate; the chloroform was removed by distillation. Distillation under reduced pressure gave 2 main fractions.

**Fraction 1** (2.0g.; b.p.125°-130°/1mm.) was shown by the analytical gas chromatograph to consist of 3 components. Comparison of their retention times with authentic samples provisionally identified the components as 1-naphthylamine, N-methyl-1-naphthylamine and N,N-dimethyl-1-naphthylamine. With the preparative gas chromatograph samples of two of these components
were obtained and characterised:

1. l-Naphthylamine, m.p. 50°(50°); benzoyl derivatives, m.p. 150°-160°.
2. N-Methyl-l-naphthylamine; benzoyl derivative, m.p. 131°-123° (131°)66, unchanged when mixed with an authentic sample.

Fraction 2 (1.15; b.p. 220°-240°/1mm.) was stirred with ether to give yellow crystals of 1,2,6,9-dibenzacridine, m.p. 137°-138° (139°)67 after recrystallisation from benzene; picrate, m.p. 193° (193°-194°)67.

The relative amounts of the volatile components determined by gas chromatography were:

<table>
<thead>
<tr>
<th>Component</th>
<th>Amount (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Naphthylamine</td>
<td>16%</td>
</tr>
<tr>
<td>N-Methyl-l-naphthylamine</td>
<td>30%</td>
</tr>
<tr>
<td>N,N-Dimethyl-l-naphthylamine</td>
<td>5%</td>
</tr>
<tr>
<td>1,2,6,9-Dibenzacridine</td>
<td>27%</td>
</tr>
</tbody>
</table>

* Based on weight of isolated sample.

Decomposition of N-Methyl-l-naphthylamine Hydrobromide

N-Methyl-l-naphthylamine hydrobromide (5.0g.) was sealed into a hard glass tube and heated to 250° for 2 hrs. in a furnace. The dark red glassy solid obtained was neutralised with 10% aqueous sodium hydroxide and the liberated bases extracted with ether. The ether solution was washed with water, dried over anhydrous magnesium sulphate and the ether was removed. Distillation of the residue gave a distillate with no obvious fractions (2.5g.; b.p. 139°-155°/1mm.). This was shown by the analytical gas chromatograph to contain 7 components, and by comparing retention times with authentic samples 5 of these were provisionally identified. The closeness of the retention
times made it possible to isolate only three of the components with the preparative gas chromatograph.

They were:

1-Naphthylamine, m.p. 43°-50° (50°) after recrystallization from ether, unchanged when mixed with an authentic sample.

N-Methyl-1-naphthylamine; benzoyl derivative 121°-122° (121°) 66.

2-Methyl-1-naphthylamine; obtained contaminated with N-methyl-1-naphthylamine but on four recrystallizations from petroleum ether gave white crystals, m.p. 30° (32°) 66; benzoyl derivative, m.p. 170°-180° (180°) 66.

The residue (0.4 g.) from the distillation was stirred with ether to give yellow crystals of 1,2,3,9-tetrahydrobenzacridine, m.p. 186°-187° (189°) 67 unchanged with an authentic sample. With the integrating amplifier on the analytical gas chromatograph the relative amounts of the more volatile components were determined and the percentage amounts of these with respect to the original amine were:

\[
\begin{align*}
1\text{-Naphthylamine} & \quad 25\% \\
\text{N,N'-Dimethyl-1-naphthylamine} & \quad 4\% \\
\text{N-Methyl-1-naphthylamine} & \quad 15\% \\
4\text{-Methyl-1-naphthylamine} & \quad 7\% \\
2\text{-Methyl-1-naphthylamine} & \quad 20\% \\
1,2,3,9\text{-Tetrahydrobenzacridine} & \quad 8\% \\
\end{align*}
\]

(1) Identified by comparing the retention time with a sample prepared from 1-naphthylamine and methyl iodide.

(2) Identified by comparing the retention time with a sample prepared in this department.
Preparation and Decomposition of Salts of N-Methyl-2-naphthylamine

Preparation

Aceto-2-naphthalide: By a method analogous to that used to prepare aceto-1-naphthalide (p. 103), recrystallized 2-naphthylamine (75g.; m.p. 110°-111°) and a mixture of acetic anhydride (75ml.) and acetic acid (500ml.) gave aceto-2-naphthalide as white feathery crystals (75g.; 62% theory), m.p. 135°-136° (151°).66

N-Methyl-aceto-2-naphthalide: By a method analogous to that used to prepare the 1 isomer (p. 103), aceto-2-naphthalide (75g.) and methyl iodide (80g.) gave, via the sodo-derivative, N-methyl-aceto-2-naphthalide as a yellow oil (57g.; 72% theory; b.p. 138°-172°/1mm.).

N-Methyl-2-naphthylamine hydrochloride: By a method analogous to that used to prepare the 1 isomer (p. 103), N-methyl-aceto-2-naphthalide (57g.) was hydrolyzed with hydrochloric acid to give the required product, (24g.; 33% theory), m.p. 130°-131° (132°-133°).66

N-Methyl-2-naphthylamine hydrobromide: The hydrochloride of the base was neutralized with sodium hydroxide solution (10% aqueous) to give the base as an oil; benzoyl derivative m.p. 84° (84°).66. An ether solution of the base was then saturated with dry hydrogen bromide to give crystals of N-methyl-2-naphthylamine hydrobromide, m.p. 195°-196°.

Decomposition of N-Methyl-2-naphthylamine Hydrochloride

N-Methyl-2-naphthylamine hydrochloride (5.0g.) was sealed into a glass tube and heated (furnace) at 250° for 3 hours. When the dark red glassy solid was
neutralized with sodium hydroxide solution (10% aqueous), a strong fishy odour characteristic of methylamines was noticed. The ether extract (A) of the bases was shaken with hydrochloric acid (15% aqueous) to precipitate 3,4,6,7-dibenzacridine hydrochloride as a yellow solid m.p. 345°-348° (346°-348°)64. This salt was neutralized with sodium hydroxide solution to give on recrystallization from benzene yellow crystals of 3,4,6,7-dibenzacridine (0.8g.) m.p. 218°-219° (220°)51; piorate, m.p. 330°-335° (332°-334°) 51. The ethereal extract (A) and the hydrochloric acid solution were shaken with sodium hydroxide solution and the ether solution was separated. On removal of the ether, distillation gave a mixture of 2-naphthylamine and unchanged N-methyl-2-naphthylamine. The mixture was subsequently separated on the preparative gas chromatograph. Percentage amounts (of volatile components determined by peak areas on the recorder graph), with respect to the original base were:

2-Naphthylamine 1
N-Methyl-2-naphthylamine 2
3,4,6,7-Dibenzacridine 3

1. m.p. 110°-111° (112°-113°) unchanged when mixed with an authentic sample.
2. Benzoyl derivative m.p. 121° (121°)56.
3. Based on weight of isolated sample.

Decomposition of N-Methyl-2-naphthylamine Hydrobromide
N-Methyl-2-naphthylamine hydrobromide (6.8g.) was sealed into a glass tube and heated (furnace) at 250° for 3 hours. When the dark red glassy solid
was neutralized with sodium hydroxide solution a strong fishy odour characteristic of methylamines was noticed. The bases were extracted with ether and this ether solution (A) was shaken with hydrochloric acid (15% aqueous) to precipitate yellow crystals of 3,4,6,7-dibenzacridine hydrochloride. Subsequent neutralization of this salt gave yellow crystals of the base (0.5g.; m.p. 216°-217°, unchanged when mixed with previous sample).

The ether solution (A) and the hydrochloric acid solution were shaken with excess sodium hydroxide solution and the ether solution was separated. On removal of the ether, distillation gave a fraction (2.7g.; b.p. 135°-145°/1mm.) which was shown by the analytical gas chromatograph to contain 4 components. Three of these components were separated on the preparative gas chromatograph; they were:-

2-naphthylamine, m.p. 110° (112°-113°) unchanged when mixed with an authentic sample. Benzoyl derivative m.p. 161°-162° (162°-165°).

N-methyl-2-naphthylamine, benzoyl derivative m.p. 94°, unchanged when mixed with an authentic sample.

1 Methyl-2-naphthylamine, m.p. 50° (51°)66, recrystallized from petroleum ether (b.p. 50°-70°). Benzoyl derivative m.p. 226°-227° (222°)66.

Analysis of Benzoyl derivative:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>% Found</td>
<td>5.49</td>
</tr>
<tr>
<td>% Calculated</td>
<td>5.36</td>
</tr>
</tbody>
</table>

With the integrating amplifier on the analytical gas chromatograph the relative amounts of the more volatile components were determined. The percentage amounts of each component with respect to the original amine
The compounds were:

<table>
<thead>
<tr>
<th>Compound</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Naphthylamine</td>
<td>15%</td>
</tr>
<tr>
<td>N-Methyl-2-naphthylamine</td>
<td>24%</td>
</tr>
<tr>
<td>1-Methyl-2-naphthylamine</td>
<td>37%</td>
</tr>
<tr>
<td>3,4,6,7-Dibenzacridine</td>
<td>13%</td>
</tr>
</tbody>
</table>

* Based on weight of sample isolated.
DISCUSSION

Only naphthylamines and dibenzacridines were obtained from the decompositions of the hydrochloride salts of the N-methylnaphthylamines. However, the hydrobromide salts gave naphthylamines and ring-methylated compounds in good yields, with corresponding reductions in the yields of dibenzacridines. The volatile fractions contained the ring-methylated compounds but the similarity of the components in these fractions made chemical separation impossible. Gas chromatography was employed to effect a separation although even this was not completely successful. The close retention times of N-methyl-1-naphthylamine and 2-methyl-1-naphthylamine meant that only the former could be obtained pure because it was eluted first; the 2-methyl-1-naphthylamine was contaminated and was purified by repeated recrystallizations. The analytical gas chromatograph showed evidence for four other components in (addition to 1-naphthylamine and the two compounds above) in the decomposition of N-methyl-1-naphthylamine. Two of these were provisionally identified as N,N-dimethyl- and 4-methyl-1-naphthylamine. It is of interest to note that although N-alkyl-anilines rearrange to give mainly p-alkylanilines, N-methyl-1-naphthylamine gives mainly the 3- or ortho-isomer. From the decomposition of N-methyl-2-naphthylamine the only rearranged product isolated, and indeed the only expected, was 1-methyl-2-naphthylamine.

The dibenzacridines are interesting products in these decompositions. The formation of these bases has been reported by Hey when 2-naphthylamine hydrochloride was heated with methanol, in which case two acridines were isolated. Similar experiments with the p- and p-toluidines and with other
aryamines have shown that high yields of substituted acridines are obtained. However, with the decomposition of N-methylarylamines hydrohalide salts, no direct evidence had previously been obtained for the presence of an acridine base although Hickinbottom, in decomposing N-methylaniline hydroiodide, obtained tertiary amines that he suspected to be largely of the acridine or phenanthridine type. He concluded that under his conditions the formation of an acridine derivative involved either the interaction of the amino groups of two molecules with the elimination of ammonia (or methylamines) or the interaction of an amino group in one molecule with a hydroxyl group in another and the elimination of water. In the breakdowns now reported, only the first scheme is possible.

That the formation of C-alkyl products from the methyl-naphthylamines is dependent on the type of halide ion present could be a reflection of the relative nucleophilicity of the halide ions. Thus it might be more difficult for the chloride ion, with less nucleophilic character, to form reactive alkyl halide intermediates.

\[ \text{Cl}^- + \text{CH}_3\text{NH}_2\text{-Ar} \xrightarrow{\text{Hofmann-}} \text{Cl-CH}_3 + \text{NH}_2\text{-Ar} \]

The fact that N-alkylanilines rearrange with little or no acridine formation may indicate that the rate-determining step leading to rearrangement is of lower energy than the corresponding step with the naphthylamines. It seems, therefore, that there are two possible reaction courses for the N-methylnaphthylamines to follow during breakdown. Either the methyl group is removed from the nitrogen by a bimolecular mechanism, with the formation of an alkyl halide and subsequent ring alkylation (as in the normal Hofmann-
Martius reaction) or, because this is energetically unfavourable, two N-methyllnaphthylamines molecules react to form dibenzacridine.

The mechanism of acridine formation is not clear but it must involve the interaction of two amine molecules with the elimination of ammonia or methylamine. One simple scheme would be:

\[
\text{Ar-NHCH}_3 + \text{Ar-NH}_3 \text{CH}_3 \rightarrow \text{Ar-NHCH}_3 + \text{CH}_3 \rightarrow \text{XXXVI}
\]

The first step is in accord with the known formation of di-2-naphthylamine from 2-naphthylamine at high temperatures. However, no di-2-naphthylamine derivatives could be isolated from the corresponding reaction mixture. With 2-naphthylamine, three dibenzacridines are theoretically possible but, as expected, the only one obtained (XXXVI) involved linkages at the 1-positions.

From this short investigation it is apparent that N-methyl-1- and N-methyl-2-naphthylamine hydrobromides decompose under the Hofmann-Martius conditions to give not only the expected ring-methylated naphthylamines but also dibenzacridines. It would seem worthwhile to investigate further; (a) the apparent ortho-substitution in 1-naphthylamine, (b) the effects of different hydrohalide acids on the rate of Hofmann-Martius rearrangements and (c) the mechanism of dibenzacridine formation.
REFERENCES

1. A.W. Hofmann and C.A. Martius; Ber., 4, 743 (1871).
2. A.W. Hofmann; Ber., 5, 701 (1872); Ber., 7, 526 (1874).
12. A. Michael; Ber., 14, 2105 (1931).
15. W. Scholte; Ber., 32, 2352 (1899).
18. A. Henssen; Ber., 20, 731 (1937).
21. R.D. Topley; Private Communication.
24. G. Finkus; Ber., 25, 2302 (1892).
29. C. Trapesczjan; Ber., 25, 3271 (1892).
34. L.W. Deady; Current work, University of Canterbury.
39. Ref. 38 p.446.
40. Ref. 38 p.455.
44. Pye and Co., Ltd., Instrument handbook for Pye Argon Chromatograph.
45. L.K. Greener; Private communication.
47. Ref. 38 p.264.
54. N. Bristow, P. Oxley, A. Williams, E. Wilmshurst and G. Woolfe; Chem. Abs. 15003 (1959).
60. I. Walker and I.K. McDonald; Private communication.
69. G. Liebermann and M. Kardos; Ber, 46, 208 (1913).
I am grateful to the University Grants Committee for the award of Research Fund Fellowship, enabling this work to be carried out.