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The Preparation of Long Chain Secondary Aliphatic Amines

Robert Fay Betts

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THE PREPARATION

OF

LONG CHAIN SECONDARY ALIPHATIC AMINES

By

Robert Fay Betts

A Thesis Submitted to the Faculty
of the
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for the
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Preface

As organic chemistry has always seemed to be the most interesting study to me, I have chosen this particular branch of chemistry for a thesis.

I found through correspondence with some of the larger petroleum companies in the United States that the preparation of long chain secondary amines would constitute a good thesis topic because these compounds have begun to assume importance as additives to lubricating oil.

It has always been my desire to work as a chemist for a petroleum concern, and I therefore thought that a subject of this type would be helpful and very much worth while.

I wish to thank all those who have helped me undertake this work. I desire especially to express my appreciation to my thesis adviser, Mrs. Toraballa, for her kind suggestions and cooperation.
# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preface</td>
<td>11</td>
</tr>
<tr>
<td>I. Introduction</td>
<td>1</td>
</tr>
<tr>
<td>II. History and Properties of Amines</td>
<td>3</td>
</tr>
<tr>
<td>General Preparations of Amines</td>
<td>4</td>
</tr>
<tr>
<td>Specific Preparative Methods for Secondary Amines</td>
<td>11</td>
</tr>
<tr>
<td>III. Experimental Work</td>
<td>20</td>
</tr>
<tr>
<td>Description of Apparatus</td>
<td>20</td>
</tr>
<tr>
<td>Typical Experiment</td>
<td>22</td>
</tr>
<tr>
<td>III. Experimental Data and Results</td>
<td>28</td>
</tr>
<tr>
<td>IV. Discussion</td>
<td>39</td>
</tr>
<tr>
<td>V. Summary and Conclusions</td>
<td>43</td>
</tr>
<tr>
<td>VI. Suggestions for Further Study</td>
<td>45</td>
</tr>
<tr>
<td>VII. Annotated Bibliography</td>
<td>46</td>
</tr>
</tbody>
</table>
List of Tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>The Preparation of Dibutylo cyanamide</td>
<td>28</td>
</tr>
<tr>
<td>II.</td>
<td>The Preparation of Dibutylamine from Dibutylo cyanamide</td>
<td>30</td>
</tr>
<tr>
<td>III.</td>
<td>The Preparation of Diamyl cyanamide</td>
<td>31</td>
</tr>
<tr>
<td>IV.</td>
<td>The Preparation of Diamylamine from Diamyl cyanamide (Solid)</td>
<td>32</td>
</tr>
<tr>
<td>V.</td>
<td>The Preparation of Diamylamine from Diamyl cyanamide (Liquid)</td>
<td>33</td>
</tr>
<tr>
<td>VI.</td>
<td>The Preparation of Dihexylo cyanamide</td>
<td>34</td>
</tr>
<tr>
<td>VII.</td>
<td>The Preparation of Dihexylamine from Dihexylo cyanamide</td>
<td>35</td>
</tr>
<tr>
<td>VIII.</td>
<td>The Preparation of Amyl-butylamine</td>
<td>36</td>
</tr>
<tr>
<td>IX.</td>
<td>The Preparation of Dibutylamine</td>
<td>37</td>
</tr>
<tr>
<td>X.</td>
<td>The Preparation of Secondary Amyl-butyl amine</td>
<td>38</td>
</tr>
</tbody>
</table>
I. INTRODUCTION

The subject of this thesis is the preparation of long-chain secondary amines. These compounds have found wide usage in the petroleum industry. It has been found that when small quantities of high molecular weight secondary amines are added to lubricating oil that a very desirable property is achieved. The amine acts as an inhibitor and prevents oxidation of the oil. It has been proven by numerous petroleum companies in the United States that these amines actually modify the properties of the lubricating oil to such an extent that the oil can withstand the more rigid operating conditions of our modern diesel engines, high compression internal combustion engine engines.

The value of an additive, such as the type I am attempting to prepare has been definitely verified, not only by technicians in research laboratories, but also by large producing companies and commercial airlines.

At this point it should also be mentioned that the term oxidation stability refers to the ability of an oil to resist oxidation and decomposition during service use. All lubricating oils, regardless of whether or not they contain suitable additives, tend to oxidize and break down in service, to a greater or lesser extent, depending upon the service application, the severity of the operating conditions, and the quality of the oil. In practice the oxidation stability is controlled by selection of base stocks and additives so that relatively little oil decomposition occurs in the service application for which the oil is recommended. When oil
The subject of this thesis is the preparation of long chain secondary amines. These compounds have found wide usage in the petroleum industry. It has been found that when small quantities of high molecular weight secondary amines are added to lubricating oil that a very desirable property is achieved. The amine acts as an inhibitor and prevents oxidation of the oil. It has been proven by numerous petroleum companies in the United States that these amines actually modify the properties of the lubricating oil to such an extent that the oil can withstand the more rigid operating conditions of our modern diesel engines, high compression internal combustion engines and aviation engines.

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oxidizes and decomposes in an engine, acids are formed which may be corrosive to alloy bearings, resins are formed which may cause varnish build up on pistons and valve stems with consequent piston ring or valve sticking, and insoluble material forms in the oil which may aggravate ring sticking and cause sludge deposits in the engine. The rate of decomposition increases markedly as the oil temperature goes up, doubling for every eighteen degrees Fahrenheit. Thus, an increase in oil temperature from 200 degrees Fahrenheit to a value of 254 degrees Fahrenheit will increase the rate of decomposition eight-fold. (13)

With these facts in mind I have attempted in this thesis to find a few good preparations for secondary aliphatic amines in which there are more than eight carbon atoms per molecule. Through correspondence with four large petroleum companies, it has been discovered that this subject carries the general interest of the petroleum industry.

Although there are many preparations for long chain secondary amines most of them are beyond the scope of this thesis because the final product must be a pure secondary amine (there must be no primary or tertiary components present). Furthermore, the final product must be synthesized from comparatively cheap starting materials so that the entire process may be economically adapted to commercial production.

Since amines are ammonia derivatives which are obtained

from ammonia by replacement of one, two, or three of its hydrogens by alkyl groups, it can readily be seen that secondary amines are organic compounds in which two alkyl radicals have replaced two hydrogen atoms of ammonia. (25) The alkyl radicals which I will try to substitute for two hydrogen atoms of ammonia will contain enough carbon atoms so that there will always be a total of at least eight carbon atoms in the final secondary amine.

History and Properties of Amines

The existence of alkylamines or alcohol bases was very definitely predicted by Liebig in 1842 (Handwortenbuch fur Chemie). In 1849 Wurtz discovered a method for the preparation of primary amines which consisted in decomposing isocyanic ester with aqueous potassium hydroxide. This was a discovery of the greatest importance for the development of organic chemistry. Shortly afterwards, in 1849, A. W. Hoffmann, by the action of alkyllogens on ammonia, discovered a reaction which made possible the preparation of all classes of amines, namely: primary, secondary, and tertiary. Besides the amines Hoffmann found that alkyl ammonium bases were also formed. This afforded experimental bases for the introduction of the ammonia type into organic chemistry. (14)

At room temperature the lower members of the series of amines are gases, propylamine to dodecylamine are liquids, and the higher members are solids. Odor and solubility in water decrease with increase in the length of the alkyl group. Those below hexylamine are readily soluble in water and are more basic than its ammonia. The amines possess a fishy odor and their vapors are inflammable. It was this property that enable Wurtz in 1849 to recognize that he had obtained amines by the hydrolysis of alkyl isocyanates. The amines are all colorless in the pure state. The higher members resemble the hydrocarbons much more than they do ammonia. (4)

General Preparations for Amines

There are four general methods for the preparation of amines. They fall under the general headings of ammonolysis, aminolysis, hydrogenation and special methods. Examples for each of these synthetic methods are the following. (4)

I. Ammonolysis

a) Alkyl halides when treated with ammonia, under heat and pressure, will yield amines according to the following equation:

\[ \text{RCl} + \text{NH}_3 \rightarrow \text{RNH}_2 \text{Cl} \]

\[ \text{RNH}_2 \text{Cl} + \text{NaOH} \rightarrow \text{RNH}_2 \text{NaCl} + \text{H}_2\text{O} \]

Unless a large excess of ammonia is used, the


(4) Degering, Edward F., Ibid., 200.
reaction gives a mixture of primary, secondary, and tertiary amines. The proportions of each are functions of the following variables:
1. The reactivity of the alkyl halide
2. The concentrations of the reactants
3. The reactivity of the intermediate compounds
4. The solubilities
5. The solvent used
6. Temperature
7. Time
8. Pressure

Although methods have been devised for the separation of these different types of amines from the mixture, the procedures are somewhat unsatisfactory.

b) Aldehydes or ketones when treated with ammonia, under heat and pressure. The aldehydes and ketones in general are converted to the corresponding amines when treated with ammonia in the presence of hydrogen and a nickel or other appropriate hydrogenation catalyst. (26)

\[
\begin{align*}
\text{RC(R)}(\text{H}) \quad \text{NH}_3 & \quad \rightarrow \quad \text{RC(R)}(\text{H}) \quad \text{H}_2\text{O} \\
\text{RC(R)}(\text{H}) \quad \text{H}_2 & \quad \rightarrow \quad \text{RC(R)}(\text{H}) \\
\text{NH} \quad \text{Ni} & \quad \text{NH}_2
\end{align*}
\]

II. Aminolysis

a) Alkyl halides or halogen compounds when treated

(26) Westphal and Jerchel, Ber., 73E, 1002 (1940).
with amines, under heat and pressure, will yield amines, as:

\[ \text{RCl} + \text{HNR} \xrightarrow{\text{H}} \text{H} \xrightarrow{\text{RNR}} \text{HCl} \]

With respect to 1-chloro paraffins, the experimental data in the literature indicates that:

1. Secondary amines may be obtained under proper conditions as the principal product.

2. The primary, secondary, and tertiary derivatives may be separated by rectification.

3. The derivatives higher than n-butyl give no appreciable amount of quaternary salt.

4. The yields are increased by the use of a solvent such as alcohol in the ratio of one to one in liquid ammonia.

5. The yield of tertiary alkylamine is reduced as the length of the alkyl group is increased practically none being obtained in the case of octyl chloride. (7)

b) Alcohols, when treated with amines, under heat and pressure as:

\[ \text{RCH}_2\text{OH} + \text{HNR} \xrightarrow{\text{Ni}} \text{H} \xrightarrow{\text{RCH}_2\text{NR}} \text{H}_2\text{O} \]

Hydrogenation catalysts such as cobalt, copper, and nickel are used. Both secondary and tertiary

amines are obtained. (7)

c) Aldehyde or ketones when treated with amines, in the presence of a hydrogenation catalyst as:

\[
\begin{array}{cccc}
0 & H & RC(R)(H) & \text{NR} \\
\text{heat} & & H & \rightarrow & \text{RC=NR} & H_2O \\
\text{Pt} & & H & \rightarrow & \text{RC} & \text{NR} \\
\end{array}
\]

A number of amines have been prepared in yields of about 90%. (7)

This reaction has been used on ketones to prepare antispasmodics of the type \(\text{CH}_3\text{CHRNR'}\) where \(R\) is a four to seven carbon atom chain and \(R'\) contains 1, 3, or 5 carbon atoms or a cycloalkyl residue. Zinc dust and sulfuric acid have been used as the hydrogenation reagent. (3)

III. Hydrogenation

a) Nitriles, isonitriles, or other nitrogen compounds, as:

\[
\begin{array}{cccc}
\text{RC=N} & 2\text{H}_2 & \text{liquid} & \text{RCNH}_2 \\
\text{Ni} & & \text{phase} & \\
\end{array}
\]

The nitriles of five or more carbon atoms are hydrogenated in the presence of ammonia and a catalyst. The catalytic reductions often yield small amounts of both secondary and tertiary amines because of condensation between the imine, formed as the first product, and the amine. This can be avoided by using platinum oxide, in acetic

anhydride, as the catalyst for the acetylation of the amine as it is formed and thus prevent condensation between the imine and the amine.

b) The amides or their simple derivatives, as:

\[
\text{RCNH}_2 \quad 2\text{H}_2 \quad \xrightarrow{250 \text{ atm.}} \quad \text{RCH}_2\text{NH}_2 \quad \text{H}_2\text{O}
\]

Cu-Cr oxides

A number of amines have been prepared in yields of 70% to 95%. Under similar conditions, the addition of barium oxide induces the formation of appreciable amounts of the secondary amines. (23)

c) The nitroalkanes, as:

\[
\text{RNO}_2 \quad 3\text{H}_2 \quad \xrightarrow{\text{Ni}} \quad \text{RNH}_2 \quad \text{H}_2\text{O}
\]

15 to 150°C

This reaction affords a means of obtaining primary amines, which are free from traces of secondary and tertiary amines.

IV. Special Reactions

a) By the use of special reactions as that of the Gabriel synthesis of primary amines.

This reaction is a general one. In certain cases the hydrolysis proceeds with difficulty, and heating in a sealed tube at an elevated temperature is necessary to effect complete liberation of the amine.

b) Grignard or Frankland on haloamines, alkoxyamines, and amides, as:

1. Haloamines

\[ RMgX \quad ClNH_2 \rightarrow RNH_2 \quad MgX_2 \]

2. Alkoxyamines

\[ ROCH_2NR'R \quad R'MgX \rightarrow R'CH_2NR'R \quad ROMgX \]

The alkoxyamine for this reaction may be prepared as follows:

\[ CH_2O \quad HCl \quad ROH \rightarrow ClCH_2OR \quad H_2O \]
\[ R_2NH \quad ClCH_2OR \rightarrow R_2NCH_2OR \quad HCl \]

3. Amides

\[ HCONR_2 \quad 3R'MgX \rightarrow R'CHNHR_2 \quad \text{other products} \]

c) Hofmann reaction for the preparation of amines from amides, as:

\[ RCONH_2 \quad Br_2 \xrightarrow{NaOH} \quad RCONHBr \quad NaBr \quad H_2O \]
\[ RCONHBr \quad NaOH \rightarrow RN=CO \quad NaBr \quad H_2O \]
\[ RN=CO \quad 2NaOH \rightarrow RNH_2 \quad Na_2CO_3 \]

This reaction gives satisfactory yields with the lower amides, but as the length of the alkyl group is increased a side reaction decreases the yield.
by the formation of the nitrile, as:

\[
RCH_2NH_2 + 2Br_2 \rightarrow RCH_2NBr_2 + RCON 4HBr
\]

d) Curtius for the preparation of amines from azides, as:

\[
\begin{align*}
RCONHNNH_2 + NaNO_2/HCl & \rightarrow RCON_3 + NaCl + 2H_2O \\
RCON_3 + CH_3CH_2OH & \rightarrow RNHCOOCH_2CH_3 + N_2
\end{align*}
\]

This last reaction may be considered as a special case of a Beckmann rearrangement, as indicated by:

\[
\begin{align*}
RCON_3 + ROH & \rightarrow RCOHNOR + N_2 \\
RCONH & \rightarrow RCOH^\text{NR} + ROC=0
\end{align*}
\]

\[
\begin{align*}
ROI = 0 + H_2O/\text{conc.}HCl & \rightarrow RNH_3Cl + CO_2 + ROH
\end{align*}
\]

Since some azides are explosive, the reaction has its limitations.

e) The Leuchart synthesis for the preparation of amines from aldehydes or ketones and formamide or ammonium formate, as:

\[
\begin{align*}
RC=0 & \rightarrow 2HCOONH_4 \rightarrow RCH_2NHCHO + NH_3 + CO_2 + 2H_2O \\
RCH_2NHCHO + H_2O/\text{HCl} & \rightarrow RH_2CNH_2Cl + HCOOH
\end{align*}
\]

A modification of the reaction is:

\[
\begin{align*}
RHC=0 & \rightarrow 2HC=0 \rightarrow R'NH_2 + RHCHNR'CHO + CO_2 + \text{NHR'} \\
RCH_2NR'CHO + H_2O/\text{HCl} & \rightarrow RCH_2NR'H + HCOOH
\end{align*}
\]

One equivalent of an aldehyde reacts with one part of ammonium formate to give an alkylamine, CO_2.
and water.

\[ \text{RCCH}=\text{O} \rightarrow \text{HCOONH}_4 \rightarrow \text{RCH}_2\text{NH}_2 \quad \text{CO}_2 \quad \text{H}_2\text{O} \]

f) Amines can be formed by the decomposition of miscellaneous nitrogen compounds, as:

\[ \text{RCNOH} \quad \text{H}_2 \rightarrow \text{RCHNH}_2 \quad \text{H}_2\text{O} \]

The starting point in the above synthesis may be regarded as a ketoxime.

Other nitrogen compounds which may be subjected to hydrolysis to give amines are: the \( \text{N},\text{N}-\text{dialkylcyanamides} \) (\( \text{R}_2\text{NCN} \)), the \( \text{alkylisocyanates} \) (\( \text{RN} = \text{C}=\text{O} \)), the \( \text{alkylisothiocyanates} \), \( \text{p-nitroso-} \text{N-alkylaniline} \) (\( \text{p-O}=\text{NC}_6\text{H}_4\text{NR} \)), and \( \text{p-nitroso-} \text{N,N-dialkylanilines} \).

Specific Preparative Methods for Secondary Amines

From the general preparations for amines which I have listed above it is obvious, for many reasons, that the preparation of a pure product is a difficult problem, not only because most methods yield a mixture of amines, but also because many of the methods employ excessive temperatures and pressures. Therefore I will now try to outline a few of the better synthetic preparations which give good yields of pure secondary amines.

In searching for a method of preparing \( \text{di-} \text{n-butylamine} \) and \( \text{diallylamine} \) in relatively pure form, free from primary and tertiary amines, the hydrolysis of disubstituted cyanamides
was investigated by Vliet in 1924. (24) Diethylamine has been formed in this manner by the action of acids and alkalis on diethylcyanamide, while di-iso-amylcyanamide and dibenzylcyanamide have converted into the corresponding amines by treatment with hydrochloric acid to 140 to 150 degrees Centigrade. However, this method of obtaining secondary amines is handicapped by the lack of a practical method for preparing disubstituted cyanamides.

Dialkylcyanamides have been prepared by the reaction of dialkylamines with chlorocyanogen or bromocyanogen, by the reaction of dialkylchloroamines with potassium cyanide, and the action of bromine on a mixture of dialkylamines and potassium cyanide. Dimethylcyanamide has been obtained from dimethyl sulfate and free cyanamide, $H_2NCN$. It is obvious that these methods are not practical.

Dialkylcyanamides have also been prepared by the action of alkyl halides on disilver cyanamide and on disodiumcyanamide. Since disodium cyanamide cannot be obtained on the market and is difficult to prepare, these methods could not be considered.

Traube and Engelhardt have treated a suspension of lime nitrogen with dimethyl sulfate and then, without isolating the resulting dimethylcyanamide, have hydrolyzed it to dimethylamine by refluxing with hydrochloric acid. This method cannot be used for preparing the products desired because of the difficulty of obtaining the necessary organic sulfates.

Since lime nitrogen is the only commercially available cyanamide derivative, it would seem to be the logical starting material for synthesizing dialkylcyanamides. Traube and Engelhardt have reported a 45 per cent yield of dibenzylcyanamide by the reaction of benzyl chloride with lime nitrogen suspended in 50 per cent alcohol. However, when this method of preparation was tried with n-butyl bromide, only a trace of product was obtained. (22) Various other procedures were tried and a method was finally developed by which di-n-butylcyanamide and diallylcyanamide can be obtained in fairly good yields using lime nitrogen with n-butyl bromide and allyl bromide. (24) A solution of sodium cyanamide is first formed by the action of sodium hydroxide on a suspension of lime nitrogen in water and this, upon the addition of some alcohol, readily reacts with the bromides to give the desired products. This method can undoubtedly be used for the preparation of many other disubstituted cyanamides.

The hydrolysis of these cyanamides to give di-n-butylamine and diallylamine of good quality was found to proceed satisfactorily by merely refluxing with dilute sulfuric acid. Di-n-butylcyanamide and diallylcyanamide have not been previously described. Di-n-butylamine has been prepared by the reaction of a dilute alcoholic solution of ammonia with n-butyl chloride and with n-butyl bromide while diallylamine has been obtained by the action of mono-allylamine on

(22) Traube and Engelhardt, *Ber.*, 44, 3149 (1911).
allyl bromide and allyl chloride. The products resulting from the use of these methods contained relatively large amounts of primary and tertiary amines from which it was difficult to separate pure secondary amines.

The second method of preparation for secondary amines which I will consider has a definite advantage over the one referred to above in that it demonstrates a process for the successful isolation of unsymmetrical secondary aliphatic amines while the only products which can be prepared from the first method of synthesis are symmetrical amines.

Until recently unsymmetrical secondary aliphatic amines have been difficult to prepare in quantity. One of the most promising methods of preparing these amines would appear to be by reduction of aliphatic aldimines. A survey of the literature has shown that this approach has been investigated before, with varying degrees of success. Although several workers have reported the preparation of various aliphatic aldimines (8) there appears to be no good general description of the method of preparation. Reduction of aliphatic aldimines by sodium and alcohol has been reported to yield the secondary amines (21) but the yields are not always good; possibly considerable cleavage or polymerization of the aldime occurs during the reduction. Skita and his co-workers (17), investigated the low pressure catalytic hydrogenation

(8) Henry, Compt. rend., 120, 837 (1895).
(21) Stoermer and von Lepel, Ber., 29, 2115 (1896).
of aldimines, using platinum as a catalyst and acetic acid as solvent. They obtained secondary amines, but the carbon content was greater than would be expected. Winans and Adkins (29) and Henze and Humphreys (9) have shown that aldehyde-amine condensation products can be hydrogenated to secondary amines of the same carbon content at high pressures and the presence of nickel catalyst; these workers did not isolate the intermediate aldimines, and while their method gives good yields of amines, there is also need for a procedure which does not involve the use of high-pressure hydrogenation equipment. Campbell, Sommers, and Campbell at the University of Notre Dame undertook a study of the preparation and isolation of aliphatic aldimines and of their catalytic hydrogenation at low pressures and temperatures. (3)

Campbell, Sommers, and Campbell have found that aldimines can be obtained in a pure state and good yield from aliphatic aldehydes and amines only by observing certain precautions rather strictly. The method finally adopted is a modification of the one described by Chancellor for propylidene propylamine; the reaction is best carried out by adding the aldehyde to the amine without a solvent at zero degrees Centigrade. When the order of addition is reversed, the yields are much lower. After the addition is complete, solid potassium hydroxide is added to remove the water formed in the reaction. This step is essential; when other drying agents

such as potassium carbonate or magnesium sulfate were tried, practically no aldimine was obtained on distillation and attempts to hydrogenate the undistilled material were unsuccessful. The aldimine should be distilled from fresh potassium hydroxide. The aldimines obtained in this work were water white when freshly distilled; they are unstable, and polymerize on standing, and should be used within a few hours after distillation.

The aldimines can be hydrogenated to secondary amines of the same carbon content at room temperature and pressures of two to three atmospheres with certain restrictions. The best solvent appears to be absolute ethyl alcohol. Palladium charcoal catalyst can be used, but the hydrogenation is more rapid, and the yields of amine seem better when produced platinum oxide is used. With Raney nickel the calculated amount of hydrogen is taken up rather rapidly, but side reactions appear to predominate, and but little of the desired secondary amine is formed. The hydrogenations are best carried out in the presence of a small amount of the original primary amine in order to minimize cleavage of the aldimines.

The third method under consideration likewise prepares mixed or unsymmetrical amines. In this reaction a mixture of vapors of an alcohol and a primary amine are passed over thoria at temperatures between 300 and 350 degrees Centigrade. A condensation reaction results and a secondary amine is formed. Aluminum oxide may also be used as a catalyst but thoria is the best. Among the aliphatic alcohols, methyl
gives the poorest results. Ethyl-isoamyl amine, boiling at 126, propyl-isoamyl amine, boiling at 145, and isobutyl-isoamyl amine, boiling at 158, have been prepared in this manner.

The chemical equations for this process can be generalized as follows: (15)

\[
2CnH_{2n+1} \text{OH} + \text{ThO}_2 \rightarrow H_2O + \text{ThO}(O\text{CnH}_{2n+1})_2
\]

\[
\text{ThO}(O\text{CnH}_{2n+1})_2 + 2H \rightarrow N-\text{CnH}_{2n+1}H_2O + \text{ThO}_2
\]

\[
2CnH_{2n+1} \rightarrow N \rightarrow \text{CnH}_{2n+1} \text{H}
\]

It can be readily seen from the chemical equations that the product of the first reaction is the thorinate addition product of an alcohol. When this addition product reacts with a primary amine (second equation) a secondary aliphatic amine is produced and the catalyst is regenerated for further usage.

It should be mentioned, however, that the literature on this reaction states that there is a possibility that some of the secondary amine which is prepared will react again with the alcohol and cause the formation of some tertiary amine.

The fourth method of preparing long chain secondary amines was taken from United States patent number 2,256,434. (10) This invention gives a process for the preparation of new and valuable chemical compounds which are saturated derivatives of ethylamine of the general formula.

R1 is an alkyl radical containing four, five, six, or seven carbon atoms in a straight or branched chain, and R2 is an alkyl radical containing one, three, or five carbon atoms or a cycloalkyl radical. These compounds have a favorable antispasmodic action.

R1 may, for example, be butyl, isobutyl, amyl, isoamyl, hexyl, or heptyl. R2 may be an alkyl radical, for example, methyl, propyl, isopropyl, amyl, isoamyl, or a cyclo-alkyl radical, for example, cyclopentyl, cyclohexyl, or methyl-cyclohexyl.

The new compounds are produced by condensing alkyl methyl ketones of the general formula \( R_1 - CO - CH_3 \) with primary amines of the general formula \( R_2 NH_2 \). Methylamino-4-methyl-2-pentane, \( C_7H_{17}N \), was obtained in this process by subjecting 50 grams of methyl-2-pentanone-4 to catalytic reduction in the presence of 12 grams of methylamine and 100 cc. of 1% colloidal platinum solution. By using activated aluminum as the reducing agent the same base was obtained with a yield of 70 to 80 per cent of the theoretical amount. The equation for this reaction is as follows:

\[
\begin{align*}
\text{HC-NH}_2 & \quad \text{HC-C-C-C-CH} \\
\text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{O} & \quad \text{H} \\
\text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} \\
\text{HCH} & \quad \text{HCH} & \quad \text{HCH} & \quad \text{HCH} & \quad \text{H} & \quad \text{H} \\
\text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} \\
\end{align*}
\]

2-methyl pentanone 4 4-methyl imine

2-methyl pentane
The ketimine formed from this first reaction was subjected to hydrogenation in the presence of a colloidal solution of platinum. The following chemical equation illustrates the process.

\[
\begin{align*}
&\text{HC-C-C-CH} \\
&\text{HCH} \\
&\text{H}
\end{align*}
\]

\[
\begin{align*}
&\xrightarrow{H_2} \\
&\text{Pt}
\end{align*}
\]

\[
\begin{align*}
&\text{HC-C-C-CH} \\
&\text{HCH} \\
&\text{H}
\end{align*}
\]

Although the above mentioned process is a very good method for preparing long chain secondary amines, no work was done on this method in the laboratory because a specific laboratory procedure was not mentioned in the patent and any attempt to find the proper temperature and pressure for such a reaction would constitute a thesis in itself.

After due consideration of these methods of preparation for the secondary amines it was decided that the scope of this work must be limited to a certain extent. Therefore, the laboratory work which will follow will be confined to a few preparations using each of the three first methods which were outlined above.
Description of apparatus

In the preparation of dibutylcyanamide, diethylcyanamide, and dibenzylicyanamide, a three-necked three liter Wolf flask was used as the reaction flask. This flask was fitted with a mechanical stirrer with a mercury seal. The other two necks on the flask were fitted with a thermometer, and a 500 milliliter separatory funnel. The temperature of the reaction during the time when the crude calcium cyanamide and sodium hydroxide were reacting was controlled by using a large pail. Cold water was kept continually running into the pail by means of a rubber tubing connected to a water outlet. Water was also discharged into the pail by means of a rubber tubing employed as a siphon.

When the reaction mixture had to be refluxed, the thermometer was replaced by a reflux condenser. After the refluxing was completed the reflux condenser was worked into the Wolf flask so as to permit downward distillation of the solvent, ethyl alcohol.

A vacuum distillation apparatus was employed to distill the dialkylcyanamides. This setup consisted of a 150 milliliter Claisen flask which was immersed in an oil bath of Crioce. A capillary tube was fitted with a rubber stopper and placed into one neck of the Claisen flask to prevent bumping and a thermometer tightly fitted with another rubber stopper was placed into the neck of the flask which contains the side arm. The distillation temperature was recorded by
Description of Apparatus

In the preparation of dibutylcyanamide, diamylcyanamide, and dihexylcyanamide a three-necked three liter Wolf flask was used as the reaction flask. This flask was fitted with a mechanical stirrer with a mercury seal. The other two necks on the flask were fitted with a thermometer, and a 300 milliliter separatory funnel. The temperature of the reaction during the time when the crude calcium cyanamide and sodium hydroxide were reacting was controlled by using a large pail. Cold water was kept continually running into the pail by means of a rubber tubing connected to a water outlet. Water was also discharged from this cold bath by means of a rubber tubing employed as a siphon.

When the reaction mixture had to be refluxed, the thermometer was replaced by a reflux condenser. After the refluxing was completed the reflux condenser was corked into the Wolf flask so as to permit downward distillation of the solvent, ethyl alcohol.

A vacuum distillation apparatus was employed to distill the dialkylcyanamides. This setup consisted of a 250 milliliter Claisen flask which was immersed in an oil bath of Crisco. A capillary tube was fitted with a rubber stopper and placed into one neck of the Claisen flask to prevent bumping and a thermometer tightly fitted with another rubber stopper was placed into the neck of the flask which contains the side arm. The distillation temperature was recorded by
means of this thermometer. The receiver employed was a conventional 250 milliliter distillation flask. Thick walled rubber suction tubing was fitted over the side arm of the receiver. This rubber suction tubing was then hooked to a suction flask which was employed as a water trap. Two more rubber suction tubings were connected to the water trap. These led respectively to a conventional laboratory aspirator pump and to a mercury manometer calibrated in millimeters of mercury.

Cold water was allowed to run over the bulb of the receiver flask. Two valves were used on the system. One was fitted on the trap and the other on the top of the capillary tube on the Claisen flask. Hofmann clamps were used to control the air inlet into these valves. All rubber stoppers were fitted to minimize air leakage. An alcoholic solution of collodion was used to coat the stoppers if leaks were found.

The apparatus for the vapor phase catalytic reaction between an alcohol and a primary amine was quite complicated. Since these reactions were performed at 300-350 degrees Centigrade, an apparatus had to be improvised in which a high temperature reaction could be performed.

A piece of pyrex glass tubing approximately a yard long and one-half inch in diameter was bent into a "U" shape. This tubing was then immersed in a sand bath, and approximately three inches of rock wool were placed on top of the sand to prevent rapid evolution of heat from the hot bath.
The catalyst, aluminum oxide, was placed inside the "U" tube and the vapors of the organic reactants were passed over the alumina when the sand reached a temperature of 320 degrees Centigrade. A regular distillation flask was used as a receiver and a continual stream of cold water was run over the bulb of this flask in order to condense the distillate. A condenser was stoppered on to the side arm of the receiver. This condenser was clamped in a vertical position. This had a two-fold purpose. It prevented escape of gaseous distillate which had failed or condense in the receiver and it provided an opening to the atmosphere and thereby prevented a closed system. Two blast lamps were used as the source of heat for this reaction.

A Typical Experiment

The first reaction which was attempted in the laboratory was the preparation of dibutylcyanamide. The dibutylcyanamide was then subjected to acid hydrolysis and the free amine, dibutylamine, was then liberated after adding a suitable amount of sodium hydroxide and distilling. The detailed procedure for the preparation of dibutylcyanamide and the hydrolysis of this compound to dibutylamine is as follows: (24)

flask, is fitted with a reflux condenser and a stirrer with a mercury seal. To this is added 666 cc. of cold water and 133 grams of cracked ice. Then 200 grams of lime nitrogen is slowly added while the mixture is stirred. As soon as the solid is thoroughly suspended, a cold solution of 111 grams of sodium hydroxide in 200 cc. of water is added and brisk stirring is continued for one hour. If the temperature goes above 25 degrees Centigrade at this time a little more ice should be added.

After one hour, 433 grams of n-butyl bromide and 666 cc. of 95% alcohol are added. While the mixture is stirred it is heated on a water bath until it refluxes gently and the refluxing and stirring are continued for two and one-half hours. At the end of this time the reflux condenser is replaced by one which will permit the alcohol to distill. After about 500 cc. of liquid has been collected (stirring should continue during the distillation), the reaction mixture is cooled to room temperature.

Butyl bromide is recovered from the distillate by adding 670 cc. of cold water and enough hydrochloric acid to make the water layer acid to litmus. The butyl bromide layer is then washed with concentrated sulfuric acid to remove traces of alcohol, then with water and is finally dried and distilled. About 85 grams of butyl bromide is recovered.

The cold reaction mixture is filtered with suction and the residue washed with alcohol. The filtrate, which is in two layers, is extracted twice with benzene, first using 270 cc. and then 130 cc. The benzene is distilled from the com-
bined extracts at atmospheric pressure and the dibutylcyanamide is then distilled in vacuo. About 100 grams of product boiling at 147-151 under a pressure of 35 millimeters of mercury or 137-191 at 190 millimeters of mercury is obtained. This corresponds to a yield of 52% based on the amount of butyl bromide used.

Di-n-butyl cyanamide is a clear, slightly viscous liquid, insoluble in water, but soluble in alcohol, benzene and usual organic solvents. It is readily hydrolyzed by boiling with dilute mineral acids and alkalies.

The Preparation of Dibutylamine

To solution of 100 grams of concentrated sulfuric acid in 300 cc. of water is added 100 grams of di-n-butylcyanamide and the mixture is refluxed for six hours. A homogeneous solution results. It is cooled and a cold solution of 156 grams of sodium hydroxide in 285 cc. of water is added. A condenser is attached and the amine which separates is distilled, together with some water. Distillation is continued until no amine separates from a test portion of the distillate. The amount of water in the distillate is estimated and about one-half of this amount of solid potassium hydroxide is added. The solution should be kept cool while this is dissolving. Ammonia gas is evolved. The amine is separated, dried, for several hours over solid sodium hydroxide and distilled. About 62 grams of di-n-butylamine, boiling at 157-160 degrees Centigrade is obtained, accompanied by only a very small amount of low and high boiling material. This corresponds to a yield of 75%.
Chemical Equations

a) \( CaNCN + 2NaOH \rightarrow Na_2NCN + Ca(OH)_2 \)
   disodium cyanamide

b) \( Na_2NCN + 2C_4H_9Br \rightarrow 2NaBr + C_4H_9-N-C_4H_9 \)
   butyl bromide

c) \( C_4H_9-N-C_4H_9 + 2H_2SO_4 + 2H_2O \rightarrow C_4H_9-N-C_4H_9 \cdot CO_2 \cdot NH_4HSO_4 \)

The Preparation of Dibutylamine

Equimolar quantities of n-butyl and dibutyl alcohol were added to an equal volume of conc. \( 32\% \) sulfuric acid in a 30 milliliter glass-stoppered flask. The flask was connected to a long pyrex \( "\) shaped tube. Five grams of aluminum oxide was placed inside the tubing and then the entire tube was immersed in a sand bath. A receiver was connected to the other end of the tubing. The sand bath was then heated to 320 degrees Centigrade by using a water bath.

Before proceeding further, it must be noted at this point that all reacting quantities are in terms of 100% pure product.

As a result of correspondence with the American Cyanamid Company, it was discovered that the crude lime nitrogen used in this preparation was 55% pure. Therefore 200 grams of the crude lime nitrogen were used in the reaction. Fifty-five percent of this 200 grams (or 110 grams) can then be expressed as 100% calcium cyanamide.

Since the author of this experimental procedure expresses the possibility that other longer chain secondary amines...
might possibly be prepared by this general method, I have at­
ttempted to prepare diamylamine and dihexylamine by proceed­
ing through the intermediate products diamylcyanamide and di­
hexylcyanamide respectively.

I also investigated a different method of preparing long
chain secondary amines. The process is catalytic and was
described in my introduction as a method of preparation for
mixed secondary amines. (15) A typical experiment of this
type can be simply described as follows:

The Preparation of Dibutylamine

Equimolar quantities of n-butyl amine and n-butyl alco­
hol were placed in a 250 milliliter distilling flask. This
flask was connected to a long pyrex "U" shaped glass tubing.
Five grams of aluminum oxide was placed inside the tubing
and then the entire tube was immersed in a sand bath. A re­
ceiver was connected to the other end of the "U" tube. The
sand bath was then heated to 320 degrees Centigrade by using
two blast lamps. After the bath, containing the "U" tube,
had attained this high temperature, the mixture of n-butyl
amine and n-butyl alcohol was steadily distilled from the
250 milliliter distilling flask. The vapors passed over the
hot aluminum oxide in the "U" tube and were condensed in the
water cooled receiver. After the mixture had been entirely
distilled, the product in the receiver was subjected to frac­
tional distillation in order to separate the dibutylamine

(15) Sabatier, Paul, Catalysis in Organic Chemistry, New York,
from any unreacted alcohol or primary amine. The distillate obtained was dried by direct contact with solid sodium hydroxide and was distilled from a conventional distillation flask.

Three preparations were attempted, namely (1) amyl-butyl amine, (2) dibutylamine, and (3) secondary amyl-butylamine.

Chemical Equations

a) \(2\text{C}_4\text{H}_9\text{OH} + \text{Al}_2\text{O}_3 \rightarrow \text{Al}_2\text{O}_2(\text{O-C}_4\text{H}_9)_2 + \text{H}_2\text{O}\)

b) \(\text{Al}_2\text{O}_2(\text{O-C}_4\text{H}_9)_2 + 2\text{C}_4\text{H}_9\text{NH}_2 \rightarrow 2\text{C}_4\text{H}_9\text{N-C}_4\text{H}_9 + \text{H}_2\text{O} + \text{Al}_2\text{O}_3\)

aluminate addition dibutylamine product of butyl alcohol
III. EXPERIMENTAL DATA AND RESULTS

<table>
<thead>
<tr>
<th>Substance</th>
<th>Molecular Weight</th>
<th>Grams</th>
<th>Moles</th>
<th>Molar Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca(NH)CN</td>
<td>60.11</td>
<td>200(55%) → 110</td>
<td>1.38</td>
<td>1.38</td>
</tr>
<tr>
<td>NaOH</td>
<td>39.00</td>
<td>100</td>
<td>3.48</td>
<td>1.24</td>
</tr>
<tr>
<td>C₂H₅Br</td>
<td>137.03</td>
<td>256</td>
<td>1.89</td>
<td>0.94</td>
</tr>
<tr>
<td>C₂H₅OH</td>
<td>46.07</td>
<td>252.7(92.9%) or 242.8</td>
<td>5.27</td>
<td>---</td>
</tr>
</tbody>
</table>

Butyl bromide is the limiting reagent in this reaction.

Therefore the theoretical yield was calculated as follows:

\[ \frac{x}{154.23} \times (1 + 144.9) \]

Grains of butyl bromide 
Moles of butyl bromide

Grains expected
Moles of dibutylcyanamide

Practical Yield (as stated in the procedure followed):
32% 75.6 grams

Actual Yield (obtained in the laboratory reaction):
28.6 grams

Percentage Yield:
\[ \frac{28.6}{144.9} \times 100\% = 19.74\% \]

Side Reactions

It must be borne in mind in this experiment that an excess of calcium cyanamide must be used in the inorganic reaction (a). If an excess of NaOH is used it will react with
Table I

The Preparation of Dibutylcyanamide

Tabulation of Reacting Quantities

<table>
<thead>
<tr>
<th>Substance</th>
<th>Molecular Weight</th>
<th>Grams Used</th>
<th>Moles Used</th>
<th>Molar Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaNCN</td>
<td>80.11</td>
<td>200 (55%)</td>
<td>1.38</td>
<td>1.38</td>
</tr>
<tr>
<td>NaOH</td>
<td>40.00</td>
<td>109</td>
<td>2.48</td>
<td>1.24</td>
</tr>
<tr>
<td>C₄H₉Br</td>
<td>137.03</td>
<td>258</td>
<td>1.88</td>
<td>0.94</td>
</tr>
<tr>
<td>C₂H₅OH</td>
<td>46.07</td>
<td>262.7 (92.5%) or 248.9</td>
<td>5.27</td>
<td>----</td>
</tr>
</tbody>
</table>

Butyl bromide is the limiting reagent in this reaction. Therefore the theoretical yield was calculated as follows:

\[
\frac{258}{274} \times \frac{x}{154.25} = \frac{144.9}{x}
\]

Grams of butyl bromide
2 (Molecular wgt. C₄H₉Br)

grams expected
Mol. wgt. dibutylcyanamide

Practical Yield (as stated in the procedure followed):

52% 75.4 grams

Actual Yield (obtained in the laboratory reaction):

28.6 grams

Percentage Yield:

28.6
144.9

100%

19.74%

Side Reactions

It must be borne in mind in this experiment that an excess of calcium cyanamide must be used in the inorganic reaction (a). If an excess of NaOH is used it will react with
the butyl bromide, when it is added, according to the following equation:

\[ C_4H_9Br + NaOH \rightarrow NaBr + C_4H_9OH \]

The dibutylcyanamide obtained by reaction (c) was isolated. It is distilled in vacuo with a boiling range of 145-150 degrees Centigrade at 35 millimeters of mercury. This product was then subjected to acid hydrolysis according to equations (a), (d), and (e).

### Tabulation of Reacting Quantities

<table>
<thead>
<tr>
<th>Substance</th>
<th>Molecular Weight</th>
<th>Grams Used</th>
<th>Moles Used</th>
<th>Molar Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>H2SO4</td>
<td>98</td>
<td>40 (98.5%)</td>
<td>0.406</td>
<td>0.194</td>
</tr>
<tr>
<td>N2</td>
<td>14.02</td>
<td>100</td>
<td>7.1</td>
<td>1.77</td>
</tr>
<tr>
<td>di-n-butylcyanamide</td>
<td>154.35</td>
<td>20.6</td>
<td>0.135</td>
<td>0.125</td>
</tr>
<tr>
<td>NaOH</td>
<td>40</td>
<td>30</td>
<td>0.75</td>
<td>0.375</td>
</tr>
</tbody>
</table>

Di-n-butylcyanamide is the limiting reagent in this reaction. The theoretical yield was calculated as follows:

\[
\frac{20.6}{154.35} = \frac{3}{152.35} \quad (x = 23.96 \text{ grams})
\]

### Practical Yield (as stated in the procedure):

78% = 17.98 grams

### Actual Yield (obtained in the laboratory reaction):

15.2 grams

### Percentage Yield:

\[
\frac{15.2}{23.98} \times 100\% = 63.4\%
\]
Table II

The Preparation of Dibutylamine from Dibutylcyanamide

The dibutylcyanamide obtained by reaction (b) was isolated. It is distilled in vacuo with a boiling range of 146-150 degrees Centigrade at 35 millimeters of mercury. This product was then subjected to acid hydrolysis according to equations (c), (d), and (e).

Tabulation of Reacting Quantities

<table>
<thead>
<tr>
<th>Substance</th>
<th>Molecular Weight</th>
<th>Grams Used</th>
<th>Moles Used</th>
<th>Molar Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂SO₄</td>
<td>98</td>
<td>40(95.5%) - 38.2</td>
<td>0.389</td>
<td>0.194</td>
</tr>
<tr>
<td>H₂</td>
<td>18.02</td>
<td>100</td>
<td>5.55</td>
<td>2.77</td>
</tr>
<tr>
<td>di-n-butyl cyanamide</td>
<td>154.25</td>
<td>28.6</td>
<td>0.185</td>
<td>0.185</td>
</tr>
<tr>
<td>NaOH</td>
<td>40</td>
<td>30</td>
<td>0.75</td>
<td>0.375</td>
</tr>
</tbody>
</table>

Di-n-butylcyanamide is the limiting reagent in this reaction. The theoretical yield was calculated as follows:

\[
\frac{28.6}{154.25} = \frac{x}{129.24} \quad (x = 23.95 \text{ grams})
\]

Gms. of dibutylcyanamide \( \div \) Mol.wgt.(dibutylcyanamide) = Grams expected

Mol.wgt.\( \text{dibutylamine} \)

Practical Yield (as stated in the procedure):

75% = 17.96 grams

Actual Yield (obtained in the laboratory reaction):

15.2 grams

Percentage Yield:

\[
\frac{15.2}{23.95} \cdot 100\% = 63.4\%
\]
### Table III

The Preparation of Diamylo cyanamide

Tabulation of Reacting Quantities

<table>
<thead>
<tr>
<th>Substance</th>
<th>Molecular Weight</th>
<th>Grams Used</th>
<th>Moles Used</th>
<th>Molar Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaNCN</td>
<td>80.11</td>
<td>200 (55%) - 110</td>
<td>1.38</td>
<td>1.38</td>
</tr>
<tr>
<td>NaOH</td>
<td>40.00</td>
<td>95</td>
<td>2.37</td>
<td>1.18</td>
</tr>
<tr>
<td>C₅H₁₁Br</td>
<td>151.05</td>
<td>345</td>
<td>2.28</td>
<td>1.14</td>
</tr>
<tr>
<td>C₂H₅OH</td>
<td>46.07</td>
<td>262.7 (92.5%)</td>
<td>5.27</td>
<td>----</td>
</tr>
</tbody>
</table>

Amyl bromide is the limiting reagent in this reaction.

The theoretical yield was calculated as follows:

\[
\frac{345}{302.10} = \frac{x}{182.25}
\]

\[
(x = 208)
\]

Grams of amyl bromide = Grams expected

\[
\frac{2 \times \text{Molecular wgt. } C₅H₁₁Br}{\text{Mol. wgt. diamylo cyanamide}}
\]

Actual Yield (obtained in the laboratory reaction):

92.3 grams

Percentage Yield:

\[
\frac{92.3}{208} \times 100\% = 44.3\%
\]
Table IV

The Preparation of Diamylamine from Diamylcyanamide (Solid)

Tabulation of Reacting Quantities

<table>
<thead>
<tr>
<th>Substance</th>
<th>Molecular Weight</th>
<th>Grams Used</th>
<th>Moles Used</th>
<th>Molar Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>di-n-amyl cyanamide</td>
<td>182.25</td>
<td>10</td>
<td>0.055</td>
<td>0.055</td>
</tr>
<tr>
<td>H₂SO₄</td>
<td>98</td>
<td>14 (95.5%)</td>
<td>0.136</td>
<td>0.068</td>
</tr>
<tr>
<td>H₂O</td>
<td>18.02</td>
<td>50</td>
<td>2.77</td>
<td>1.38</td>
</tr>
<tr>
<td>NaOH</td>
<td>40.00</td>
<td>10</td>
<td>0.25</td>
<td>0.125</td>
</tr>
</tbody>
</table>

The limiting reagent for this reaction was diamylcyanamide. The theoretical yield was calculated as follows:

\[
\frac{10}{182.25} = \frac{x}{157.29} \quad (x = 8.2 \text{ grams})
\]

Actual Yield (obtained in the laboratory reaction):

no product
The Preparation of Diamylamine from Diamylocyanamide (Liquid)

Table V

Tabulation of Reacting Quantities

<table>
<thead>
<tr>
<th>Substance</th>
<th>Molecular Weight</th>
<th>Grams Used</th>
<th>Moles Used</th>
<th>Molar Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>di-n-amyl cyanamide</td>
<td>210.25</td>
<td>81.7</td>
<td>0.388</td>
<td>0.388</td>
</tr>
<tr>
<td>H₂SO₄</td>
<td>98</td>
<td>146 (95.5%) or 139.43</td>
<td>1.42</td>
<td>0.71</td>
</tr>
<tr>
<td>H₂O</td>
<td>18.02</td>
<td>350</td>
<td>19.42</td>
<td>9.71</td>
</tr>
<tr>
<td>NaOH</td>
<td>40.00</td>
<td>72</td>
<td>1.8</td>
<td>1.4</td>
</tr>
</tbody>
</table>

Diamylocyanamide is the limiting reagent in this reaction.

The theoretical yield was calculated as follows:

\[
\frac{81.7}{210.25} = \frac{x}{157.29} \quad (x = 61.1 \text{ grams})
\]

Actual Yield (obtained in the laboratory reaction):

no product
Table VI

The Preparation of Dihexylo cyanamide

Tabulation of Reacting Quantities

<table>
<thead>
<tr>
<th>Substance</th>
<th>Molecular Weight</th>
<th>Grams Used</th>
<th>Moles Used</th>
<th>Molar Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>n-hexyl bromide</td>
<td>165.08</td>
<td>100</td>
<td>0.606</td>
<td>0.303</td>
</tr>
<tr>
<td>CaNCN</td>
<td>80.11</td>
<td>100 (55%)</td>
<td>0.69</td>
<td>0.69</td>
</tr>
<tr>
<td></td>
<td></td>
<td>or 55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NaOH</td>
<td>40.00</td>
<td>40</td>
<td>1.00</td>
<td>0.50</td>
</tr>
<tr>
<td>C$_2$H$_5$OH</td>
<td>46.07</td>
<td>150 (92.5%)</td>
<td>3.01</td>
<td>----</td>
</tr>
<tr>
<td></td>
<td></td>
<td>or 138.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Hexyl bromide is the limiting reagent in this reaction. The theoretical yield was calculated as follows:

\[
\frac{100}{330.16} = \frac{x}{210.25} \quad (x = 63.7 \text{ grams})
\]

Actual Yield (obtained in the laboratory reaction):

Solid product - 14.6 grams

Percentage Yield:

\[
\frac{14.6}{63.7} \times 100\% = 22.97\%
\]
Table VII

The Preparation of Dihexylamine from Dihexylcyanamide

Tabulation of Reacting Quantities

<table>
<thead>
<tr>
<th>Substance</th>
<th>Molecular Weight</th>
<th>Grams Used</th>
<th>Moles Used</th>
<th>Molar Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>di-n-hexylcyanamide</td>
<td>210.25</td>
<td>13.3</td>
<td>0.0632</td>
<td>0.632</td>
</tr>
<tr>
<td>H₂SO₄</td>
<td>98</td>
<td>15 (95.5%)</td>
<td>0.1461</td>
<td>0.73</td>
</tr>
<tr>
<td></td>
<td></td>
<td>or 14.32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H₂O</td>
<td>18.02</td>
<td>40.0</td>
<td>2.22</td>
<td>1.11</td>
</tr>
<tr>
<td>NaOH</td>
<td>40.0</td>
<td>10.0</td>
<td>0.25</td>
<td>0.125</td>
</tr>
</tbody>
</table>

Dihexylcyanamide is the limiting reagent in this reaction. The theoretical yield was calculated as follows:

\[
\frac{13.3}{210.25} = \frac{x}{185.34} \quad (x = 11.72 \text{ grams})
\]

\[
\frac{\text{Gms. of dihexylcyanamide}}{\text{Mol. wgt. dihexylcyanamide}} = \frac{\text{Grams expected}}{\text{Mol. wgt. dihexylamine}}
\]

Actual Yield (obtained in the laboratory reaction):

no product
Table VIII

The Preparation of Amyl-butylamine

Tabulation of Reacting Quantities

<table>
<thead>
<tr>
<th>Substance</th>
<th>Molecular Weight</th>
<th>Grams Used</th>
<th>Moles Used</th>
<th>Molar Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>n-amyl alcohol</td>
<td>88.15</td>
<td>44</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>n-butyl amine</td>
<td>73.14</td>
<td>36.5</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>101.94</td>
<td>6.0</td>
<td>0.59</td>
<td>----</td>
</tr>
</tbody>
</table>

Theoretically 0.5 mole of amylo-butyl amine was expected from this reaction. However, when the product was fractionally distilled only the original reactants were recovered.
The supposed product was light yellow in color. One-half mole of dibutylamine was expected; but when the product was subjected to fractional distillation, the original reactants were obtained.

The last reaction attempted in the laboratory was the preparation of secondary amyl-butyl amine.
Table X

The Preparation of Secondary Amyl–butyl amine

Tabulation of Reacting Quantities

<table>
<thead>
<tr>
<th>Substance</th>
<th>Molecular Weight</th>
<th>Grams Used</th>
<th>Moles Used</th>
<th>Molar Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>sec. amyl alcohol</td>
<td>86.15</td>
<td>44</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>butyl amine</td>
<td>73.14</td>
<td>36.5</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>101.94</td>
<td>6.0</td>
<td>0.059</td>
<td>----</td>
</tr>
</tbody>
</table>

The products of this reaction also failed to yield the 0.50 moles of secondary expected when subjected to fractional distillation.
The preparation of dibutylcyanamide, and the acid hydrolysis of dibutylcyanamide to dibutylamine were attempted twice. The products were obtained in extremely low yields both times. Therefore, correspondence was undertaken with the American Cyanamid Company in hopes that some information could be obtained whereby the yield could be increased.

The following quotation is taken from a letter received from the New Product Development Department of the American Cyanamid Company:

"Supplementing the information contained in a previous letter to you, I would like to point out that disodium cyanamide is not a stable compound in aqueous solutions. It is quite possible that you may be able to carry out reactions involving the dialkylation of aqueous solutions through the use of two equivalents of sodium hydroxide. This method has been used in a number of alkylation reactions of this type."

IV. DISCUSSION

With this information I decided to attempt the preparation of dimethylcyanamide by placing special emphasis on a low temperature reaction in order to minimize the decomposition rate of disodium cyanamide.

The preparation of dimethylcyanamide proved to be even more perplexing than the preparation of dibutylcyanamide because the reaction yielded about 14 grams of solid material and also approximately 93 grams of a viscous oil. These two materials were separated from each other on a Buchner funnel.

The problem was further complicated by the fact that a description of the physical constants of dimethylcyanamide could not be found in the literature. All of the Decennial Indexes of the Chemical Abstracts make no mention of the compound or
The preparation of dibutylocyanamide, and the acid hydrolysis of dibutylocyanamide to dibutylamine were attempted twice. The products were obtained in extremely low yields both times. Therefore, correspondence was undertaken with the American Cyanamid Company in hopes that some information could be obtained whereby the yield could be increased.

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With this information I decided to attempt the preparation of diamylcyanamide by placing special emphasis on a low temperature reaction in order to minimize the decomposition rate of disodium cyanamide.

The preparation of diamylcyanamide proved to be even more perplexing than the preparation of dibutylocyanamide because the reaction yielded about 14 grams of solid material and also approximately 93 grams of a viscous oil. These two materials were separated from each other on a Buchner funnel.

The problem was further complicated by the fact that a description of the physical constants of diamylcyanamide could not be found in the literature. All of the Decennial Indexes of the Chemical Abstracts make no mention of the compound or
its properties. After separation of the solid material from the viscous organic oil I attempted to find some pertinent information about the physical constants of this oil. A small sample of this oil was distilled to determine how the compound would act if it was distilled at atmospheric pressure. One-half of this sample boiled at 250-260 while the remaining portion of this oil seemed to polymerize into a very viscous substance and did not distill. The distillate which was obtained from this high temperature distillation was yellow in color. The rest of the product (85 gms.) was now subjected to vacuum distillation. The largest percentage of this material distilled in vacuo at 155-159 degrees Centigrade under 38 millimeters of mercury. The distillate from this distillation in vacuo was colorless and oily.

I now attempted to discover some pertinent information about the solid material which had been separated from the oil on the Buchner funnel. The following points which I will enumerate definitely proved that this substance was organic.

1) The solid recrystallized from benzene to form a non-crystalline gelatinous mass.

2) The solid recrystallized from water in a definite crystalline needle formation.

3) The melting point of these crystals was 92-94 degrees Centigrade.

4) The solid was fused with metallic sodium and nitrogen was found to be present.

5) One-tenth gram portions of the solid were found to
be insoluble in three milliliters of water, insoluble in three milliliters of 5% NaOH solution and soluble in three milliliters of 5% HCl solution. According to organic characterization procedures this definitely placed the solid material in Class B.

The attempted conversion of ten grams of this solid crystalline material, which was believed to be diamyloynanamide, to diamyllumine proved a complete failure. After six hours of refluxing in aqueous acidic medium, the sodium hydroxide was added, and a layer of free base which should have been diamyllumine did not form. The only thing which did form was the original solid crystalline material which has been previously shown to be insoluble in alkaline media. I attempted to distill this alkaline hydrolysis mixture, but the substance decomposed and charred in the distillation flask. This naturally resulted in no yield of diamyllumine.

The colorless organic oil which was previously purified by distilling in vacuo under 38 millimeters of pressure and at a temperature of 155-159 degrees Centigrade was now subjected to acid hydrolysis. This colorless oil was refluxed with sulfuric acid and water for over twelve hours. At the end of this time the reaction mixture was not homogenous.

The original colorless oil which was used in this reaction formed an almost black layer after this period of refluxing. Sodium hydroxide was added to this reaction mixture and the whole mixture was steam distilled. No product resulted from this steam distillation after four hours of continuous dis-
tillation. The original oil had changed during acid hydrolysis to a very sticky resinous material.

The preparation of dihexylcyanamide yielded approximately 15 grams of solid material. This solid was recrystallized from water in bright shiny leaflets which melted sharply at 74-75 degrees Centigrade. This product was believed to be dihexylcyanamide but once again no information could be found in the literature which even mentioned this compound. The entire yield was subjected to acid hydrolysis in an attempt to form dihexylamine. The hydrolysis mixture was not homogeneous after six hours of refluxing, and the solid completely separated from the hydrolysis reaction mixture after sodium hydroxide was added. An attempted distillation charred the solid material and no yield of dihexylamine was obtained.

No products were obtained from the high temperature catalytic reactions between an alcohol and a primary amine. The three reactions attempted were the preparation of dibutylamine, amylbutyl amine and secondary amyl-butyl amine. Some of the probable reasons for the failure of these reactions are:

1) The short time of contact of the mixture of vapors with the catalyst.

2) There was no assurance that equimolar quantities of alcohol and primary amine in the vapor state were passing over the catalyst at any given time.

3) The velocity of the mixture of vapors might have been too fast. This effect would limit the time of contact of the reactants with the catalyst.
I have attempted six reactions in this thesis. Three of these six were the preparation of dibutylamine, the preparation of dianylelamine and the preparation of dimethylaniline.

These secondary amines were synthesized by proceeding through the intermediate compounds dibutylcyanamid, dimethylanamine, and dianylecyanamide. The three dialkylenamides were prepared by dialkylating calcium cyanamide. Diethylamine was actually prepared but in very low yields. The preparations of dimethylanine and dimethylanmine failed completely because of the fact that the intermediate compounds, dimethylanamide and dihydrocyanamide, either charred or polymerized to viscous oils when they were subjected to acid hydrolysis.

Dianylecyanamide is believed to be isolated in this thesis. However, even though sharp melting points were obtained on these substances, there still is no actual proof of whether these compounds were actually isolated or whether they were merely products from side reactions due to the fact that a description of both dianylecyanamide and dihydrocyanamide was unobtainable in the literature.

Three other reactions attempted in the laboratory met with failure also. I attempted to synthesize dibutylamine, amyl-butyl amine and secondary amyl-butyl amine by passing a mixture of vapors of an alcohol and a primary amine over alumina at temperatures between 500-550 degrees Centigrade. Fractional distillation of the condensates from this catalytic process failed to yield any secondary amine.

I would like to point out that the dialklylation of cal-
I have attempted six reactions in this thesis. Three of these six were the preparation of dibutylamine, the preparation of diamylamine and the preparation of dihexylamine. These secondary amines were synthesized by proceeding through the intermediate compounds dibutylcyanamide, diamylcyanamide, and dihexylcyanamide. The three dialkylcyanamides were prepared by dialkylating calcium cyanamide. Dibutylamine was actually prepared but in very low yields. The preparations of diamylamine and dihexylamine failed completely because of the fact that the intermediate compounds, diamylcyanamide and dihexylcyanamide, either charred or polymerized to viscous oils when they were subjected to acid hydrolysis.

Diamylcyanamide and dihexylcyanamide were believed to be isolated in this thesis. However, even though sharp melting points were obtained on these substances, there still is no actual proof of whether these compounds were actually isolated or whether they were merely products from side reactions due to the fact that a description of both diamylcyanamide and dihexylcyanamide was unobtainable in the literature.

Three other reactions attempted in the laboratory met with failure also. I attempted to synthesize dibutylamine, amyl-butyl amine and secondary amyl-butyl amine by passing a mixture of vapors of an alcohol and a primary amine over alumina at temperatures between 300-350 degrees Centigrade. Fractional distillation of the condensates from this catalytic process failed to yield any secondary amine.

I would like to point out that the dialkylation of cal-
Calcium cyanamide leads to many difficulties as can be seen from the preparations which I have attempted. All of these syn-
thetis were handicapped due to the instability of disodium cyanamide in aqueous media. The reaction temperature was re-
duced to ten degrees Centigrade during the reaction between calcium cyanamide and the two equivalents of sodium hydroxide in order to increase the stability of the disodium cyanamide which forms. However, the yields of diamylcyanamide and di-
hexylcyanamide were still quite low. These low yields seemed to vindicate the fact that drastic reductions in temperature have only small effects upon the stability of disodium cyan-
amide in aqueous solutions.

Another factor, which is never an ideal situation in synthetic work, and which often times leads to undesirable and unpredictable side reactions, was caused by the impurity of the calcium cyanamide. This starting material was only 55% pure. The impurities present in this material, according to a letter received from the American Cyanamid Company, are calcium carbide and elemental carbon. The presence of calcium carbide in this product was verified in the laboratory due to a vigorous evolution of acetylene gas during the process of suspending the calcium cyanamide in aqueous solution.

Probably the greatest problem encountered in this thesis was the fact that the literature contained no references on both diamylcyanamide and dihexylcyanamide. Therefore there was no way of proving that the solids which were obtained in the laboratory were actually the desired products or whether they resulted from side reactions.
VI. SUGGESTIONS FOR FURTHER STUDY

For any students who desire to continue work on the di-
alkylation of cyanamide I strongly suggest that they corre-
respond with the American Cyanamid Company. More valuable in-
formation can be obtained from this company than from any
other source on the subject.

I would also like to suggest to a prospective thesis
writer on this subject that it is absolutely mandatory that
diiodide cyanamide be prepared under the coldest possible
reaction temperatures. If the reaction is carried out at
20 to 35 degrees Centigrade there will be little or absolute-
ly no yield of the dialkylcyanamide.

VI. SUGGESTIONS FOR FURTHER STUDY

I also suggest that the symmetrical long chain second-
ary aliphatic amines probably can be performed very success-
fully by condensing a primary amine and an aldehyde to form
an aldehyde-imine. The resulting hydrogenation of the alde-
hyde-imine using platinum as a hydrogenation catalyst should
result in good yields of secondary amines. References de-
scribing the synthesis of secondary amines containing 6, 7,
8, and 9 carbon atoms are readily available. Therefore, I
suggest that the possibility of obtaining longer chain amines
by this same method would be a very interesting and worth-
while thesis topic.
For any students who desire to continue work on the dialkylation of cyanamide I strongly suggest that they correspond with the American Cyanamid Company. More valuable information can be obtained from this company than from any other source on the subject.

I would also like to suggest to a prospective thesis writer on this subject that it is absolutely mandatory that disodium cyanamide be prepared under the coldest possible reaction temperatures. If the reaction is carried out at 20 to 25 degrees Centigrade there will be little or absolutely no yield of the dialkylcyanamide.

I also suggest that the synthesis of long chain secondary aliphatic amines probably can be performed very successfully by condensing a primary amine and an aldehyde to form an aldehyde-imine. The resulting hydrogenation of the aldehyde-imine using platinum as a hydrogenation catalyst should result in good yields of secondary amines. References describing the synthesis of secondary amines containing 5, 6, 7, and 8 carbon atoms are readily available. Therefore, I suggest that the possibility of obtaining longer chain amines by this same method would be a very interesting and worthwhile thesis topic.
VII. ANNOTATED BIBLIOGRAPHY


A discussion of a vapor phase reaction between a primary amine and an alcohol is found. The general properties of additives are also described.


A means of preparing secondary amines by using Schiff's bases as intermediates is discussed.


A detailed experimental procedure and a good discussion of unexplained reactions in primary amines is listed.

VII. ANNOTATED BIBLIOGRAPHY


A brief discussion of the history of amines and the various general methods of preparation are listed.


A detailed procedure for the preparation of diallylcyanamide and its acid hydrolysis to diallylamines is given.


A discussion of recent progress in amination by ammoxidation is given.
A discussion of a vapor phase reaction between a primary amine and an alcohol is found. The general properties of additives are also described.

A means of preparing secondary amines by using Schiff's bases as intermediates is discussed.

A detailed experimental procedure and a good discussion of the preparation of unsymmetrical secondary aliphatic amines is listed.

A brief discussion of the history of amines and the various general methods of preparation are listed.

A detailed procedure for the preparation of diallylcyananide and its acid hydrolysis to diallylamine is given.

A discussion of recent progress in amination by ammonolysis is given.

This reference gives a discussion of the preparation of secondary amines by treating alcohols with amines by the use of heat, pressure, and catalysts.

(8) Henry, Compt. rend., 120, 857 (1895).

This is one of the first papers ever published which describes the preparation of aliphatic aldimes.


This work discusses the hydrogenation of aliphatic aldimes to obtain secondary amines.


This patent describes a method for the preparation of long chain and branched chain secondary aliphatic amines by condensation of a ketone with a primary amine and hydrogenation of the ketimine formed to a secondary amine.


A description of a catalytic preparation of secondary amines by passing a mixture of vapors of an alcohol and a primary amine over thoria at elevated temperatures is discussed.


A brief discussion of the disadvantages of the Hofmann degradation reaction are listed.


A brief discussion of the value of additives in lubricating oil is given in this reference.

This book mentions some of the history of the primary, secondary and tertiary amines and also discusses the preparation of secondary amines by the hydrogenation of aldamines.


This reference mentions a catalytic process for preparing secondary amines by passage of a mixture of vapors of an alcohol and amine over either thoria or alumina at high temperatures. A description of laboratory apparatus for this reaction is also mentioned.


Catalytic processes for the preparation of the secondary amines are mentioned.


This work investigates the low pressure catalytic hydrogenation of aldamines using platinum as catalyst and acetic acid as solvent.


The hydrogenation of aldamines in the presence of a nickel catalyst and high pressure is discussed.


The action of amalgamated aluminum, which is a possible condensation catalyst, upon water is given.


A summary of the reactions of aldehydes with amines is discussed.

The reduction of aliphatic aldimines by the use of sodium in alcohol was discussed in this work.

(22) Traube and Engelhardt, *Ber.*, **44**, 3149 (1911).

The preparation of dimethylcyanamide by reacting dimethyl sulfate and crude calcium cyanamide is discussed.


A discussion of the preparation of secondary amines by the high pressure catalytic hydrogenation of amides is discussed. Mention is also made that additions of small amounts of barium oxide induce the formation of secondary amines.


A lengthy discussion and a detailed laboratory procedure for the preparations of dibutylcyanamide and dibutylamine are given.


This textbook mentions the differences in structure of primary, secondary, and tertiary amines.


This article mentions the general preparation of secondary amines by aminolysis reactions between a primary amine and an alkyl halide by the use of high temperatures and pressure.


This article discusses some of the new aliphatic amines which have been prepared.

A method of preparation for dialkylcyanamides is briefly mentioned in which disodium cyanamide reacts with alkyl halides.


This reference gives a method for the hydrogenation of aldehyde-imines to secondary amines using high pressure and a nickel catalyst.
APPROVED

Gloria C. Torok
Major Professor

Date May 24, 1951

John R. Koch
Director, Department of Chemistry

Virgil Roach, S.J.
Dean