The Reaction of Beta-Hydroxy Ketones With Phenyl Magnesium-Bromide Keteneimines.

Mack Castleman Fuqua

Louisiana State University and Agricultural & Mechanical College

Follow this and additional works at: https://digitalcommons.lsu.edu/gradschool_disstheses

Part of the Chemistry Commons

Recommended Citation


https://digitalcommons.lsu.edu/gradschool_disstheses/7866

This Dissertation is brought to you for free and open access by the Graduate School at LSU Digital Commons. It has been accepted for inclusion in LSU Historical Dissertations and Theses by an authorized administrator of LSU Digital Commons. For more information, please contact gradetd@lsu.edu.
MANUSCRIPT THESES

Unpublished theses submitted for the master's and doctor's degrees and deposited in the Louisiana State University Library are available for inspection. Use of any thesis is limited by the rights of the author. Bibliographical references may be noted, but passages may not be copied unless the author has given permission. Credit must be given in subsequent written or published work.

A library which borrows this thesis for use by its clientele is expected to make sure that the borrower is aware of the above restrictions.

LOUISIANA STATE UNIVERSITY LIBRARY
PART ONE

THE REACTION OF BETA-HYDROXY KETONES WITH PHENYL MAGNESIUM BROMIDE

PART TWO

KETENEIMINES

A DISSERTATION

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy

in

The Department of Chemistry

by

Mack Castleman Fuqua
B.A., Mississippi College, 1936
M.S., Louisiana State University, 1940
June, 1943
ACKNOWLEDGMENT
The author wishes to express his appreciation for the advice and guidance of Dr. J. L. E. Erickson, under whose supervision this work was done.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acknowledgment</td>
<td>111</td>
</tr>
<tr>
<td><strong>PART ONE</strong></td>
<td></td>
</tr>
<tr>
<td>Abstract</td>
<td>v</td>
</tr>
<tr>
<td>Review of Literature</td>
<td>2</td>
</tr>
<tr>
<td>Theoretical Discussion</td>
<td>13</td>
</tr>
<tr>
<td>Summary</td>
<td>22</td>
</tr>
<tr>
<td>Experimental</td>
<td>27</td>
</tr>
<tr>
<td>Bibliography</td>
<td>42</td>
</tr>
<tr>
<td><strong>PART TWO</strong></td>
<td></td>
</tr>
<tr>
<td>Abstract</td>
<td>11</td>
</tr>
<tr>
<td>Review of Literature</td>
<td>2</td>
</tr>
<tr>
<td>Theoretical Discussion</td>
<td>11</td>
</tr>
<tr>
<td>Summary</td>
<td>27</td>
</tr>
<tr>
<td>Experimental</td>
<td>29</td>
</tr>
<tr>
<td>Bibliography</td>
<td>45</td>
</tr>
<tr>
<td>Biography</td>
<td>43</td>
</tr>
</tbody>
</table>
PART ONE

THE REACTION OF BETA-HYDROXY KETONES WITH PHENYL MAGNESIUM BROMIDE
ABSTRACT
It has already been shown that beta-diketones, which either do not enolize or are incapable of such behavior, cleave when treated with organic magnesium compounds. The magnesium addition product formed by the reaction of one molecule of phenyl magnesium bromide with a beta-diketone of this type is identical in structure with the magnesium product obtained by interaction of one mole of phenyl magnesium bromide and the corresponding beta-hydroxy ketone.

Since beta-hydroxy ketones are thus one step nearer cleavage than beta-diketones, the following beta-hydroxy ketones were selected for study:

1. Diacetone alcohol
   
   \((\text{CH}_3)_2\text{C(OH)CH}_2\text{COCH}_3\)

2. Hydracetylacetone
   
   \(\text{CH}_3\text{CH(OH)CH}_2\text{COCH}_3\)

3. 9-Hydroxy-9-fluorenyl-gamma-acetophenone
   
   \((\text{C}_6\text{H}_5)_2\text{C(OH)CH}_2\text{COC}_6\text{H}_5\)

4. 1,3-Diphenyl-3-hydroxy-1-butaneone
   
   \(\text{C}_6\text{H}_5(\text{CH}_3)\text{C(OH)CH}_2\text{COC}_6\text{H}_5\)

5. 2,2-Dimethyl-5,5-diphenyl-5-hydroxy-3-pentanone
   
   \((\text{C}_6\text{H}_5)_2\text{C(OH)CH}_2\text{COC}(\text{CH}_3)_3\)

6. 3,3-Dimethyl-9-hydroxy-9-fluorenyl-2-butaneone
   
   \((\text{C}_6\text{H}_4)_2\text{C(OH)CH}_2\text{COC}(\text{CH}_3)_3\)
Diacetone alcohol gave cleavage products and addition products when treated with phenyl magnesium bromide, the amount of each depending upon the method of operation. When diacetone alcohol was added to an excess of the Grignard reagent, the predominating reaction was addition to the carbonyl group, yielding a glycol.

\[
\text{(CH}_3\text{)}_3\text{C-CH}_3\text{-C-CH}_3 \rightarrow \text{(CH}_3\text{)}_3\text{C-CH}_2\text{-C-CH}_3\text{-CCH}_3\text{(C}_6\text{H}_5\text{)}_2 \rightarrow
\text{OMgBr} \quad \text{OMgBr}
\]

However, when the Grignard reagent was slowly added to diacetone alcohol, cleavage resulted, yielding acetone as a primary cleavage product.

\[
\text{(CH}_3\text{)}_3\text{C-CH}_3\text{-C-CH}_3 \rightarrow \text{(CH}_3\text{)}_3\text{C-CH}_2\text{CCH}_3 \rightarrow \text{CH}_3\text{C-CH}_2\text{CCH}_3 \rightarrow \text{CH}_3\text{C-CH}_2\text{CCH}_3
\]

The acetone formed reacted with another molecule of phenyl magnesium bromide to form dimethylphenyl carbinol.

Hydracetylacetone yielded only the glycol when treated with phenyl magnesium bromide.

The beta-hydroxy ketone, 9-hydroxy-9-fluorenyl-gamma-acetophenone, gave both addition to the carbonyl group and cleavage. When the compound was added slowly to an excess of phenyl magnesium bromide, the glycol was the chief product.

\[
\text{(C}_6\text{H}_4\text{)}_2\text{C-CH}_2\text{CCH}_3 \rightarrow \text{(C}_6\text{H}_4\text{)}_2\text{C-CH}_2\text{CCH}_3 \rightarrow \text{(C}_6\text{H}_5\text{)}_2 \rightarrow
\text{OMgBr} \quad \text{OMgBr}
\]

\[
\text{(C}_6\text{H}_4\text{)}_2\text{C-CH}_2\text{CCH}_3 \rightarrow \text{(C}_6\text{H}_5\text{)}_2 \rightarrow
\text{OMgBr} \quad \text{OMgBr}
\]

\[
\text{(C}_6\text{H}_4\text{)}_2\text{C-CH}_2\text{CCH}_3 \rightarrow \text{(C}_6\text{H}_5\text{)}_2
\]
However, when the Grignard reagent was added slowly to the beta-hydroxy ketone, cleavage occurred, yielding acetophenone and fluorenone.

\[
\text{(C}_6\text{H}_5\text{)}_2\text{C} = \text{CH}_2\text{CC}_6\text{H}_5 \rightarrow \text{(C}_6\text{H}_5\text{)}_3\text{C} \text{C}_6\text{H}_5
\]

\[
\text{(C}_6\text{H}_5\text{)}_2\text{CO} + \text{CH}_2 = \text{C} \text{C}_6\text{H}_5 \rightarrow \text{CH}_3\text{COCC}_6\text{H}_5
\]

The compound, 1,3-diphenyl-3-hydroxy-1-butanone, gave only the products of cleavage when phenyl magnesium bromide was added slowly to the beta-hydroxy ketone.

\[
\text{CH}_3\text{C} = \text{C} \text{C}_6\text{H}_5 + \text{C}_6\text{H}_5\text{MgBr} \rightarrow \text{CH}_3\text{C} \text{C}_6\text{H}_5
\]

\[
\text{CH}_2 = \text{C} \text{C}_6\text{H}_5 + \text{CH}_3\text{CC}_6\text{H}_5 \rightarrow (\text{C}_6\text{H}_5)_2\text{C} = \text{CH}_3
\]

If the beta-hydroxy ketone is slowly added to an excess of phenyl magnesium bromide, both the cleavage products and the addition products are formed.

\[
\text{CH}_3\text{C} = \text{C} \text{C}_6\text{H}_5 + \text{C}_6\text{H}_5\text{MgBr} \rightarrow \text{CH}_3\text{C} \text{C}_6\text{H}_5
\]

Only the starting material was recovered from the reaction of phenyl magnesium bromide and 2,2-dimethyl-5,5-diphenyl-5-hydroxy-3-pentanone. An active hydrogen determination showed that the compound reacted in the enolic form.

\[
(\text{C}_6\text{H}_5\text{)}_2\text{C} = \text{CH}_2\text{CC}(\text{CH}_3)_3 \leftrightarrow (\text{C}_6\text{H}_5\text{)}_3\text{C} = \text{CH}_2\text{CC}(\text{CH}_3)_3
\]

\[
(\text{C}_6\text{H}_5\text{)}_2\text{C} = \text{CH}_2\text{CC}(\text{CH}_3)_3 \rightarrow \text{(C}_6\text{H}_5\text{)}_2\text{C} \text{CH} = \text{CC}(\text{CH}_3)_3
\]
The action of phenyl magnesium bromide on 3,3-dimethyl-9-hydroxy-9-l-fluorenyl-2-butane gave only the starting material as a product. An active hydrogen determination showed that the compound reacted in the enolic form.

\[
\begin{align*}
(C_6H_5)_2C-CH_2OG(CH_3)_3 & \quad \leftrightarrow \quad (C_6H_5)_2C-CH=O(CH_3)_3 \\
\text{OH} & \quad \text{OH} & \quad \text{OH} & \quad \text{OH}
\end{align*}
\]

\[
(C_6H_5)_2C-CH=CG(CH_3)_3 \quad \rightarrow \quad (C_6H_5)_2C-CH=CC(CH_3)_3 \\
\text{OH} & \quad \text{OH} & \quad \text{OH} & \quad \text{OH}
\]

\[
(C_6H_5)_2C-CH_2CC(CH_3)_3 \\
\text{OH} & \quad \text{O}
\]
REVIEW OF LITERATURE
I. THE ALPHA-OXIDO KETONES

The first detailed study of cleavage by organic magnesium compounds was made by Kohler, Richtmyer, and Hester. They studied the action of the Grignard reagent on alpha-oxide ketones and glycidic esters. In each case, cleavage of the molecule was observed.

Benzalacetophenone oxide, $\text{C}_6\text{H}_5\text{CH}^-\text{CHCOC}_6\text{H}_5$, was treated with phenyl magnesium bromide and triphenyl carbinol and a resin were formed. Ethyl magnesium bromide also gave cleavage products.

Primary cleavage products were obtained by treating the oxide of benzalacetone with mesityl magnesium bromide.

\[
\text{C}_6\text{H}_5\text{CH}^-\text{CHCOC}_6\text{H}_5 + (\text{CH}_3)_3\text{C}_6\text{H}_5\text{MgBr} \rightarrow \\
(\text{C}_6\text{H}_5\text{C}_6\text{H}_5\text{O})\text{MgBr} + \text{CH}_3\text{CCC}_6\text{H}_5(\text{CH}_3)_3
\]

The acetomesitylene formed did not react with more Grignard reagent because of steric hindrance. The second cleavage product of this reaction was not identified, but the nature of this compound was obtained by using the oxido ketone, $(\text{C}_6\text{H}_5)_2\text{C}^-\text{CHCOC}_6\text{H}_5$. This compound gave well defined products when treated with phenyl magnesium bromide. The products of the reaction were triphenylcarbinol and diphenylacetaldehyde.

One glycidic ester, $(\text{CH}_3)_3\text{C}^-\text{CHCO}_2\text{C}_6\text{H}_5$, was treated with phenyl magnesium bromide and the molecule cleaved as expected.
Only one cleavage product, triphenylcarbinol, was obtained. The action of the Grignard reagent upon this type compound is represented as follows:

\[
(C_6H_5)_2C=CHCOC_6H_5 \ + \ RMgX \rightarrow (C_6H_5)_2C=CH(OMgX) \ + \ RCOC_6H_5
\]

\[
C_6H_5CH=CHCOC_6H_5 \ + \ RMgX \rightarrow [C_6H_5CH=CHOMgX]_n \ + \ RCOC_6H_5
\]

The fact was also established in the same paper that cleavage involved the spontaneous decomposition of the compound formed by addition of one molecule of the Grignard reagent to the oxido ketone or glycidic ester.

A part of the above work was repeated by Bergmann and Wolff and the work was confirmed, but two other oxido ketones were found which did not cleave. Addition without cleavage was reported on benzal-p-phenylacetophenone oxide, \( C_6H_5CH=CHCOC_6H_4C_6H_5 \), and benzal-p-methoxyacetophenone oxide, \( C_6H_5CH=CHCOC_6H_4OCH_3 \). The reactions were represented as follows:

\[
C_6H_5CH=CHCOC_6H_4C_6H_5 \ + \ C_6H_5MgBr \rightarrow H_2O
\]

\[
C_6H_5CH=CH-C(OH)C_6H_4C_6H_5
\]

II. THE BETA KETONIC ESTERS

Grignard treated acetoacetic ester with methyl magnesium bromide by several different procedures and obtained the starting material in each case. He believed the ester reacted only in the enol form.
In the same investigation ethyl ethylacetooacetate and methyl diethylacetooacetate were treated with methyl magnesium iodide. A part of the starting material was recovered from the reaction with the first compound, indicating reaction in the enol form. From the second compound, some starting material was recovered and some beta-hydroxy ester was formed.

\[
\begin{align*}
\text{CH}_3\text{C-CH-COCH}_3 + \text{CH}_3\text{MgI} & \rightarrow (\text{CH}_3)_2\text{C-CH-COCH}_3 \\
\text{O} & \text{C}_2\text{H}_5 \quad \text{O} & \text{OH} & \text{C}_2\text{H}_5 \quad \text{O}
\end{align*}
\]

If the proportion of the magnesium compound to the ester was three to one and the reaction was warmed for two days, the ester group also reacted to give some glycol. Starting material was also recovered after the period of two days.

Grignard\textsuperscript{1} reported only the starting material from the action of methyl magnesium bromide on ethylacetooacetic acid regardless of the procedure used.

Methyl acetylpyrotartrate, \(\text{CH}_3\text{C-CH(COCH}_3\text{CH}_3\text{CHCOCH}_3\)

was treated with phenyl magnesium bromide and also isobutyl magnesium bromide by Barbier and Locquin\textsuperscript{3}. The mono-hydroxy compound was formed in each case, leaving the ester groups unattacked. In a more recent paper\textsuperscript{4} they described the action of the Grignard reagent on acetoacetic ester and its derivatives with subsequent hydrolysis by potassium hydroxide in methyl alcohol. When the reaction product of benzyl magnesium chloride and methyl dimethyooacetooacetate was hydrolyzed in this manner, benzylmethyl ketone was formed.
Dimethylacetacetic ester and dimethyl malonic ester, when treated with methyl magnesium iodide by Slavjanoff, gave the same products in varying proportions. The following products were obtained:

1. Isobutyric acid, \((\text{CH}_3)_2\text{CCH}_2\text{COOH}\)
2. Tetramethylethylene lactic acid,
   \((\text{CH}_3)_2\text{C}(\text{OH})(\text{C}(\text{CH}_3)_2\text{COOH})\)
3. Hexamethyltrimethylene glycol,
   \((\text{CH}_3)_2\text{C}(\text{OH})(\text{C}(\text{CH}_3)_2\text{C}(\text{CH}_3)_2\text{OH})\)

Compounds (2) and (3) resulted from straight addition of the Grignard reagent to the carbonyl and carboxyl groups:

\[
\begin{align*}
\text{CH}_3\text{C}(\text{CH}_3)_2\text{COC}_2\text{H}_5 + \text{CH}_3\text{MgI} &\rightarrow (\text{CH}_3)_2\text{C}-\text{C}(\text{CH}_3)_2\text{C}-\text{OC}_2\text{H}_5
\end{align*}
\]

\[
\begin{align*}
\text{CH}_3\text{C}(\text{CH}_3)_2\text{COC}_2\text{H}_5 + \text{CH}_3\text{MgI} &\rightarrow (\text{CH}_3)_2\text{C}-\text{C}(\text{CH}_3)_2\text{C}(\text{CH}_3)_2
\end{align*}
\]

Slavjanoff suggests no mechanism to account for the formation of isobutyric acid.

Belt found that beta-ketonic esters, that were incapable of enolizing, formed unstable magnesium compounds when treated with phenyl magnesium bromide. Esters that exist in enolic form were not found to undergo cleavage when treated with phenyl magnesium bromide, but a small quantity of the corresponding beta-hydroxy ketone was formed. Ethyl benzoylacetate did not cleave when treated with phenyl magnesium bromide, but a small amount of beta-hydroxy-beta, beta-diphenyl-propiophenone was obtained together with the unchanged ester. The formation of the beta-hydroxy ketone may be explained by the following equation:
When ethyl alpha-benzoyl isobutyrate was treated with phenyl magnesium bromide, a definite cleavage reaction resulted, yielding triphenyl carbinol and isopropyl phenone.

When the compound was added to an excess of reagent and refluxed for fifteen to twenty minutes before hydrolyzing, the cleavage reaction accounted for about 20% of the ester.

When the reaction was run at -15°, no cleavage was obtained, and the ester group was not attacked by the Grignard reagent.

III. THE BETA DIKETONES

Dibenzoyl methane was treated with phenyl magnesium bromide by Vorlander, Osterburg and Meyer and the corresponding hydroxy ketone was formed. The hydroxyketone, (C₆H₅)₂CCH₂CO₆H₅, was treated with phenyl magnesium bromide and no reaction was reported. This same compound was treated with phenyl magnesium bromide by Kohler and Erickson, who
reported that it reacted rapidly to form the corresponding glycol and triphenyl carbinol. The carbinol was a result of cleavage of the molecule.

\[
(C_6H_5)_2C\overset{\text{OH}}{\text{O}}CH_2\overset{\text{O}}{\text{C}}C_6H_5 \rightarrow (C_6H_5)_2C\overset{\text{O}}{\text{C}}CH_2\overset{\text{O}}{\text{C}}C_6H_5
\]

\[
(C_6H_5)_2C=O + \overset{\text{OMgX}}{\text{CH}_3=\text{C}}C_6H_5
\]

The benzophenone formed by cleavage reacted with additional phenyl magnesium bromide to give triphenyl carbinol.

Dimethyldibenzoyl methane was treated with methyl magnesium bromide by Smedley\textsuperscript{88} who reported the formation of a glycol. Kohler and Erickson\textsuperscript{18} later proved this result erroneous. The product analyzed by Smedley evidently was a mixture of cleavage products.

A number of beta diketones were treated with the Grignard reagent by Kohler and Erickson\textsuperscript{18} and in every case cleavage products were obtained, except where the compound treated was largely or entirely enolic.

\[
C_6H_5\overset{\text{O}}{\text{C}}CH_2\overset{\text{O}}{\text{C}}C_6H_5 \rightarrow C_6H_5\overset{\text{OMgX}}{\text{C}}\overset{\text{O}}{\text{C}}CHC_6H_5
\]

\[
C_6H_5\overset{\text{OMgX}}{\text{C}}\overset{\text{OMgX}}{\text{C}}\overset{\text{OH}}{\text{C}}(C_6H_5)_2 \rightarrow C_6H_5\overset{\text{OMgX}}{\text{C}}\overset{\text{OMgX}}{\text{C}}(C_6H_5)_2
\]

Compounds which contained a substituted methylene group were cleaved in every case by the action of a Grignard reagent.

\[
C_6H_5\overset{\text{OMgX}}{\text{C}}\overset{\text{OMgX}}{\text{C}}\overset{\text{OMgX}}{\text{C}}(C_6H_5)_2 \rightarrow C_6H_5\overset{\text{OMgX}}{\text{C}}\overset{\text{OMgX}}{\text{C}}(C_6H_5)_2
\]

\[
C_6H_5\overset{\text{OMgX}}{\text{C}}\overset{\text{OMgX}}{\text{C}}\overset{\text{OMgX}}{\text{C}}(C_6H_5)_2 \rightarrow C_6H_5\overset{\text{OMgX}}{\text{C}}\overset{\text{OMgX}}{\text{C}}(C_6H_5)_2
\]
Compounds which were disubstituted reacted in a similar manner to give the cleavage products.

The following table shows the compounds investigated and the products obtained from them.

<table>
<thead>
<tr>
<th>COMPOUNDS</th>
<th>PRODUCTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. $C_6H_5COCH_2COC_6H_5$</td>
<td>$(C_6H_5)_2C(OR)CH_2COC_6H_5$</td>
</tr>
<tr>
<td>2. $CH_3COCH_2COCH_3$</td>
<td>$(CH_3)_2C(OH)CH_2COCH_3$</td>
</tr>
<tr>
<td>3. $C_6H_5COCH(C_6H_5)COC_6H_5$</td>
<td>$C_6H_5COCH_2C_6H_5 + (C_6H_5)_2COH$</td>
</tr>
<tr>
<td>4. $C_6H_5COCH(CH_3)COC_6H_5$</td>
<td>$C_6H_5COCH_2CH_3 + (C_6H_5)_2COH$</td>
</tr>
<tr>
<td>5. $CH_3CO(CH_3)_2COCH_3$</td>
<td>$CH_3COCH(CH_3)_2 + (C_6H_5)_2CH_2COH$</td>
</tr>
<tr>
<td>5a. &quot;&quot;&quot;&quot;</td>
<td>&quot;&quot;&quot;&quot; + $CH_3COC_6H_2(CH_3)_2$</td>
</tr>
<tr>
<td>6. $C_6H_5COC(CH_3)_2COC_6H_5$</td>
<td>$C_6H_5COC(CH_3)_2 + (C_6H_5)_2COH$</td>
</tr>
<tr>
<td>7. $C_6H_5COC(Br)_2COC_6H_5$</td>
<td>$(C_6H_5)_2COCHBrCOC_6H_5$</td>
</tr>
<tr>
<td>8. $C_6H_5COCOCOC_6H_5$</td>
<td>$C_6H_5COCH(OH)C_6H_5 + (C_6H_5)_2COH$</td>
</tr>
</tbody>
</table>
(a) was run with mesityl magnesium bromide.

Diacetyl, acetylacetone, and acetonylacetone were treated with methyl magnesium bromide by Zelinsky. Acetylacetone yielded a small amount of liquid boiling at 100-2° at 16 mm. The material corresponded to $C_{17}H_{16}O_2$, and the reaction was attributed to the fact that the compound was largely enolic. Only the glycols were obtained from the other two compounds.

Tetramethylcyclobutanone was treated with ethyl magnesium iodide by Wedekind and Miller. This cyclic beta diketone gave the cyclic glycol in an almost quantitative yield.

\[ (CH_3)_2C-C=O + C_8H_5MgI \rightarrow (CH_3)_2C-C(OH)(C_8H_5) \]

\[ C_8H_5(OH)C-C(CH_3)_2 \]
IV. THE BETA HYDROXY ESTERS

Ethyl α-ethyl-β-hydroxy-β-methylbutyrate,
\[(\text{CH}_3)\text{C}(\text{OH})\text{CH} (\text{C}_6\text{H}_5)\text{CO}_2\text{C}_2\text{H}_5\], was treated with methyl magnesium iodide by Grignard\(^\text{**}\). When an excess of the Grignard reagent was used, the product was the glycol, but when one equivalent of the Grignard reagent was used, the starting material was recovered.

Berberianu\(^\text{*}\) obtained the glycol only when he treated
\[\beta\text{-hydroxy-β-phenylhydrocinnamate}, (\text{C}_6\text{H}_5)\text{C} \text{CH}_2\text{CO}_2\text{C}_3\text{H}_5, \text{ with methyl magnesium iodide and ethyl magnesium iodide.}\]

\[(\text{C}_6\text{H}_5)\text{C} (\text{OH})\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5 + \text{CH}_3\text{MgI} \rightarrow (\text{C}_6\text{H}_5)\text{C}(\text{OH})\text{CH}_2\text{C}(\text{OH})(\text{CH}_3)\text{a}\]

In addition to the glycol, a small amount of the dehydration product, \((\text{C}_6\text{H}_5)\text{C} = \text{C}(\text{CH}_3)\text{a}\), was isolated.

V. THE BETA HYDROXY KETONES

Several hydroxy phenyl compounds were treated with the Grignard reagent by Baeyer\(^\text{a}\), and he obtained only the normal addition products. Methyl salicylate gave \(\alpha\)-hydroxytri-phenyl carbinol when treated with phenyl magnesium bromide. Dihydroxybenzophenone gave \(\rho\)-\(\rho\)-dihydroxy triphenyl carbinol when treated with phenyl magnesium bromide.

A number of beta-hydroxy ketones and aldehydes were treated with the Grignard reagent by Franke and Kohn\(^\text{a}\). They reported the corresponding glycol from diacetone alcohol and methyl magnesium iodide.

\[(\text{CH}_3)\text{C} (\text{OH})\text{CH}_2\text{COCH}_3 + \text{CH}_3\text{MgI} \rightarrow (\text{CH}_3)\text{C} (\text{OH})\text{CH}_2\text{C}(\text{CH}_3)\text{a}\]
Aldol reacted in a similar manner with methyl magnesium bromide.

\[ \text{CH}_2\text{CH(OH)CH}_2\text{CHO} + \text{CH}_3\text{MgI} \rightarrow \text{CH}_2\text{CH(OH)CH}_2\text{CH(OH)}\text{CH}_3 \]

When one mole of formaldehyde was treated with two moles of methyl magnesium iodide, the expected glycol was obtained.

\[ \text{HOCH}_2\text{C(CH}_3)_2\text{CHO} + \text{CH}_3\text{MgI} \rightarrow \text{HOCH}_2\text{C(CH}_3)_2\text{CH(OH)}\text{CH}_3 \]

Ethyl magnesium bromide and phenyl magnesium bromide gave similar addition products with this hydroxy-ketone.

Diacetone alcohol was treated with methyl magnesium bromide by Lemaitre and he obtained the corresponding glycol in yields up to 75 per cent.

Ablemann used methyl, ethyl and n-propyl reagents to treat 3-methyl-4-butanol-2-one and obtained the beta-glycols in small yields from each reagent. The small yields were attributed to the formation of polymerization products.

One beta-hydroxy ketone, \( \beta-\beta \)-diphenyl-\( \beta \)-hydroxypropionic-phenone, was treated with phenyl magnesium bromide by Kohler and Erickson. The products showed cleavage to be the predominating reaction, but an appreciable amount of the glycol was also formed.

Diacetone alcohol was treated, by Maitland and Tucker, with 9-fluorenyl magnesium bromide. Four compounds were isolated from the reaction, two of which were identified. 9-Fluorenylmethyl carbinol was isolated and explained as either a cleavage product or the product of the Grignard reagent on acetone contained in the diacetone alcohol as an
impurity. The corresponding glycol was obtained from one reaction in a small yield. Two other substances, C₁₉H₆₈ melting at 80-82°, and C₁₉H₆₈ melting at 58-61° were isolated, but they were not identified.

Sebastain, Sabetay and Bieger found that β-hydroxy-α,α-dimethyl propionaldehyde gave the glycol in 50 per cent yields when treated with Grignard reagents.

\[
\text{HOCH}_2\text{C(CH₃)₂CHO} + \text{1-C₇H₁₈MgBr} \rightarrow \\
\text{HOCH}_2\text{C(CH₃)₂-CH(OH)C₇H₁₈}
\]

Bickel used lithium phenyl to treat (C₆H₅)₂C(OH)CH₂-COC₆H₄OCH₃ and C₆H₅COCH₂C(OH)(C₆H₅)C₆H₄CH₃, and obtained the corresponding glycols in each case.

Jaquemain treated diacetone alcohol with several Grignard reagents and obtained in each case the glycol. The Grignard reagents used contained the groups ethyl, n-propyl, n-butyl, n-amyl, i-propyl, i-hexyl.
It is shown from a survey of the literature that compounds containing certain types of linkages cleave when treated with organic magnesium compounds. These compounds show certain similarities in that they all have a chain of three carbon atoms terminated by an unsaturated group capable of reacting with the Grignard reagent.

\[(R)\text{C=C}=\text{O}\]

alpha-oxido ketones

\[R\]
\[R-C-C-C-OR\]
\[OR\]

beta-ketonic esters

\[R\]
\[R-C-C-C-R\]
\[OR\]

beta-diketones

\[R\]
\[(R)\text{C=C}=\text{C-OR}\]
\[\text{OH}\]

beta-hydroxy esters

The beta-diketones which do not enolize, form an unstable magnesium compound when reacted with one molecule of a Grignard reagent. The result is a cleavage of the molecule.

\[R\text{C=C-C-R + R'MgX \rightarrow R-C-C-C-R \rightarrow R-C-C-C-R}\]
\[\text{OR} \quad \text{OMgX}\]
\[\text{OMgX} + R'-C-R\]

13
Beta-diketones which enolize react with the hydroxyl group of the enol form and the unstable magnesium complex is not formed, therefore, no cleavage occurs.

Beta-hydroxy ketones form magnesium compounds with the Grignard reagents, by reaction of the hydroxyl group with the Grignard reagent, that are identical in structure to the compound formed from a beta-diketone and the Grignard reagent.

\[
\begin{align*}
\text{R}^' \text{C} - \text{C} - \text{C} - \text{R} + \text{R'MgX} & \rightarrow \text{R}^' \text{C} - \text{C} - \text{C} - \text{R}, \quad \text{A} \\
\text{R} - \text{C} - \text{C} - \text{C} - \text{R} + \text{R'MgX} & \rightarrow \text{R}^' \text{C} - \text{C} - \text{C} - \text{R}, \quad \text{B}
\end{align*}
\]

Assuming the behavior of the compound formed by the reaction of beta-diketones and a Grignard reagent to be general, the beta-hydroxy ketones could be expected to behave in a similar manner. The reaction would be represented by the following equation:

\[
\begin{align*}
\text{R}_2\text{CCH}_2\text{CR} + \text{R'MgX} & \rightarrow \text{R}_2\text{C}-\text{CH}_2\text{C}-\text{R} \rightarrow \text{R}_2\text{CO} + \text{CH}_2=\text{C}-\text{R} \\
\text{OH} \quad \text{OH} & \quad \text{OMgX} \quad \text{OMgX}
\end{align*}
\]

The reactions of six beta-hydroxy ketones with phenyl magnesium bromide were investigated.

1. Diacetone alcohol
   \((\text{CH}_3)_2\text{C(OH)CH}_2\text{COCH}_3\)

2. Hydracetylacetone
   \(\text{CH}_3\text{CH(OH)CH}_2\text{COCH}_3\)

3. 9-Hydroxy-9-fluorenyl-gamma-acetophenone
   \((\text{C}_9\text{H}_4)_2\text{C(OH)CH}_2\text{COC}_6\text{H}_5\)
(4) 1,3-Diphenyl-3-hydroxy-1-butanone
\[
\begin{align*}
\text{CH}_3 & \quad \text{C}_6\text{H}_5 \quad \text{C} - \text{CH}_3 - \text{C} - \text{C}_6\text{H}_5 \\
\text{OH} & \quad \text{O}
\end{align*}
\]

(5) 2,2-Dimethyl-5,5-diphenyl-5-hydroxy-3-pentanone
\[
\begin{align*}
(\text{C}_6\text{H}_5)_2\text{C} & (\text{OH}) \text{CH}_3 \text{COC (CH}_3)_3 \\
\text{OH}
\end{align*}
\]

(6) 3,3-Dimethyl-9-hydroxy-9-1-fluorenyl-2-butanone
\[
\begin{align*}
(\text{C}_6\text{H}_4) & \text{C} - \text{CH}_3 \text{COC (CH}_3)_3 \\
\text{OH}
\end{align*}
\]

The products obtained from diacetone alcohol and phenyl magnesium bromide depend to a certain degree upon the method of operation. If diacetone alcohol is added to an excess of phenyl magnesium bromide, the formation of the corresponding glycol is the predominant reaction.
\[
\begin{align*}
(\text{CH}_3)_2\text{C} - \text{CH}_2\text{CCCH}_3 & + 2\text{C}_6\text{H}_5\text{MgBr} \xrightarrow{\text{H}_2\text{O}} (\text{CH}_3)_2\text{C} - \text{CH}_2\text{C} & < \text{C}_6\text{H}_5 \\
\text{OH} & \quad \text{O} & \text{OH} & \quad \text{OH}
\end{align*}
\]

A small amount of dimethylphenyl carbinol is formed as a result of cleavage of the molecule.
\[
\begin{align*}
(\text{CH}_3)_2\text{C} - \text{CH}_2\text{CCH}_3 & + \text{C}_6\text{H}_5\text{MgBr} \rightarrow (\text{CH}_3)_2\text{C} - \text{CH}_2\text{C} & \text{CH}_3
\\
\text{OMgBr} & \quad \text{O}
\end{align*}
\]

\[
(\text{CH}_3)_2\text{C}=\text{O} + \text{CH}_3=\text{C}=\text{CH}_3
\]

The dimethylphenyl carbinol is a result of the acetone formed by cleavage reacting with additional Grignard reagent.

If one mole of phenyl magnesium bromide is slowly added to one mole of diacetone alcohol (inverse addition), cleavage occurs to a greater extent, and the products obtained from the reaction are dimethylphenyl carbinol, starting material and a small amount of glycol. The reason for more cleavage when
operating in this manner may be explained on the basis of no excess Grignard reagent being present at any time. Reaction first occurs with the hydroxyl group forming an unstable compound which may cleave or react with additional phenyl magnesium bromide. Since there is no Grignard reagent present, the cleavage reaction is favored and only small amounts of glycol are formed.

\[
(CH_3)_2C\text{CCH}_2\text{CCH}_3 + C_6H_5\text{MgBr} \rightarrow (CH_3)_2C\text{CCH}_2\text{CCH}_3 + O\text{MgBr} \text{OH}
\]

In order to avoid cleavage if possible, there were reactions carried out at 0°. It was found that reactions carried out at 0° gave the same amount of cleavage as the ones carried out at the boiling point of ether. In order to establish if the time the reaction was permitted to stand before hydrolysis changed the ratio of cleavage to addition products, runs were made at 0° and hydrolyzed just as soon as the reagent had been added. This procedure gave the same amount of cleavage products as the runs that were refluxed from thirty minutes to two hours before hydrolyzing.

Only the glycol and the starting material were recovered from the addition of phenyl magnesium bromide to hydracetyl acetone. Equal moles of the Grignard and hydracetylacetone were used.

\[
\text{CH}_3\text{CCH}_2\text{C} - \text{CH}_3 + C_6H_5\text{MgBr} \rightarrow \text{CH}_3\text{C} - \text{CH}_2\text{C} - \text{CH}_3 + \text{OH} \text{OMgBr} \text{OH}
\]
There seems to be no plausible reason for the difference in the behavior of diacetone alcohol and hydracetyl acetone.

The reaction of phenyl magnesium bromide with 9-hydroxy-9-fluorenyl-gamma-acetophenone gave the expected products, fluorenone and acetophenone. When the beta-hydroxy ketone was added to an excess of the Grignard reagent, the formation of the glycol was the predominant reaction, but when equal moles of the reagent and the beta-hydroxy ketone were used, the addition being made inversely, the cleavage reaction was the predominating one.

\[
(C_6H_4)_2C-CH_2CC_6H_5 + C_6H_5MgBr \rightarrow (C_6H_4)_2CH_2C(C_6H_5)_2
\]

The reason for the cleavage occurring when the reagent is added inversely is because there is never an excess of the Grignard reagent present to react with the carbonyl group of the compound, and consequently, addition to the carbonyl group is largely avoided and the reaction favoring the formation of the unstable compound is promoted. The primary cleavage products were isolated and identified.

The reaction of phenyl magnesium bromide and 1,3-diphenyl-3-hydroxy-1-butanone gave the expected products, acetophenone and diphenyl methyl carbinol. Only the cleavage products were obtained if the Grignard reagent was slowly added to the hydroxyketone.
One half of the molecule was isolated as acetophenone and the other half as the reaction product of acetophenone and phenyl magnesium bromide, diphenylmethyl carbinol.

When the compound was added slowly to an excess of the Grignard reagent, both cleavage and addition to the carbonyl group was obtained. Addition to the carbonyl group is represented as follows:

\[
\begin{align*}
\text{CH}_3 & \geq \text{C} - \text{CH}_2 \text{C}_6\text{H}_5 \quad \text{CH}_2 \geq \text{C} - \text{CH}_2 \text{C}_6\text{H}_5 \\
\text{OMgBr} & \quad \text{OMgBr}
\end{align*}
\]

The reaction of phenyl magnesium bromide and 2,2-dimethyl-5,5-diphenyl-5-hydroxy-3-pentanone did not result in cleavage. Only the starting material was recovered from the reaction. This behavior can be explained on the basis of the compound reacting entirely in the enolic form.

\[
\begin{align*}
\begin{align*}
\text{OMgBr} & \quad \text{OMgBr}
\end{align*}
\end{align*}
\]

An active hydrogen determination showed 1.0 m. mole of the beta-hydroxy ketone to liberate 1.93 m. mole of methane.
The treatment of 3,3-dimethyl-9-hydroxy-9-1-fluorenyl-2-butanone with phenyl magnesium bromide by both direct and inverse procedures gave only the starting material as products.

\[
\begin{align*}
(C_6H_5)_3C-\text{CH}_3\text{CC(CH}_3)_3 & \rightarrow (C_6H_5)_3C=\text{CHCC(CH}_3)_3 \text{OH} \text{ OH} \\
(C_6H_5)_3C=\text{CHCC(CH}_3)_3 & \rightarrow (C_6H_5)_3C-\text{CHC-C(CH}_3)_3 \text{OH} \text{ OH} \text{ OMgBr} \text{ OMgBr}
\end{align*}
\]

Active hydrogen determinations again showed two active hydrogens for each mole of material.

Grignard and Blanchon\cite{15} reported that all ketones capable of enolization existed more or less in that form, and that this enolization was promoted by the Grignard reagent. Kohler and Baltzly\cite{17} made a special study of certain mesitylenic ketones and came to the conclusion that Grignard reagents did not cause the ketone to exist to a larger extent in the enol form, but that if there was enough hindrance next to the carbonyl group to prevent reaction with the Grignard reagent, the compound would react with the hydroxyl group of the enol form and the equilibrium would be shifted toward the enolic form until all the material had reacted in the enolic form. It seems reasonable to believe that in the ketone, 2,2-dimethyl-5,5-diphenyl-5-hydroxy-3-pentanone and 3,3-dimethyl-9-hydroxy-9-1-fluorenyl-2-butanone, the tertiary butyl group would offer enough hindrance to prevent the addition of the Grignard reagent. According to the results of the active hydrogen determination, reaction with the enolic form was the only reaction which occurred.
Of the six compounds studied, three were observed to cleave when treated with phenyl magnesium bromide. The compounds which did cleave were diacetone alcohol, 9-hydroxy-9-fluorenyl-gamma-acetophenone, and 1,3-diphenyl-3-hydroxy-1-butanol. The amount of cleavage in each case was determined to a large degree by the method of operation. Where the hydroxyketone was added to an excess of the Grignard reagent, the corresponding glycol was the predominating reaction. If the Grignard reagent was added to the hydroxyketone, conditions for the cleavage observed were ideal.

Hydracetylacetone was not observed to cleave. There seems to be no apparent reason for its behavior being different from diacetone alcohol.

The two other compounds which did not cleave, 2,2-dimethyl-5,5-diphenyl-5-hydroxy-3-pentanone and 3,3-dimethyl-9-hydroxy-9-1-fluorenyl-2-butanol, were shown to react in the enol form, thereby giving magnesium products which were stable.
Diacetone alcohol and hydracety lacetone were prepared by well known methods. Four other beta-hydroxy ketones, 9-hydroxy-9-fluorenyl-gamma-acetophenone, 1,3-diphenyl-3-hydroxy-1-butanone, 2,2-dimethyl-5,5-diphenyl-5-hydroxy-3-pentanone and 3,3-dimethyl-9-hydroxy-9-1-fluorenyl-2-butanone, were prepared by a method developed by Colon. The reactions of each substance with phenyl magnesium bromide have been studied.

I. Diacetone alcohol underwent both cleavage and normal addition to the carbonyl group when treated with phenyl magnesium bromide. The cleavage products were dimethyl phenyl carbinol and acetone. The addition product was the corresponding glycol.

II. Hydracetylacetone did not undergo cleavage, and gave only the corresponding glycol.

III. Both cleavage and addition resulted from the reaction of phenyl magnesium bromide and 9-hydroxy-9-fluorenyl-gamma-acetophenone. The cleavage products were acetophenone and fluorenone. The addition product was the corresponding glycol.

IV. Cleavage and addition to the carbonyl group resulted from the reaction of phenyl magnesium bromide and 1,3-diphenyl-3-hydroxy-1-butanone. The cleavage product was acetophenone and the addition product the corresponding glycol.

V. Phenyl magnesium bromide reacted with the enol form of 2,2-dimethyl-5,5-diphenyl-5-hydroxy-3-pentanone, and upon
hydrolysis, the starting material was regenerated.

VI. Phenyl magnesium bromide reacted with the enol form of 3,3-dimethyl-9-hydroxy-9-1-fluorenyl-2-butanone. The starting material was recovered in each case.
<table>
<thead>
<tr>
<th>COMPOUND</th>
<th>MOLES</th>
<th>MOLES GRIGNARD</th>
<th>METHOD OF ADDITION</th>
<th>TEMPERATURE</th>
<th>PRODUCTS</th>
<th>PERCENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diacetone alcohol</td>
<td>0.345</td>
<td>0.405</td>
<td>Inverse</td>
<td>35°</td>
<td>Starting material</td>
<td>24.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Dimethyl phenyl carbinoxol</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Glycol</td>
<td>46.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.9</td>
</tr>
<tr>
<td>Diacetone alcohol</td>
<td>0.431</td>
<td>0.451</td>
<td>Inverse</td>
<td>0°</td>
<td>Starting material</td>
<td>33.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Dimethyl phenyl carbinoxol</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Glycol</td>
<td>24.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.3</td>
</tr>
<tr>
<td>Diacetone alcohol*</td>
<td>0.215</td>
<td>0.215</td>
<td>Inverse</td>
<td>0°</td>
<td>Starting material</td>
<td>38.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Dimethyl phenyl carbinoxol</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Glycol</td>
<td>20.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.9</td>
</tr>
<tr>
<td>Diacetone alcohol</td>
<td>0.439</td>
<td>2.195</td>
<td>Direct</td>
<td>35°</td>
<td>Dimethyl phenyl carbinoxol</td>
<td>27.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Glycol</td>
<td>59.3</td>
</tr>
<tr>
<td>Diacetone alcohol</td>
<td>0.161</td>
<td>0.825</td>
<td>Direct</td>
<td>35°</td>
<td>Dimethyl phenyl carbinoxol</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Glycol</td>
<td>70.1</td>
</tr>
</tbody>
</table>

* Reaction mixture was hydrolyzed immediately after reagent had been added.
<table>
<thead>
<tr>
<th>COMPOUND</th>
<th>MOLES</th>
<th>MOLES GRIGNARD</th>
<th>METHOD OF ADDITION</th>
<th>TEMPERATURE</th>
<th>PRODUCTS</th>
<th>PERCENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrazetyl acetone</td>
<td>0.196</td>
<td>0.230</td>
<td>Inverse</td>
<td>35°C</td>
<td>Starting Material, Glycerol</td>
<td>39.4</td>
</tr>
<tr>
<td>9-Hydroxy-9-fluorenyl-gamma-acetophenone</td>
<td>0.033</td>
<td>0.165</td>
<td>Direct</td>
<td>35°C</td>
<td>Acetophenone, Glycerol</td>
<td>1.2</td>
</tr>
<tr>
<td>9-Hydroxy-9-fluorenyl-gamma-acetophenone</td>
<td>0.033</td>
<td>0.039</td>
<td>Inverse</td>
<td>35°C</td>
<td>Starting material, Glycerol, Acetophenone, Fluorenone</td>
<td>34.0, 51.0, 52.1</td>
</tr>
<tr>
<td>1,3-Diphenyl-3-hydroxy-1-butanone</td>
<td>0.042</td>
<td>0.130</td>
<td>Inverse</td>
<td>35°C</td>
<td>Acetophenone, Diphenyl methyl carbinol</td>
<td>29.9, 97.6</td>
</tr>
<tr>
<td>1,3-Diphenyl-3-hydroxy-1-butanone</td>
<td>0.037</td>
<td>0.140</td>
<td>Direct</td>
<td>35°C</td>
<td>Glycerol, Diphenyl methyl carbinol</td>
<td>49.2, 29.4, Trace</td>
</tr>
<tr>
<td>2,2-Dimethyl-5,5-diphenyl-5-hydroxy-3-pentanone</td>
<td>0.0354</td>
<td>0.0461</td>
<td>Inverse</td>
<td>35°C</td>
<td>Starting material</td>
<td>85.0</td>
</tr>
<tr>
<td>2,2-Dimethyl-5,5-diphenyl-5-hydroxy-3-pentanone</td>
<td>0.0354</td>
<td>0.0461</td>
<td>Inverse</td>
<td>60°C</td>
<td>Starting material</td>
<td>60.0</td>
</tr>
<tr>
<td>3,3-Dimethyl-9-hydroxy-9-1-fluorenyl-2-butanone</td>
<td>0.017</td>
<td>0.120</td>
<td>Direct</td>
<td>35°C</td>
<td>Starting material</td>
<td>90.0</td>
</tr>
</tbody>
</table>
EXPERIMENTAL
Preparation of Diacetone Alcohol.- Diacetone alcohol was prepared as described in Organic Syntheses. The acetone, 454 g., was refluxed over barium hydroxide for about 50 hours, and then distilled at approximately 20 mm. pressure. The portion, 276 g., distilling from 74° to 78° was collected and used in the following reactions. Yield, 60.3%.

The diacetone alcohol was redistilled before each reaction.

Preparation of Hydracetylacetone.- A mixture of 210 g. of acetone and 10 g. of KCN, dissolved in 20 cc. of water, was cooled to -5°. To this mixture was added 80 g. of freshly distilled acetaldehyde. After the addition of the acetaldehyde, the reaction mixture was permitted to stand thirty minutes in ice. At the end of the thirty minute period, 150 cc. of alcohol free ether was added to precipitate the KCN. The solution was washed three times with saturated NaCl solution, and then dried over calcium chloride. The excess acetone and ether were distilled off using reduced pressure and the remaining material distilled at 20 mm. pressure. There was 18 g. of material boiling at 80-35° taken at this pressure. There were 20 g. of resinous material formed during the reaction.

The other four compounds were prepared by a method developed by Colonges. The condensing agent is an amino magnesium compound, usually ethyl amino magnesium bromide. This substance is easily made from methyl aniline and ethyl magnesium bromide.
A large number of ketones can be condensed with this reagent to furnish the corresponding beta-hydroxy ketone. Colonge represents the reaction as taking place in two stages: the first step involves addition of the amino magnesium compound to one molecule of the ketone.

\[
\begin{align*}
C_6H_5(CH_3)NH + C_2H_5MgBr & \rightarrow C_6H_5(CH_3)NMgBr \\
R-C-CH_3 + XMgN(CH_3)C_6H_5 & \rightarrow R-C-N(CH_3)C_6H_5
\end{align*}
\]

In the second stage the amine is regenerated by the action of a second molecule of ketone on the magnesium amino complex, and the magnesium derivative of the beta-hydroxy-ketone is obtained.

\[
\begin{align*}
OMgX + R-C-N(CH_3)C_6H_5 & \rightarrow R-C-CH_3 + R-C-C-R + C_6H_5(CH_3)NH
\end{align*}
\]

The compound, \( R-C-CH_3-C-R \), is the magnesium compound of the beta-hydroxy ketone that would be expected to cleave. This probably accounts for the small yields of the beta-hydroxy ketones obtained.

**Preparation of 9-Hydroxy-9-fluorenyl-gamma-acetophenone**

The compound, \( (C_6H_4)_2CO(\text{OH})CH_3COC_6H_5 \), was prepared essentially by the method developed by Colonge. Ethyl magnesium bromide was prepared from 3.0 g. (0.125 moles) of magnesium and 15.8 g. (0.145 moles) of ethyl bromide. To the Grignard reagent was added 15.5 g. (0.145 moles) of methyl aniline, and when the reaction was complete, the mixture was warmed for thirty minutes.
To 100 cc. of benzene, 20 g. (0.111 moles) of fluorenone and 13.4 g. (0.111 moles) of acetophenone was added. The product of the Grignard and the methyl aniline was added slowly to this mixture. After the addition was made, the reaction mixture was gently heated, with stirring, for two and one-half hours. The product was hydrolyzed with ice and 0.125 moles of hydrochloric acid. The product of hydrolysis was extracted with ether and the ether solution was dried over sodium sulfate. The ether and benzene were distilled off using reduced pressure, and the remaining material crystallized from ethyl alcohol and from petroleum ether. There was obtained 25 g. (yield, 66.6%) of the ketone which melted at 110-112°.

Preparation of 1,3-Diphenyl-3-hydroxy-1-butaneone. Phenyl magnesium bromide was prepared from 24.3 g. (1 mole) of magnesium and 125.3 g. (1.15 moles) of ethyl bromide. To this reagent 107 g. (1 mole) of methyl aniline, in ether solution, was slowly dropped. The product of this reaction was filtered through a plug of glass wool into a separatory funnel, and dropped slowly, and with vigorous stirring into a benzene solution containing 180.2 g. (1.5 moles) of acetophenone. The reaction was cooled to prevent excessive overheating. The resulting mixture was permitted to stand for one hour and then treated with ice and dilute HCl. The ether and benzene layers were separated and the ether layer washed with water and dried with sodium sulfate. The ether and benzene were removed under reduced pressure and the remaining
material redissolved in petroleum ether. On cooling, 42 g. (yield, 24.4%) of crystals were obtained, which melted at 60-62°.

**Preparation of 2,2-dimethyl-5,5-diphenyl-5-hydroxy-3-pentanone**. - \( \text{(C}_6\text{H}_5)_2\text{C(OH)CH}_2\text{COO(CH}_3)_2 \) - An ethereal solution of phenyl magnesium bromide was prepared from 4.4 g. (0.18 moles) of magnesium and 21.8 g. (0.20 moles) of ethyl bromide. To this reagent 21.4 g. (0.20 moles) of methyl aniline were slowly added. After addition was complete, the reaction mixture was refluxed for thirty minutes and then added slowly and with rapid stirring to 100 cc. of benzene containing 14.0 g. (0.14 moles) of pinacolone and 25.5 g. (0.14 moles) of benzophenone. It was found advantageous to drop the product of the Grignard and methyl aniline from a separatory funnel into the benzene solution contained in a three-necked flask and to stir with a mechanical stirrer. After the material was all added, the mixture was gently heated for two and one-half hours. The product was hydrolyzed with ice and 15 cc. of hydrochloric acid, and then extracted with ether. The ether was evaporated using reduced pressure, and on addition of petroleum ether to the remaining material, there separated out of the petroleum ether a mass of white crystals. The material was recrystallized from benzene and high boiling petroleum ether, and 22 g. (yield, 59%) of the beta-hydroxy ketone were obtained, which melted at 100-102°. An unsuccessful attempt was made to prepare the semi-carbazone.

Analysis of the material showed:
Calculated for C₁₉H₂₉O₄: C, 80.8; H, 7.8.

Found: C, 80.7; H, 8.0.

**Preparation of 3,3-dimethyl-9-hydroxy-2-fluorenyl-2-butanone** - The condensing agent was prepared from 15.3 g. (0.143 moles) of methyl aniline, 17.5 g. (0.160 moles) of ethyl bromide, and 4.1 g. (0.170 moles) of magnesium. This was added to a solution of 28.8 g. (0.160 moles) of fluorenone in benzene, and 16.0 g. (0.160 moles) of pinacolone was added immediately. The reaction mixture was permitted to stand for twelve hours and then hydrolyzed with ice and dilute hydrochloric acid. The hydrolysis mixture was extracted with ether and the ether solution was dried over anhydrous sodium sulfate. The solvent was evaporated with reduced pressure and the residue crystallized from petroleum ether. There was obtained 14.0 g. (yield, 31%) of the beta-hydroxy ketone which melted at 93-94°.

**Action of Phenyl Magnesium Bromide on Diacetone Alcohol**

**Inverse Addition** - A solution of phenyl magnesium bromide prepared from 9.3 g. (0.405 moles) of magnesium and 66.7 g. (0.425 moles) of bromobenzene was added very slowly, three hours being required for the addition, to 40.0 g. (0.345 moles) of diacetone alcohol dissolved in anhydrous ether. The reaction mixture was not permitted to become warm enough to reflux while the Grignard was being added. After the reagent had been added, the mixture was refluxed vigorously for one hour and permitted to stand overnight. A gray gummy substance separated out of the mixture. The reaction mixture was hydrolyzed with ice.
and NH₄Cl and extracted three times with ether. The ether solution was dried with sodium sulfate, and then distilled using a Widmer column. The material remaining after the ether was removed was distilled using a vacuum pump. Three fractions were taken and then refractionated in order to purify them. The first fraction was identified as diacetone alcohol by adding a drop of KOH solution and condensing the resulting acetone with benzaldehyde. M.p. 109-111°. The second fraction was analyzed for dimethylphenyl carbinol. M.p. 23°.

Calculated for C₉H₁₈O₄: C, 79.3; H, 8.8.
Found: C, 79.8; H, 9.1.

The third fraction, a white crystalline solid, was recrystallized from petroleum ether. The material melted at 50-52°, and was analyzed for the glycol.

Calculated for C₁₈H₁₆O₂: C, 74.2; H, 9.4.
Found: C, 73.8; H, 9.1.

The yields were as follows:

<table>
<thead>
<tr>
<th>Compound</th>
<th>Yield (g)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diacetone Alcohol</td>
<td>9.9 g.</td>
<td>24.9%</td>
</tr>
<tr>
<td>Dimethylphenyl carbinol</td>
<td>23.3 g.</td>
<td>46.8%</td>
</tr>
<tr>
<td>Glycol</td>
<td>2.0 g.</td>
<td>2.9%</td>
</tr>
</tbody>
</table>

**Action of Phenyl Magnesium Bromide on Diacetone Alcohol.**

**Inverse Addition at 0°.**- Diacetone alcohol, 50 g. (0.431 moles), was cooled to 0° in an ice and salt bath and a solution of phenyl magnesium bromide, prepared from 10.4 g. (0.431 moles) of magnesium and 70.8 g. (0.451 moles) of bromobenzene was added very slowly so that the temperature did not rise more
than 5°. When all the reagent had been added, the mixture was refluxed for two hours and then hydrolyzed with ice and NaCl. The product of hydrolysis was extracted with ether and the ether solution dried over sodium sulfate. The ether solution was distilled through a Widmer column in an effort to isolate any acetone present, but no acetone was isolated. The material remaining after the temperature had reached 78° was distilled using a vacuum pump at 2 mm. pressure. The products were:

- Diacetone alcohol 16.5 g. 33.0%
- Dimethylphenyl carbinol 11.8 g. 24.6%
- Glycol 2.7 g. 1.3%

**Action of Phenyl Magnesium Bromide on Diacetone Alcohol.**

**Inverse Addition at 0°.** The diacetone alcohol, 25 g. (0.215 moles), in ether solution was cooled to 0° by using an ice and salt bath, and a phenyl magnesium bromide solution prepared from 5.2 g. (0.215 moles) of magnesium and 35.4 g. (0.225 moles) of bromobenzene was added very slowly. The temperature was not permitted to rise more than 5° at any time during the reaction. The reaction mixture was stirred until the reaction was complete and hydrolyzed immediately with ice and NaCl. The product of hydrolysis was extracted with ether, and the ether solution was dried over sodium sulfate. The ether solution was distilled using a Widmer column until the temperature had risen to 78° and the distillation was completed using a vacuum pump at 2 mm. pressure. The products were as follows:
Diacetone alcohol 9.5 g. 38.0%
Dimethylphenyl carbinol 8.1 g. 20.6%
Glycol 2.0 g. 4.8%

Action of Phenyl Magnesium Bromide on Diacetone Alcohol.

A solution of phenyl magnesium bromide was prepared from 347.7 g. (2.215 moles) of bromobenzene and 52.68 g. (2.195 moles) of magnesium in anhydrous ether. Diacetone alcohol, 51.0 g. (0.439 moles) was added to the reagent drop by drop. After the compound was added, the reaction mixture was refluxed for twenty minutes and allowed to stand overnight. The reaction mixture was hydrolyzed with ice and NH₄Cl and extracted three times with ether. The ether and benzene were distilled using reduced pressure. The recovered distillate was redistilled through a Widmer column in an effort to isolate any acetone present, but no acetone was isolated. The material remaining after the ether and benzene had been removed was distilled at 2 mm. pressure. A total of 97 g. remained after the ether and benzene had been removed and 32 g. of this was taken for distillation at 2 mm. pressure. Three fractions were taken and identified. The first fraction was identified as dimethylphenyl carbinol, the second as diphenyl, and the third as the glycol. The yield was as follows:

Dimethylphenyl carbinol 5.4 g. 27.3%
Glycol 16.7 g. 59.3%

Action of Phenyl Magnesium Bromide on Diacetone Alcohol.

In an effort to isolate acetone from the reaction, another run
was made using the Grignard reagent prepared from 19.56 g. (0.805 moles) of magnesium and 129.5 g. (0.825 moles) of bromobenzene. To this reagent 18.7 g. (0.161 moles) of diacetone alcohol was added and the reaction mixture worked up in the usual way. No acetone was isolated from the reaction. The products were:

Dimethylphenyl carbinol 4.4 g. 4.0%
Glycol 22.6 g. 70.1%

Action of Phenyl Magnesium Bromide on Hydracety lacetone.

Reverse Addition.—To an ethereal solution containing 18 g. (0.196 moles) of hydracety lacetone a solution of phenyl magnesium bromide, prepared from 5.6 g. (0.230 moles) of magnesium and 39.2 g. (0.250 moles) of bromobenzene, was slowly added. After the addition was complete, the reaction mixture was refluxed for one hour and then hydrolyzed with ice and NH₄Cl. The hydrolysis mixture was extracted with ether and the ether solution was dried over calcium chloride. The ether was evaporated using reduced pressure and the remaining material distilled at 4 mm. pressure. Two fractions were taken; the first (b.p. 80-85° at 4 mm. pressure) was identified as the starting material, and the second (b.p. 136-140° at 4 mm. pressure) was analyzed for the glycol.

Calculated for C₁₁H₁₂O₂: C, 73.3; H, 8.9.

Found: C, 73.6; H, 8.9.

The yields were:

Glycol 9.5 g. 26.9%
Starting material 7.1 g. 39.4%
Action of Phenyl Magnesium Bromide on 9-Hydroxy-9-fluorenyl-gamma-acetophenone. - A solution of 9-hydroxy-9-fluorenyl-gamma-acetophenone, 10.0 g. (0.033 moles), was slowly added to phenyl magnesium bromide prepared from 3.9 g. (0.165 moles) of magnesium and 29.0 g. (0.185 moles) of bromobenzene. After the addition of the compound, the reaction mixture was refluxed for thirty minutes and allowed to stand for two hours. The reaction mixture was hydrolyzed with ice and NH₄Cl and then extracted with ether. The ether solution was dried with sodium sulfate and then evaporated using reduced pressure. There was left a viscous oil that refused to crystallize. The oil was subjected to vacuum distillation and 0.5 g. of a substance boiling at 65° at 2 mm. pressure was removed. The small quantity of material was identified as acetophenone by preparing the semi-carbazone. M.p. 201-2°. The remaining material was crystallized from benzene and high boiling petroleum ether, and 11.1 g. of white crystalline solid melting at 94-96° was obtained. The material was analyzed for the glycol.

Calculated for C₉₇H₇₈O₃: C, 85.7; H, 5.8.

Found: C, 85.3; H, 6.1.

The yields were as follows:

Glycol 11.1 g. 89.0%
Acetophenone 0.5 g. 1.2%

Action of Phenyl Magnesium Bromide on 9-Hydroxy-9-fluorenyl-gamma-acetophenone. Inverse Addition. - An ethereal solution of phenyl magnesium bromide prepared from 0.93 g.
(0.039 moles) of magnesium and 9.26 g. (0.059 moles) of bromobenzene were slowly added to 10.0 g. (0.033 moles) of the beta-hydroxy ketone. After addition was complete, the reaction mixture was refluxed for two hours and then hydrolyzed with ice and NH₄Cl. The product of hydrolysis was extracted with ether and the ether solution was dried with sodium sulfate. The ether solution was evaporated using reduced pressure and the remaining material partially distilled at 2 mm. pressure. There was obtained 2.0 g. of material boiling at 65° at this pressure, which was identified as acetophenone by preparing the semi-carbazone. M.p. 201-202°. The residue from the distillation was poured into ethyl alcohol and 3.4 g. of the starting material was recovered. The alcohol was removed using reduced pressure and the remaining material was dissolved in benzene. On addition of petroleum ether 0.3 g. of glycol was obtained. M.p. 95-96°. The material remaining in solution after this crystallization was obtained by evaporating the benzene and petroleum ether and crystallizing it from ethyl alcohol and water. There was obtained 3.1 g. of material, which was identified as fluorenone by preparing the phenylhydrazone. M.p. 150-151°.

The yields were as follows:

<table>
<thead>
<tr>
<th>Material</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting material</td>
<td>3.4 g. 34.0%</td>
</tr>
<tr>
<td>Glycol</td>
<td>0.3 g. 2.4%</td>
</tr>
<tr>
<td>Acetophenone</td>
<td>2.0 g. 51.0%</td>
</tr>
<tr>
<td>Fluorenone</td>
<td>3.1 g. 52.1%</td>
</tr>
</tbody>
</table>
Action of Phenyl Magnesium Bromide on 1,3-Diphenyl-3-hydroxy-1-butaneone. Inverse Addition.—Phenyl magnesium bromide containing 3.0 g. (0.13 moles) of magnesium and 22.0 g. (0.14 moles) of bromobenzene was prepared and slowly added to an ether solution containing 10 g. (0.042 moles) of the compound. The reaction mixture was stirred for one hour after addition was completed, and then hydrolyzed with ice and HCl. The hydrolysis mixture was extracted with ether and the ether layer dried over sodium sulfate. The ether was evaporated and the residue distilled under vacuum, and 1.5 g. (30.0%) of acetophenone was obtained. The acetophenone was identified by preparing the semi-carbazone. M.p. 201°. The material remaining was dissolved in ethyl alcohol, from which 8.3 g. (97.6%) of diphenylmethyl carbinol (m.p. 81°) was obtained. The carbinol was identified by a mixed melting point with an authentic sample, which melted at 81°.

Regular Addition of Phenyl Magnesium Bromide to 1,3-Diphenyl-3-hydroxy-1-butaneone.—Phenyl magnesium bromide was prepared from 3.0 g. (0.125 moles) of magnesium and 22.0 g. (0.140 moles) of bromobenzene and added to an ether solution containing 9 g. (0.0374 moles) of the hydroxy ketone. The reaction mixture was refluxed for one hour and then hydrolyzed with ice and hydrochloric acid. The hydrolysis mixture was extracted with ether, dried over sodium sulfate and evaporated. The products were distilled under vacuum and 0.1 g. of acetophenone was obtained. Upon crystallizing the remaining material from alcohol, 2.2 g. (29.4%) of diphenylmethyl carbinol
and 5.6 g. (49.2%) of the glycol (m.p. 95-96°) were obtained. The glycol was analyzed for \( \text{C}_9\text{H}_{18}\text{O} \). Calculated: C, 82.9; H, 6.9. Found: C, 82.7; H, 7.0.

**Action of Phenyl Magnesium Bromide on 2,2-Dimethyl-5,5-diphenyl-5-hydroxy-3-pentanone.** - Inverse Addition. - Phenyl magnesium bromide prepared from 1.01 g. (0.0460 moles) of magnesium and 6.7 g. (0.0620 moles) of bromobenzene was slowly added to 10.0 g. (0.035 moles) of the beta-hydroxy ketone which was dissolved in ether. The reaction mixture was permitted to stand overnight and then it was refluxed for two hours. After refluxing, it was hydrolyzed with ice and \( \text{NH}_4\text{Cl} \), and then extracted with ether. The ether solution was dried with sodium sulfate after which it was evaporated using reduced pressure. On addition of petroleum ether to the remaining material, there was obtained 85% of the starting material.

A second reaction was carried out using the same amounts of materials and following the same procedure except that benzene was used as the solvent in place of ether. Eighty per cent of the starting material was recovered.

An active hydrogen determination with a Zerewitinoff apparatus gave 1.93 m. mole of methane for each m. mole of compound.

**Action of Phenyl Magnesium Bromide on 3,3-Dimethyl-9-hydroxy-9,1-fluorenyl-2-butane.** Direct Addition. - To phenyl magnesium bromide prepared from 2.9 g. (0.120 moles)
of magnesium and 18 g. (0.116 moles) of bromobenzene, 5 g. (0.017 moles) of the beta-hydroxy ketone was added. No precipitate was observed, but a color change indicated a reaction. The mixture was refluxed for one hour and then hydrolyzed with ice and dilute hydrochloric acid. The hydrolysis mixture was extracted with ether and the ether solution was dried over anhydrous sodium sulfate. Upon evaporation the ether solution, 4.5 g. (90%) of the starting material was recovered.

An active hydrogen determination with a Zerewitinoff apparatus gave 1.78 m. mole of methane for each m. mole of compound.
BIBLIOGRAPHY


26. Vorlander, D., Osterburg, J. and Meyer, O., Beta-phenylbenzylidenacetophenone (Phenyl Diphenylvinyl Ketone) Ber. 56: 1136-44 (1923)
27. Wedekind, E. and Miller, N., A Hydrocarbon of the Cyclobutane Series, Ber. 44: 3285-7 (1911)

PART TWO

KETENHEIKINS
The keteneimines, a class of compounds having a cumulative double linkage characteristic to isocyanates, isothiocyanates, ketenes, and others, has not been investigated with respect to the mode of addition of compounds which ordinarily react with a carbonyl group. The lack of attention this class of compounds has received is probably due to the difficulty with which they are prepared. The purpose of this work was to investigate the mode of reaction of keteneimines with reagents which ordinarily react with the carbonyl group, and to prepare diphenylketene phenylimine by an easier and more direct method.

A new method of preparing diphenylketene phenylimine, based on the removal of HCl from diphenylactanilide-imide chloride by triethyl amine was investigated. The new method was found to be a more direct synthesis of the compound and to give better yields than the previously known method. The preparation consists of the following reactions:

\[
\begin{align*}
2C_6H_5CHO \xrightarrow{KCN} & C_6H_5CH-C-C_6H_5 \quad \text{OH} \\
C_6H_5CH-C-C_6H_5 + & HNO_3 \rightarrow C_6H_5C-C-C_6H_5 + H_2O + NO_2 \quad \text{OH} \\
C_6H_5C-C-C_6H_5 + & KOH \rightarrow (C_6H_5)_2COOK \xrightarrow{HCl} (C_6H_5)_2COOH \quad \text{OH} \\
(C_6H_5)_2COOH + & 2II \rightarrow (C_6H_5)_2CHCOOH + H_2O + I_2 \quad \text{OH} \\
(C_6H_5)_2CHCOOH + & SOCl_2 \rightarrow (C_6H_5)_2CHCOCl + SO_2 + HCl \\
(C_6H_5)_2CHCOCl + & NH_2C_6H_5 \rightarrow (C_6H_5)_2CHC(NHC_6H_5) + HCl \quad \text{OH}
\end{align*}
\]
Phenyl magnesium bromide and phenyl lithium were used to gain some insight as to the mechanism of the addition reactions of diphenylketene phenylimine. The product of the reaction of these reagents with diphenylketene phenylimine was diphenylacetophenone-anil.

The product, diphenylacetophenone-anil, was identified by hydrolysis with hydrochloric acid. This compound, melting at 142°, has not been reported previously.

Evidence to show that lithium phenyl reacted with the C=N linkage of diphenylketene phenylimine was obtained by treating the lithium phenyl addition product with benzoyl chloride.

The product of these reactions was subjected to oxidation with chromic acid and with potassium permanganate. The chromic acid oxidation products were benzoic acid and benzo-
phenone, which indicated the presence of an ethylenic double bond in the compound and thereby addition to the C=N linkage. One product of oxidation with potassium permanganate was benzanilide, which could be obtained only if the lithium phenyl was attached to the nitrogen atom.

Hydrolysis with alcoholic potassium hydroxide gave benzoic acid and diphenylacetophenone-anil as products:

\[
(C_6H_5)_2C=N-C_6H_5 + H_2O \xrightarrow{KOH} (C_6H_5)_2CHC=NC_6H_5
\]

\[
+ C_6H_5COOH
\]

If addition had occurred at the ethylenic linkage, the final product, upon addition of benzoyl chloride, would have been an anil instead of an amide, \((C_6H_5)_2C=NC_6H_5\), and therefore, would have easily hydrolyzed with hot concentrated hydrochloric acid to aniline and dibenzoyldiphenyl methane. The original material was obtained from every attempted hydrolysis with the acid.

A number of attempts to ozonize the compound were made, but in each case the original material was recovered.

The failure of benzoyl chloride addition compound to hydrolyze with hydrochloric acid; its product of oxidation with potassium permanganate, benzanilide; its products of oxidation with chromic acid, benzophenone and benzoic acid; and its alcoholic potassium hydroxide hydrolysis products, benzoic acid and diphenylacetophenone-anil; indicate addition to the C=N linkage. The reaction products of other compounds with the keteneimines may be explained by the same mode of reaction.
REVIEW OF LITERATURE
The keteneimines constitute one of several classes of organic compounds, whose reactions are characterized by a system of twinned or cumulative double bonds.

Keteneimines \((R)_2C=\text{C}=N=\text{R}\)

Ketenes \((R)_2C=\text{C}=O\)

Isocyanates \(\text{R-N}=\text{C}=O\)

Isothiocyanates \(\text{R-N}=\text{C}=S\)

Allenies \((R)_2C=\text{C}=\text{C}=(\text{R})_2\)

The method of preparation and the reactions of ketenes are very similar to those of the keteneimines and have been carefully studied, while the keteneimines have received very little attention.

In 1905, Staudinger\(^{18}\) prepared diphenylketene by withdrawing chlorine from a molecule of diphenylchloroacetyl chloride by means of an active metal.

\[
\begin{align*}
(C_6\text{H}_5)_2\text{C}=\text{C}=\text{O} + \text{Zn} & \rightarrow (C_6\text{H}_5)_2\text{C}=\text{C}=\text{O} + \text{ZnCl}_2 \\
\text{Cl} & \text{Cl}
\end{align*}
\]

Wedekind\(^{18}\) attempted to prepare various ketenes by a method involving the elimination of hydrogen chloride from an acyl chloride by means of a tertiary amine, but was unsuccessful, as only polymers were obtained.

\[
\begin{align*}
(C_6\text{H}_5)_2\text{C}=\text{C}=\text{O} + (\text{R})_3\text{N} & \rightarrow (C_6\text{H}_5)_2\text{C}=\text{C}=\text{O} + (\text{R})_3\text{NHCl} \\
\text{H} & \text{Cl}
\end{align*}
\]

Probably the best known method for preparing diphenylketene is by the decomposition of azibenzi\(^{17}\).
The simplest ketene is ketene itself, $\text{H}_2\text{C} = \text{C} = \text{O}$, and is best prepared by the pyrolysis of acetone.

Staudinger succeeded in preparing diphenylketene by the action of tripropyl amine on diphenylacetyl chloride,

$$\text{(C}_6\text{H}_5\text{)}_2\text{C} = \text{C} = \text{O} + (\text{C}_3\text{H}_7)_3\text{N} \longrightarrow (\text{C}_6\text{H}_5)_2\text{C} = \text{C} = \text{O} + (\text{C}_3\text{H}_7)_3\text{NHCl}$$

He worked with diphenylketene, which is much less reactive and therefore less susceptible to polymerization than the more active ketenes, which Wedekind attempts to prepare.

The keteneimines also were prepared by Staudinger in 1921 for the first time. This new class of compounds was discovered while working with organic compounds of phosphorus. The first keteneimine was prepared in the following manner.

$$3\text{C}_6\text{H}_5\text{MgX} + \text{PCl}_3 \longrightarrow (\text{C}_6\text{H}_5)_3\text{P} + 3\text{MgClX}$$

$$\text{(C}_6\text{H}_5\text{)}_3\text{P} + \text{C}_6\text{H}_5\text{N}_3 \longrightarrow (\text{C}_6\text{H}_5\text{)}_3\text{P=N=N=NC}_6\text{H}_5$$

$$\text{(C}_6\text{H}_5\text{)}_3\text{P=N=N=NC}_6\text{H}_5 \longrightarrow (\text{C}_6\text{H}_5\text{)}_3\text{P=NC}_6\text{H}_5 + \text{N}_2$$

$$\text{(C}_6\text{H}_5\text{)}_3\text{P=NC}_6\text{H}_5 + (\text{C}_6\text{H}_5\text{)}_3\text{C} = \text{C} = \text{O} \longrightarrow (\text{C}_6\text{H}_5\text{)}_3\text{C=NC}_6\text{H}_5 + (\text{C}_6\text{H}_5\text{)}_3\text{PO}$$

It was found that the phosphazide, the reaction product of phenylazide and triphenylphosphine, was unstable and decomposed spontaneously to give nitrogen and triphenylphosphine phenylimine.

The preparation of four other keteneimines was described by Staudinger.

1. Diphenylketene methylimine

$$\text{(C}_6\text{H}_5\text{)}_3\text{C=NC}_6\text{H}_5$$

2. Dimethylketene phenylimine

$$\text{(CH}_3\text{)}_2\text{C=NC}_6\text{H}_5$$

3. Ketene phenylimine

$$\text{H}_2\text{C=NC}_6\text{H}_5$$
4. Diethyl carboxylateketene phenylimine \((C_6H_5O_2)_2C=C=NC_6H_5\)

The reactions involved in the preparation of these compounds are as follows:

**Diphenylketene Methyllumine**.-

\[(C_6H_5)_2P + CH_3N_2 \rightarrow (C_6H_5)_2P=NCCH_3 + N_2\]

\[(C_6H_5)_2P=NCCH_3 + (C_6H_5)_2C=C=O \rightarrow (C_6H_5)_2C=C=NCCH_3 + (C_6H_5)_3PO\]

**Dimethylketene Phenylmimine**.-

\[(C_6H_5)_2P + C_6H_5N_2 \rightarrow (C_6H_5)_2P=NC_6H_5 + N_2\]

\[(C_6H_5)_2P=NC_6H_5 + (CH_3)_2C=C=O \rightarrow (CH_3)_2C=C=NC_6H_5 + (C_6H_5)_3P\]

**Ketene Phenylmimine**.-

\[(C_6H_5)_2P + C_6H_5N_2 \rightarrow (C_6H_5)_2P=NC_6H_5 + N_2\]

\[(C_6H_5)_2P=NC_6H_5 + H_2C=C=O \rightarrow H_2C=C=NC_6H_5 + (C_6H_5)_3P\]

**Diethyl Carboxylateketene Phenylmimine**.-

\[(C_6H_5)_2P + C_6H_5N_2 \rightarrow (C_6H_5)_2P=NC_6H_5 + N_2\]

\[(C_6H_5)_2P=NC_6H_5 + (C_6H_5O_2C)_2C=C=O \rightarrow (C_6H_5O_2C)_2C=C=NC_6H_5 + (C_6H_5)_3PO\]

Page 16 made three unsuccessful attempts to prepare ketenelimines by an easier method. The first attempt may be represented by the following reactions:

\[C_6H_5C=O + NH_2NH_2 \rightarrow C_6H_5C=NNH_2 + H_2O\]

\[C_6H_5C=O + C_6H_5NH_2 \rightarrow C_6H_5C=NNH_2 + H_2O\]

\[C_6H_5C=NNH_2 + C_6H_5NH_2 \rightarrow C_6H_5C=NNH_2 + H_2O\]
\[
\begin{align*}
\text{C}_6\text{H}_5\text{C} &= \text{NNH}_2 \\
\text{C}_6\text{H}_5\text{C} &= \text{NC}_6\text{H}_5 \\
\text{C}_6\text{H}_5\text{C} &= \text{CN}_2 \\
\text{C}_6\text{H}_5\text{C} &= \text{CH}_2
\end{align*}
\]

This method seemed likely since diphenylketene was prepared by similar procedure from azibenzil, however, all attempts to prepare the necessary benzilhydrazone-anil were unsuccessful.

A second attempt to prepare diphenylketene phenylimine involved treating \(\beta,\beta\)-dichlor-\(\alpha,\alpha\)-diphenylethylene with aniline.

\[
\text{(C}_6\text{H}_5\text{)}_2\text{C} = \text{Cl}_2 + \text{NH}_2\text{C}_6\text{H}_5 \rightarrow \text{(C}_6\text{H}_5\text{)}_2\text{C} = \text{CN}_6\text{H}_5 + 2\text{HCl}
\]

Finally, diphenylketene phenylimine was sought by the following synthesis:

\[
\text{C}_6\text{H}_5\text{CCHO} + \text{NH}_2\text{C}_6\text{H}_5 \rightarrow \text{C}_6\text{H}_5\text{CGH} = \text{NC}_6\text{H}_5 + \text{H}_2\text{O}
\]

\[
\text{C}_6\text{H}_5\text{CCH} = \text{NC}_6\text{H}_5 + \text{C}_6\text{H}_5\text{MgBr} \rightarrow \text{H}_2\text{O} \quad \text{(C}_6\text{H}_5\text{)}_2\text{C} = \text{CH} = \text{NC}_6\text{H}_5
\]

\[
\text{(C}_6\text{H}_5\text{)}_2\text{C} = \text{CCH} = \text{NC}_6\text{H}_5 \rightarrow \text{H}_2\text{O} \quad \text{(C}_6\text{H}_5\text{)}_2\text{C} = \text{CN}_6\text{H}_5 + \text{H}_2\text{O}
\]

However, the synthesis of the necessary phenylglyoxal-anil was not successful.

Staudinger tried to prepare diphenylketene phenylimine by a reaction analogous to the preparation of diphenylketene from diphenylchloroacetyl chloride, i.e., by treating chlorodiphenylacetanilide-imide chloride with zinc.
However, the desired product was not obtained.

Some reactions of the ketenes observed by Staudinger are indicated below, but it should be noted that no mechanism is provided for their reactions.

\[
\text{(C}_6\text{H}_5\text{)}_2\text{C} = \text{C} = \text{O} + \text{H}_2\text{O} \longrightarrow \text{(C}_6\text{H}_5\text{)}_2\text{CHCOOH}
\]

\[
\text{(C}_6\text{H}_5\text{)}_2\text{C} = \text{C} = \text{O} + \text{C}_6\text{H}_5\text{OH} \longrightarrow \text{(C}_6\text{H}_5\text{)}_2\text{CHC} = \text{OC}_6\text{H}_5
\]

\[
\text{(C}_6\text{H}_5\text{)}_2\text{C} = \text{C} = \text{O} + \text{NH}_3 \longrightarrow \text{(C}_6\text{H}_5\text{)}_2\text{CHC} = \text{NH}_3
\]

Analogous reactions occur with the keteneimines.

\[
\text{(C}_6\text{H}_5\text{)}_2\text{C} = \text{N} = \text{C}_6\text{H}_5 + \text{H}_2\text{O} \longrightarrow \text{(C}_6\text{H}_5\text{)}_2\text{CHC} = \text{NHC}_6\text{H}_5
\]

\[
\text{(C}_6\text{H}_5\text{)}_2\text{C} = \text{N} = \text{C}_6\text{H}_5 + \text{C}_6\text{H}_5\text{OH} \longrightarrow \text{(C}_6\text{H}_5\text{)}_2\text{CHC} = \text{NOC}_6\text{H}_5
\]

\[
\text{(C}_6\text{H}_5\text{)}_2\text{C} = \text{N} = \text{C}_6\text{H}_5 + \text{NH}_3 \longrightarrow \text{(C}_6\text{H}_5\text{)}_2\text{CHC} = \text{NH}_3
\]

The keteneimines are much less reactive than the ketenes, and Staudinger has described some of them in the following manner.

Diphenylketene methylimine is a yellow oily liquid boiling at 120° under 0.2 mm. pressure. It is very stable to water, alcohol, oxygen and unsaturated compounds. In the presence of hydrochloric acid, it adds water to form diphenylacetomethylamide.

\[
\text{(C}_6\text{H}_5\text{)}_2\text{C} = \text{NCH}_3 + \text{H}_2\text{O} \xrightarrow{\text{HCl}} \text{(C}_6\text{H}_5\text{)}_2\text{CHC} = \text{NCH}_3
\]
Dimethylketene phenylimine is a weakly yellowish green liquid which boils at 98-108° at 12 mm. pressure. It has an unpleasant odor resembling the aliphatic isocyanates. In the presence of hydrochloric acid it reacts with water to form isobutyranilide.

\[ (\text{CH}_3)_2C\equiv C\equiv N\text{C}_6\text{H}_5 + \text{H}_2\text{O} \rightarrow (\text{CH}_3)_2C\text{C}\equiv \text{NHC}_6\text{H}_5 \]

Ketene phenylimine is a colorless mobile liquid which boils at 35° at 1 mm. pressure. It polymerizes rapidly at room temperature and like the other keteneimines reacts with water in the presence of hydrochloric acid to give acetonilide.

\[ \text{H}_2\text{C}=\text{C}=\text{N}\text{C}_6\text{H}_5 + \text{H}_2\text{O} \rightarrow \text{CH}_3\text{C}\equiv \text{NHC}_6\text{H}_5 \]

Diethyl carboxylateketene phenylimine, however, is unstable to water.

\[ (\text{C}_6\text{H}_5\text{O}_2\text{C})_2\text{C}=\text{C}=\text{N}\text{C}_6\text{H}_5 + \text{H}_2\text{O} \rightarrow (\text{C}_6\text{H}_5\text{O}_2\text{C})_2\text{C}\equiv \text{NHC}_6\text{H}_5 \]

Staudinger treated diphenylketene with phenyl magnesium bromide and obtained diphenylacetophenone as a product. He explained the reaction as an addition to the ethylenic linkage.

\[ (\text{C}_6\text{H}_5)\equiv \text{C}=\equiv \text{O} + \text{C}_6\text{H}_5\text{MgBr} \rightarrow (\text{C}_6\text{H}_5)\equiv \text{C} \equiv \text{C}=\equiv \text{O} \]

\[ (\text{C}_6\text{H}_5)\equiv \text{C}=\equiv \text{O} + \text{H}_2\text{O} \rightarrow (\text{C}_6\text{H}_5)\equiv \text{C}=\equiv \text{C} \equiv \text{O} \]

Gilman and Heckert proved the reaction was not an addition to the ethylenic linkage, but rather a reaction with
the carbonyl group. The mode of addition was established by reacting the magnesium addition product with benzoyl chloride.

\[
(C_6H_5)_2C=O + C_6H_5MgBr \rightarrow (C_6H_5)_2C=O\text{OMgBr}
\]

\[
(C_6H_5)_2C=O\text{OMgBr} + C_6H_5COCl \rightarrow (C_6H_5)_2COOC_6H_5 + MgBrCl
\]

If addition to the ethylenic linkage had occurred, the final product would have been diphenyldibenzyl methane.

\[
(C_6H_5)_2C=O + C_6H_5MgBr \rightarrow (C_6H_5)_2C=\text{OCOC}_6H_5
\]

\[
(C_6H_5)_2C=\text{OCOC}_6H_5 + MgBrCl
\]

In reality the product of the reaction was the benzoate of triphenylvinyl alcohol. Gilman and Heckert reasoned from the above reaction that the final product of the reaction between diphenylketene and phenyl magnesium bromide was a secondary product, formed by ketonization of the primary addition product upon hydrolysis.

\[
(C_6H_5)_2C=O + C_6H_5MgBr \rightarrow (C_6H_5)_2C=\text{OCOC}_6H_5
\]

\[
(C_6H_5)_2C=\text{OCOC}_6H_5 + H_2O \rightarrow (C_6H_5)_2C\text{HOC}=O
\]
In a similar manner Gilman and Kinney established the mode of addition to the isocyanates and isothiocyanates. The reagent added in the same way to the carbonyl groups.

\[
\text{C}_6\text{H}_5\text{N}=\text{C}=\text{O} + \text{C}_6\text{H}_5\text{MgBr} \rightarrow \text{C}_6\text{H}_5\text{N}=\text{C}=\text{O}\text{MgBr}
\]

\[
\text{C}_6\text{H}_5\text{N}=\text{C}=\text{S} + \text{C}_6\text{H}_5\text{MgBr} \rightarrow \text{C}_6\text{H}_5\text{N}=\text{C}=\text{SMgBr}
\]

In the latter case the reagent used to establish the position of -MgBr was dimethylsulfate.

\[
\text{C}_6\text{H}_5\text{N}=\text{C}=\text{S}\text{MgBr} + (\text{CH}_3)_2\text{SO}_4 \rightarrow \\
\text{C}_6\text{H}_5\text{N}=\text{C}=\text{SCH}_3 + \text{CH}_3(\text{MgBr})\text{SO}_4
\]

Gilman and Breuberg established the mechanism of addition of lithium phenyl and sodium phenyl to phenylisothiocyanate, using diethyl and dimethyl sulfates as reagents to locate the position of -MgBr. The sodium and lithium phenyl were found to add in the same manner as the Grignard reagent.

No attempt has been recorded in the literature to establish the mechanism of the reaction between the Grignard reagent or lithium phenyl and keteneimines. The establishment of this mechanism should rationalize the manner of addition of all other reagents.
THEORETICAL DISCUSSION
The method of preparation of ketenes by means of an acid chloride and a tertiary base was conceived by Wedekind\(^3\). His attempts to prepare simple ketenes by this method were unsuccessful due to the ease with which they polymerize. Staudinger\(^9\) recognized this and applied this principle to other ketenes, which were less susceptible to polymerization. In this way he prepared diphenylketene from diphenylacetyl chloride and tripropyl amine.

\[
(C_6H_5)_2C=O + (C_3H_7)_3N \rightarrow (C_6H_5)_2C=O + (C_3H_7)_3NHCl
\]

Since diphenylketene may be prepared in an almost quantitative yield according to the above reaction, the preparation of diphenylketene phenylimine by the same method seems feasible. There are other known facts about diphenylketene which indicate that diphenylketene phenylimine can be prepared even more profitably by this method. First, the method of preparation of diphenylketene phenylimine by Staudinger\(^9\) involves a long series of difficult operations, and the overall yield is very small; and second, the reactivity of diphenylketene phenylimine is much less than that of diphenylketene, and therefore, there should be less tendency for the imine compound to polymerize.

The preparation of diphenylketene phenylimine by use of the diphenylketene and triphenylphosphine phenylimine requires the following steps:

1. Preparation of phenyl magnesium bromide

\[
C_6H_5Br + Mg \rightarrow C_6H_5MgBr
\]
(2) Preparation of triphenylphosphine

\[ 3C_6H_5MgBr + PCl_3 \rightarrow (C_6H_5)_3P + MgBrCl \]

(3) Preparation of phenylazide

\[ C_6H_5NH_2NH_2 + HNO_2 \rightarrow C_6H_5N_3 + 2H_2O \]

(4) Preparation of triphenylphosphine phenylimine

\[ (C_6H_5)_3P + C_6H_5N_3 \rightarrow (C_6H_5)_3P = NOC_6H_5 + N_2 \]

(5) Preparation of benzoic acid

\[ 2C_6H_5CH_2CHO \xrightarrow{KCN} C_6H_5CH=CH-C_6H_5 \]

(6) Preparation of benzil

\[ C_6H_5CH=C-C_6H_5 + HNO_2 \rightarrow C_6H_5C=C-C_6H_5 + NO_2 + H_2O \]

(7) Preparation of benzil mono-hydrazone

\[ C_6H_5C=C-C_6H_5 + NH_2NH_2 \rightarrow C_6H_5C=C=N-NH_2 + H_2O \]

(8) Preparation of azibenzil

\[ C_6H_5C=C=N-NH_2 + HgO \rightarrow C_6H_5C=CN_2 + Hg + H_2O \]

(9) Decomposition of azibenzil to diphenylketene

\[ C_6H_5C=CN_2 + \text{Heat} \rightarrow (C_6H_5)_2C=O + N_2 \]

(10) Preparation of diphenylketene phenylimine

\[ (C_6H_5)_2C=O + (C_6H_5)_3PO \rightarrow (C_6H_5)_2C=NOC_6H_5 + (C_6H_5)_3PO \]

The method indicated above for the preparation of diphenylketene phenylimine is an exceedingly laborious process. The preparation by the proposed method, as shown below, offers a less difficult synthesis and one which gives a better overall yield.
(1) Preparation of benzoin by the benzoin condensation

\[ 2C_6H_5CHO \xrightarrow{KCN} C_6H_5CHOHCOC_6H_5 \]

(2) Oxidation of benzoin to benzil

\[ C_6H_5CHOHCOC_6H_5 + HNO_3 \rightarrow C_6H_5COCOC_6H_5 + H_2O + NO_2 \]

(3) Rearrangement of benzil to benzilic acid

\[ C_6H_5COCOC_6H_5 + KOH \rightarrow (C_6H_5)_2COHCOOK \xrightarrow{HCl} (C_6H_5)COHCOOH \]

(4) Reduction of benzilic acid to diphenylacetic acid

\[ (C_6H_5)_2COHCOOH + 2HI \rightarrow (C_6H_5)_2CHCOOH + H_2O + I_2 \]

(5) Preparation of diphenyl acetyl chloride by the action of thionyl chloride on diphenyl acetic acid

\[ (C_6H_5)_2CHCOOH + SOCl_2 \rightarrow (C_6H_5)_2CHCOCl + SO_2 + HCl \]

(6) Preparation of diphenylacetanilide

\[ (C_6H_5)_2CHCOCl + NH_2C_6H_5 \rightarrow (C_6H_5)_2CHCONHC_6H_5 + HCl \]

(7) Preparation of diphenylacetanilide-imide chloride from diphenylacetanilide and phosphorus pentachloride

\[ (C_6H_5)_2CHCONHC_6H_5 + PCl_5 \rightarrow (C_6H_5)_2CHCCL=NC_6H_5 + POCls + HCl \]

(8) Preparation of diphenylketene phenylimine from diphenylacetanilide chloride and triphenyl amine.

\[ (C_6H_5)_2C=NC_6H_5 + (C_6H_5)_3N \xrightarrow{HCl} (C_6H_5)_2C=NC_6H_5 + (C_6H_5)_3NHCl \]

This method, as shown here, seems to have the advantages of simplicity and efficiency over the method developed by Staudinger. With these ideas in mind, it became of interest to attempt the preparation of diphenylketene phenylimine by
means of the interaction of diphenylacetanilide-imide chloride and triethyl amine.

The first six steps of the reaction are simple, straightforward reactions giving good yields of the desired product, but reaction No. 7, involving the preparation of diphenylacetanilide-imide chloride, requires careful manipulation on the part of the operator. The operation was carried out in a small flask fitted with a standard taper joint and drying tube. The diphenylacetanilide and phosphorus pentachloride were placed in the flask and warmed gently on a water bath at 30-35°C, until HCl fumes ceased to come off. Diphenylacetanilide-imide chloride began to crystallize before the reaction was complete. The flask was then fitted to a Claisen type distillation head and the phosphorus oxychloride formed was removed under reduced pressure, care being taken to exclude all atmospheric moisture. After washing the diphenylacetanilide-imide chloride with petroleum ether, it was dissolved in anhydrous ether and transferred to a three-necked flask fitted with a stirrer and dropping funnel. An ether solution of triethyl amine was added with stirring until three equivalents of the amine had been added. This mixture was refluxed for two hours and then filtered to remove the amine hydrochloride. The reaction mixture was crystallized with considerable difficulty, but finally a yield of 31% of diphenylketene phenylimine, based on the quantity diphenylacetanilide used, was obtained. Attempts to distill the product from the reaction mixture gave only
a compound melting at 240°, which probably is a polymer of diphenylketene phenylimine. Diphenylketene phenylimine was obtained invariably by this method, except in cases where an attempt was made to distill the product. The product was identified by mixed melting point with the compound prepared by Staudinger's method and also by the derivative which it yields with alcohol. By starting with benzil, this method of preparation gives a yield of 15.8% as compared with 13.3% using the method of Staudinger. However, Staudinger's method involves the preparation of another substance, triphenylphosphine phenylimine. If the yields of all the reagents necessary for the laboratory preparation of diphenylketene phenylimine by Staudinger's method are included, the yield is 2.5%.

The keteneimines may be represented by the general formula $\text{R}^R\text{C}=\text{C}=\text{N}=\text{R}$. This type of cumulative unsaturation, which is also characteristic of the ketenes, has been given considerable attention, especially with regard to its reaction with reagents for the carbonyl group.

\[
\begin{align*}
\text{R}^R\text{C}=\text{C}=\text{O} + \text{H}_2\text{O} & \rightarrow \text{R}^R\text{CHCOOH} \\
\text{R}^R\text{C}=\text{C}=\text{NR} + \text{H}_2\text{O} & \rightarrow \text{R}^R\text{CHCNHR} \\
\text{R}^R\text{C}=\text{C}=\text{O} + \text{C}_6\text{H}_5\text{NH}_2 & \rightarrow \text{R}^R\text{CHC}=\text{NH}\text{C}_6\text{H}_5 \\
\text{R}^R\text{C}=\text{N}=\text{C}_6\text{H}_5 + \text{C}_6\text{H}_5\text{NH}_2 & \rightarrow \text{R}^R\text{CHC}=\text{NC}_6\text{H}_5
\end{align*}
\]
The products of the above reactions indicate an addition to the ethylenic linkage with reagents which add ordinarily to a carbonyl group. Either the anil linkage imparts unusual activity to the ethylenic bond or the products formed are secondary products. However, the products can be accounted for by assuming addition to the carbonyl group:

\[ \text{R} \equiv \text{C} = \equiv \text{O} + \text{H}_2\text{O} \rightarrow \text{R} \equiv \text{C} = \equiv \text{O} \]

Staudinger treated diphenylketene with phenyl magnesium bromide and obtained diphenylacetophenone as a product:

\[ (\text{C}_6\text{H}_5)\equiv \text{C} = \equiv \text{O} + \text{C}_6\text{H}_5\text{MgBr} \xrightarrow{\text{H}_2\text{O}} (\text{C}_6\text{H}_5)\text{CHC} = \equiv \text{C}_6\text{H}_5 + \text{Mg(OH)Br} \]

It was assumed that this product was formed by addition of the reagent to the ethylenic linkage, but its formation can also be explained on the basis of addition to the carbonyl group.
It is unlikely that this reagent adds to the ethylenic link- 
age because it has never been established that a Grignard 
reagent adds to an ethylenic linkage. In 1920, Gilman and 
Heckert* furnished the answer to this perplexing problem and 
established the mode of addition of phenyl magnesium bromide 
to the ketenes. The Grignard reagent was selected, because 
the addition product is not reversible and it gives a primary 
addition product which may be reacted with other reagents to 
show the position of the -MgBr group. As previously shown, 
the final product of the Grignard reaction can be explained 
by either addition to the ethylenic linkage or to the car- 
bencyl group. Gilman and Heckert in the following manner 
established the mode of addition of the Grignard reagent to 
diphenylketene.

\[
\text{(C}_6\text{H}_5\text{)}_2\text{C} = \text{C} = \text{O} + \text{C}_6\text{H}_5\text{MgBr} \rightarrow \text{(C}_6\text{H}_5\text{)}_2\text{C} = \text{C} = \text{OMgBr}
\]

\[
\text{(C}_6\text{H}_5\text{)}_2\text{C} = \text{C} = \text{OMgBr} + \text{C}_6\text{H}_5\text{COCl} \rightarrow \text{(C}_6\text{H}_5\text{)}_2\text{C} = \text{C} = \text{OCOC}_6\text{H}_5 + \text{MgBrCl}
\]

If the addition had taken place at the ethylenic bond, the 
final product would have been diphenyldibenzoyl methane.

\[
\text{(C}_6\text{H}_5\text{)}_2\text{C} = \text{C} = \text{O} + \text{C}_6\text{H}_5\text{MgBr} \rightarrow \text{(C}_6\text{H}_5\text{)}_2\text{C} = \text{C} = \text{O}
\]

\[
\text{(C}_6\text{H}_5\text{)}_2\text{C} = \text{C} = \text{O} + \text{C}_6\text{H}_5\text{COCl} \rightarrow \text{(C}_6\text{H}_5\text{)}_2\text{C} = \text{C} = \text{O}
\]
Actually, the product obtained was the benzoate of triphenylvinyl alcohol.

Gilman and Kinney\(^5\) in a somewhat similar manner established the mode of addition of the Grignard reagent to the isothiocyanates. This was accomplished by treating the addition product of phenylisothiocyanate and phenyl magnesium bromide with dimethyl and also diethyl sulfate. They obtained the S-methyl thiobenzanilide and S-ethyl thiobenzanilide.

\[
\begin{align*}
C_6H_5-N=C=S + C_6H_5MgBr &\rightarrow C_6H_5N=C-S-MgBr \\
C_6H_5N=C-S-MgBr + (CH_3)_2SO_4 &\rightarrow C_6H_5N=C-S-CH_3 + MgBr(CH_3)SO_4
\end{align*}
\]

Upon hydrolysis of the final product no methyl or ethyl aniline was obtained, which would have shown that the reagent had added to the \(-N=C=\) linkage.

\[
\begin{align*}
C_6H_5-N=C=S + C_6H_5MgBr &\rightarrow C_6H_5N=C=S-MgBr \\
C_6H_5N=C=S + (CH_3)_2SO_4 &\rightarrow C_6H_5N=C=S + MgBr(CH_3)SO_4
\end{align*}
\]

The addition of lithium and sodium phenyl to phenyl isothiocyanate has also been established\(^6\). Here again the addition to the terminal unsaturated group was shown.

\[
\begin{align*}
C_6H_5N=C=S + C_6H_5Li &\rightarrow C_6H_5N=C-S-Li \\
C_6H_5N=C-S-Li + (CH_3)_2SO_4 &\rightarrow C_6H_5N=C-S-CH_3 + CH_3LiSO_4
\end{align*}
\]
The same product was obtained with both lithium and sodium phenyl.

Some generalizations on the addition of the Grignard reagent to compounds of this type were stated by Gilman, Kirby and Kinney in a more recent publication. According to these authors, all of the addition reactions to compounds having terminal cumulative unsaturated groups by the Grignard reagents show two similarities:

1. In each case addition takes place to the ultimate unsaturated group of those types having the terminal cumulative unsaturated groups.

2. The reaction stops at this unsaturated group, even when a liberal excess of phenyl magnesium bromide is added at the low temperature given by ether as a solvent.

\[
\begin{align*}
(C_6H_5)_2C=O &+ C_6H_5MgBr \rightarrow (C_6H_5)_2C=C=OMgBr \\
C_6H_5N=C=O &+ C_6H_5MgBr \rightarrow C_6H_5N=C-MgBr \\
C_6H_5N=S=O &+ C_6H_5MgBr \rightarrow C_6H_5N=S-MgBr \\
C_6H_5N=C=S &+ C_6H_5MgBr \rightarrow C_6H_5N=C-S-MgBr
\end{align*}
\]

According to the results obtained with the above mentioned compounds, it could be predicted that the Grignard reagent would add to a keteneimine compound in the following way:

\[
\begin{align*}
(R)_2C=C=N-R &+ R'MgX \rightarrow (R)_2C=C=N-R \xrightarrow{H_2O} R'MgX \\
\left[ (R)_2C=C-NHR \right] &\xrightarrow{R'} \rightarrow (R)_2CHC=NR
\end{align*}
\]
where R may be the same or different alkyl or aryl groups, or hydrogen.

Using the material prepared by the method previously mentioned, diphenylketene phenylimine was treated with phenyl magnesium bromide, using ether as the solvent, with the result that no reaction was observed and only starting material was recovered. In order to force the reaction, a portion of the ether was replaced with benzene, so that it became possible to operate at a higher temperature (65°), and the reaction mixture was refluxed for a period of three to four hours. Upon hydrolysis of the mixture, a small yield of the expected product was obtained. This product was identified as the anil of phenylacetophenone by hydrolyzing with concentrated hydrochloric acid. The products of hydrolysis were aniline and diphenylacetophenone.

\[
\text{(C}_6\text{H}_5)_2\text{CHC} = \text{NC}_6\text{H}_5 + \text{H}_2\text{O} \rightarrow \text{(C}_6\text{H}_5)_2\text{CHC} = \text{C}_6\text{H}_5 + \text{C}_6\text{H}_5\text{NH}_2
\]

In order to establish the mechanism of the reaction, benzoyl chloride was added to the addition product of phenyl magnesium bromide and refluxed for some time. The product of this reaction was an oil which resisted all attempts of crystallization. By operating at an elevated temperature, it is possible to have obtained side reactions, such as were reported by Gilman and Kirby in the forced reaction of benzophenone-anil and phenyl magnesium bromide.

\[
\text{C}_6\text{H}_5\text{C} = \text{N} = \text{C}_6\text{H}_5 + \text{C}_6\text{H}_5\text{MgBr} \rightarrow \text{C}_6\text{H}_5\text{C} = \text{N} = \text{C}_6\text{H}_5
\]

\[
\text{C}_6\text{H}_5\text{C} = \text{NH} \cdot \text{C}_6\text{H}_5
\]
It was found necessary to resort to a more reactive reagent such as lithium phenyl which would give a better yield of the desired product. Gilman and Kirby\(^7\), in a paper on the relative reactivities of lithium phenyl and phenyl magnesium bromide, found the lithium compound to be more reactive than the corresponding organo-magnesium compound. They also observed no abnormal addition of the lithium phenyl reagent to lateral - nuclear conjugated system in benzophenone-anil. Lithium phenyl, therefore, offered the advantages of being more reactive and showing no abnormal addition to this type of linkage.

An ether solution of lithium phenyl was slowly added to an ether solution of diphenylketene phenylimine and there was an immediate reaction in which heat was given off and a deep red color was produced. On hydrolysis of the reaction mixture, a good yield of diphenylacetophenone-anil, the expected product, was obtained. In order to establish the position of the Li atom in the primary addition product, benzoyl chloride was added to the reaction mixture prior to hydrolysis. In this reaction equal molecular quantities of all three reagents were added to minimize side reactions. The product of the reaction was crystallized and a good yield of a compound melting at 161° was obtained.

Assuming normal addition to the diphenylketene phenylimine used, the reactions would take place in the following manner:

\[
(C_6H_5)_2C=NC_6H_5 + \text{C}_6\text{H}_5\text{Li} \rightarrow (C_6H_5)_2\text{C} \equiv \text{CNC}_6H_5
\]
However, if addition to the ethylenic linkage was involved, the course of the reaction should proceed as follows:

\[
(C_6H_5)_2C=O + C_6H_5COCl \rightarrow (C_6H_5)_2C=O + C_6H_5COOC_6H_5
\]

\[
(C_6H_5)_2C=O + C_6H_5Li \rightarrow (C_6H_5)_2C=O + C_6H_5COOC_6H_5
\]

It has been shown that addition of lithium phenyl to diphenyldiketene phenylimine with subsequent reaction with benzoyl chloride may yield two products. As a result of addition to the ethylenic bond, the compound formed would have the following structure:

\[
A. \quad \begin{array}{c}
C_6H_5 \\
\hline
\hline
\hline
C_6H_5
\end{array}
\]

However, if reaction with the imine double bond occurred, as expected, the structure would be:

\[
B. \quad \begin{array}{c}
C_6H_5 \\
\hline
\hline
\hline
C_6H_5
\end{array}
\]

Compound A is an imine and should easily hydrolyze with hot concentrated hydrochloric acid, yielding aniline and dibenzoyldiphenyl methane as products.

\[
(C_6H_5)_2C=NC_6H_5 + H_2O + HCl \rightarrow \begin{array}{c}
C_6H_5 \\
\hline
\hline
\hline
C_6H_5
\end{array}
\]

\[
C_6H_5C=O + C_6H_5COOC_6H_5 + C_6H_5NH_2
\]
Every effort was made to hydrolyze the compound with hydrochloric acid, but invariably all of the starting material was recovered.

Compounds A and B normally could be distinguished by ozonization since B contains an ethylenic bond.

\[
\begin{align*}
(C_6H_5)_2C=NC\equivO COC_6H_5 & \quad + \quad O_3 \quad \longrightarrow \quad (C_6H_5)_2C\equivN COC_6H_5 \\
& \quad + \quad C_6H_5C\equivN - C=O \quad + \quad O_3.
\end{align*}
\]

Dibenzanilide, one product of ozonization, could not be obtained from A, since there is no benzoyl group attached to the nitrogen atom. All efforts to ozonize the compound were unsuccessful. In one instance, one gram of the material was subjected to ozonization for eight hours with apparatus producing 6% of ozone, and all of the original material was recovered.

Oxidation of B with chromic acid should yield the same products as ozonization.

\[
\begin{align*}
(C_6H_5)_2C=NC\equivO COC_6H_5 & \quad + \quad [O] \quad \longrightarrow \quad (C_6H_5)_2C\equivO + \\
& \quad + \quad COC_6H_5C\equivC_6H_5.
\end{align*}
\]

The compound was oxidized with chromic acid in acetic acid solution and the products obtained were benzoic acid and benzophenone. Dibenzanilide was found, by oxidizing an authentic sample, to be very easily oxidized to benzoic acid. This could account for not obtaining both primary oxidation products, dibenzanilide and benzophenone.
Several attempts were made to oxidize the compound by using less chromic acid than was necessary for complete reaction and in each instance a small amount of a compound melting at 185° was obtained. Carbon and hydrogen determinations gave results corresponding to the calculated amounts for the glycol.

\[
(C_6H_5)_2C=\overset{N}{\overset{-}{C}}OC_6H_5 + [O] + H_2O \rightarrow (C_6H_5)_2C\overset{C\overset{C}{\overset{N}{\overset{-}{C}}}OC_6H_5 \quad OH \quad OH \quad C_6H_5
\]

Oxidation of the compound, A or B, with potassium permanganate in acetic acid solution gave benzanilide, m.p. 163°. Benzanilide could be obtained from compound B,

\[
(C_6H_5)_2C=\overset{C\overset{C}{\overset{N}{\overset{-}{C}}}OC_6H_5 \quad C_6H_5 \quad COC_6H_5
\]

but compound A shows no benzoyl group attached to a nitrogen atom.

The final evidence of the mode of addition of lithium phenyl to diphenylketene phenylimine was gained by refluxing the compound, A or B, with alcoholic potassium hydroxide for several hours. Benzoic acid and diphenylacetophenone-anil were obtained in quantitative yields as products of hydrolysis.

\[
(C_6H_5)_2C=\overset{N}{\overset{-}{C}}OC_6H_5 + H_2O \xrightarrow{KOH} C_6H_5COOK + \left[\overset{C\overset{C}{\overset{N}{\overset{-}{C}}}OC_6H_5 \quad \text{[}}(C_6H_5)_2CHC=NOC_6H_5 \right]
\]

The evidence obtained on the mode of addition of lithium phenyl to diphenylketene phenylimine indicates addition at
the imine double bond. The reasons for assigning this mode of reaction are:

1. The failure of the compound, A or B, to hydrolyze with hot concentrated hydrochloric acid;

2. The products of oxidation by chromic acid, benzoic acid and benzophenone;

3. The product of oxidation with potassium permanganate, benzanilide; and

4. The products of hydrolysis with alcoholic potassium hydroxide, benzoic acid and diphenylacetophenone-anil.
SUMMARY
I. Staudinger's method\textsuperscript{32} for the preparation of diphenylketene phenylimine has been compared with a new and more direct method of preparation employing triethyl amine and diphenylacetanilide-imide chloride. The new synthesis has been found to give higher yields, and to be an easier method of synthesis than that of Staudinger.

II. Diphenylketene phenylimine has been reacted with phenyl magnesium bromide, and a previously unreported compound, diphenylacetophenone-anil, was obtained as a product.

III. Diphenylketene phenylimine has been reacted with lithium phenyl and diphenylacetophenone-anil was obtained as a product.

IV. The mode of addition of lithium phenyl to diphenylketene phenylimine has been studied, and evidence was presented to indicate addition to the C=N linkage.
EXPERIMENTAL
PREPARATION OF DIPHENYLKETENE PHENYLIMINE — SYNTHESIS I

C₆H₅CHO + KCN → C₆H₅CH=CHC₆H₅

HNO₂ → C₆H₅C=CC₆H₅ + KOH

(C₆H₅)₂COOH + HI → (C₆H₅)₂CHCOOH

SOCl₂ →

(C₆H₅)₂CH₂COCl + C₆H₅NH₂ → (C₆H₅)₂CHCONHC₆H₅

PCl₃ →

(C₆H₅)₂CH₃NC₆H₅ → (C₆H₅)₂C=NC₆H₅

Benzoin¹⁰.— To a solution containing 454 g. of benzaldehyde, 900 ml. of ethyl alcohol and 360 ml. of water, 54 g. of KCN was added. The mixture was refluxed for one hour and the benzoin, which crystallized upon cooling, was filtered off and washed thoroughly with water. The product was not weighed, but was used while still wet in the preparation of benzil.

Benzil¹¹.— The benzoin from the preceding preparation was placed in a 2 l. round-bottom flask and 1000 ml. of concentrated nitric acid was added. The mixture was heated on the steam bath, with frequent shaking, until the brown fumes of NO₃ ceased to be given off. The mixture was cooled, poured into ice and water, filtered and the product washed with water and a saturated solution of sodium bicarbonate. Upon crystallization of the product from ethyl alcohol, 384 g. of benzil was obtained, which melted at 95°. The overall yield was 85%, based on the quantity of benzaldehyde used.

29
**Benzilic Acid**

In a three liter round-bottomed flask, 175 g. (3.12 moles) of potassium hydroxide were dissolved in 350 ml. of distilled water and 350 g. of 95% ethyl alcohol and 175 g. (0.83 moles) of pure benzil were added. A deep bluish black solution was immediately produced. The solution was refluxed on the steam bath for fifteen minutes and then poured into a large evaporating dish and allowed to stand overnight. The potassium salt of the benzilic acid was filtered off and washed with a small amount of alcohol. The salt was then dissolved in approximately 2 l. of water and 8 ml. of hydrochloric acid was added. The small amount of precipitate formed by the addition of the first acid was brown and sticky and was filtered off and discarded. Acid was added to the filtrate until precipitation was complete. The product was filtered off and washed with water, and upon crystallization from hot water, gave 145 g. (yield, 77%) of benzilic acid, melting at 150°.

**Diphenylacetic acid**

In a one liter round-bottomed flask, a mixture of 320 ml. of glacial acetic acid, 20 g. (0.65 moles) of red phosphorus, and 6.5 g. (0.48 moles) of iodine was allowed to stand for twenty-five minutes. At the end of this time, all the iodine had reacted and 8 ml. of water and 130 g. (0.57 moles) of benzilic acid were added and the mixture was refluxed for three hours. The solution was filtered while hot, and the hot filtrate poured into 2 l. of water containing 20 g. of sodium bisulfite. The diphenylacetic acid precipitated as a fine white powder and
was collected by filtration. The product was washed with water and when crystallized from a mixture of ethyl alcohol and water, 110 g. (yield, 91%) of diphenylacetic acid was obtained, which melted at 148°.

**Diphenylacetyl Chloride.** In a Claisen flask, fitted with a reflux condenser, 110 g. (0.54 moles) of diphenylacetic acid, and 110 g. (0.81 moles) of thionyl chloride were added. The mixture was heated on a water bath until the solution was clear and fumes were no longer given off. The excess thionyl chloride was removed by distillation under diminished pressure. The diphenylacetyl chloride was distilled under vacuum and 108 g. (yield, 93%) was obtained, which boiled at 152° at 4 mm. pressure.

**Diphenylacetylamine.** In a one liter three-necked round-bottom flask, fitted with a stirrer, reflux condenser, and dropping funnel, was placed 76.5 g. (0.82 moles) of aniline dissolved in anhydrous ether and 113 g. (0.82 moles) of potassium carbonate. An ether solution containing 95 g. (0.41 moles) of diphenylacetyl chloride was then added slowly with vigorous stirring, and refluxed for thirty minutes. Upon cooling, the precipitate was filtered off and washed thoroughly with water, and the product was crystallized from methyl alcohol and water, yielding 98 g. (yield, 85%) of needle-shaped colorless crystals melting at 181.5-182°.

**Diphenylacetanilide-imide Chloride**. To a 50 ml. round-bottom flask with a standard taper joint, 20 g. (0.069 moles) of diphenylacetanilide and 16 g. (0.077 moles) of
pulverized phosphorus pentachloride were added. The flask was fitted with a drying tube and then warmed on a water bath, care being taken not to let the temperature rise above 35°. The mixture immediately began to melt and give off acid fumes. The warming was continued with constant agitation until acid fumes were no longer given off. The round-bottom flask was then fitted with a Claisen type still head and the phosphorus oxychloride removed under a vacuum. Upon cooling, 20.1 g. (yield, 95%) of nearly colorless crystals were obtained, which melted at 93°. Crystallization from a mixture of ethyl ether and petroleum ether did not appear to improve the quality of the product.

It was found that by working carefully the brown resinous material reported in the literature could be avoided, and a better yield of pure product could be obtained.

Diphenylketene Phenylamine. - To a ether solution of 9.3 g. (0.030 moles) of diphenylacetanilide chloride, 10 g. (0.066 moles) of triethyl amine was added drop by drop. The mixture was refluxed for two hours, until the precipitation of triethyl amine hydrochloride appeared to be complete. At the end of this period, the amine salt was filtered off and the solvent removed under reduced pressure. The remaining material, which was oily in nature, was dissolved in petroleum ether and cooled in a bath of ice and salt. This procedure gave 2.5 g. (yield, 31%) of pale yellow crystals melting at 56-57°. A mixed melting point with an authentic sample (prepared according to the method of Staudinger) of diphenylketene
phenylimine, m.p. 56-57°, proved the material to be the desired product. There remained an oily material from which 0.5 g. of diphenylacetanilide was obtained by crystallization from methyl alcohol.

Similar preparations were made with an average yield of approximately 30% of the desired product. There always remained an oily material which resisted all attempts of crystallization.

**PREPARATION OF DIPHENYLKETENE PHENYLIMINE - SYNTHESIS I**

**Staudinger's Synthesis:**

\[
\begin{align*}
\text{C}_6\text{H}_5\text{CHO} & \rightarrow \text{KCN} \\
\text{C}_6\text{H}_5\text{CH}-\text{C}-\text{C}_6\text{H}_5 & \rightarrow \text{HNO}_3 \\
\text{C}_6\text{H}_5\text{C} \rightarrow \text{C}-\text{C}_6\text{H}_5 & \rightarrow \text{NH}_2\text{NH}_2 \\
\text{C}_6\text{H}_5\text{C} \rightarrow \text{C}-\text{C}_6\text{H}_5 & \rightarrow \text{HgO} \\
\text{C}_6\text{H}_5\text{C} \rightarrow \text{C}-\text{C}_6\text{H}_5 & \rightarrow \text{(C}_6\text{H}_5\text{)}_3\text{P} \\rightarrow \text{(C}_6\text{H}_5\text{)}_3\text{P} \rightarrow \text{N}=\text{C}_6\text{H}_5
\end{align*}
\]

**Triphenylphosphine** - To a solution of phenyl magnesium bromide, prepared from 60 g. (2.46 moles) of magnesium and 392.5 g. (2.50 moles) of bromobenzene, 100 g. (0.30 moles) of
Phosphorus trichloride was added. A period of three hours was necessary to add the phosphorus trichloride because of the violence of the reaction. The product was hydrolyzed with ice and dilute hydrochloric acid and then extracted with ether. On evaporating the ether, there separated 91.5 g. (yield, 42.5%) of creamy white crystals which melted at 79.5°.

Phenylazide

To 4 liters of water containing 200 g. (1.84 moles) of phenylhydrazine and 300 ml. (3.75 moles) of hydrochloric acid, a water solution of 171 g. (2.50 moles) of sodium nitrite was slowly added. The mixture was stirred with a mechanical stirrer until the reaction was complete and then the product was permitted to settle out as an upper layer. The two layers were separated, and the phenylazide was steam distilled. The product of the steam distillation gave 103 g. (yield, 47%) of phenylazide, boiling at 73-74° at 22-24 mm. pressure.

Triphenylphosphine Phenylimine

An ether solution containing 91.5 g. (0.35 moles) of triphenylphosphine was added, with stirring, to an ether solution containing 41.7 g. (0.35 moles) of phenylazide. The product began to crystallize when about two-thirds of the triphenylphosphine had been added, and when addition was complete, the ether solution of the product was cooled in a bath of ice and salt and filtered. The product was washed with cold ether and permitted to dry, further purification being unnecessary. A yield of 110 g. (yield, 89.0%) of crystals melting at 131-32° was obtained.
Benzil Monohydrazone\textsuperscript{14}.– Benzil, 158 g. (0.75 moles) was dissolved in 300 ml. of hot 95\% ethyl alcohol in a three-necked flask equipped with a stirrer. To this solution 45 g. (0.75 moles) of an 85\% solution of hydrazine hydrate, was added. Benzil monohydrazone began to crystallize when about three-fourths of the hydrazine hydrate had been added. The mixture was refluxed for five minutes after the addition was complete, and then cooled in an ice bath. The product was filtered off and washed with two 100 ml. portions of cold alcohol. A yield of 156.7 g. (93\%) of benzil monohydrazone, melting at 149-51°, was obtained.

Diphenylketene\textsuperscript{15}.– Benzil monohydrazone, 112 g. (0.50 moles) was mixed in a mortar with 162 g. (0.76 moles) of yellow mercuric oxide and 70 g. of anhydrous sodium sulfate. The mixture was introduced into a one liter three-necked flask fitted with a stirrer, a condenser and a thermometer. The flask was placed on a water bath; 200 ml. of dry benzene was added and the suspension was stirred at 25-35° for four hours. The reaction mixture was filtered through a fine-grained filter paper over which was placed a layer of finely ground anhydrous sodium sulfate, and washed with dry benzene until the washings were colorless. The benzene solution of the diazo compound was poured into a separatory funnel protected with a drying tube, and inserted in a 250 ml. Claisen flask provided with a condenser for distillation. The Claisen flask was heated by means of an oil bath maintained at 100-110°, and the benzene solution was slowly dropped
into the flask. In this way the benzene was removed at about the same rate at which it was dropped into the flask. When the addition was complete, the Claisen flask was connected to a water pump and the remaining benzene removed, and then connected to a vacuum pump and distilled in an atmosphere of nitrogen, at 3-4 mm. pressure, and the fraction boiling at 115-125° was collected. Redistillation of this fraction gave 35 g. (yield, 23.7%) of diphenylketene, which boiled at 119-121° at 3-4 mm. pressure.

**Diphenylketene Phenylimine**\(^{51}\). Diphenylketene, 21.6 g. (0.111 moles), dissolved in 50 ml. of benzene, was added to a three-necked round-bottom flask, equipped with a stirrer. To this solution 39.2 g. (0.111 moles) of triphenylphosphine phenylimine, dissolved in 100 ml. of benzene, was slowly added. After addition was complete, and the mixture was heated for one hour under an atmosphere of nitrogen, a portion of the benzene was distilled off and petroleum ether was added. The precipitate of triphenylphosphine-oxide was filtered off and washed with petroleum ether, the washings being added to the filtrate. The petroleum ether solution of diphenylketene phenylimine was evaporated and cooled. The product, 18 g. (yield, 60.5%), crystallized from petroleum ether as light yellow crystals melting at 55-56°. The product was recrystallized from ethyl alcohol with no change in the melting point.

**Action of Phenyl Magnesium Bromide on Diphenylketene Phenylimine at the Boiling Point of Ether**.- An ether solu-
tion of phenyl magnesium bromide was prepared using 4.6 g. (0.20 moles) of magnesium and 32 g. (0.20 moles) of bromobenzene. To this was added dropwise an ethereal solution containing 10 g. (0.036 moles) of diphenylketene phenylimine. The reaction was carried out at the boiling point of ether, 35°, and then hydrolyzed with hydrochloric acid and ice. The hydrolysis mixture was extracted with ether and the ether solution dried over sodium sulfate. The ether solution was evaporated and the remaining oil was precipitated by the addition of petroleum ether. All attempts to crystallize the material were futile, but 8 g. amorphous material was obtained which melted around 115°.

Preparation of Diphenylacetophenone-anil, II.—A phenyl magnesium bromide solution was prepared from 4.6 g. (0.20 moles) of magnesium and 32 g. (0.20 moles) of bromobenzene. When the reagent was prepared, a part of the ether was displaced with benzene until the boiling point of the mixture reached 65°. Diphenylketene phenylimine, 10 g. (0.036 moles), was introduced as a solid, and the reaction mixture was refluxed for seven hours. The magnesium addition compound, I, either \[(\text{C}_6\text{H}_5)_2\text{C} = \text{NC}_6\text{H}_5\] or \[(\text{C}_6\text{H}_5)_2\text{C} = \text{NC}_6\text{H}_5\] was hydrolyzed with ice and hydrochloric acid. The hydrolysis mixture was extracted with ether and dried over sodium sulfate, after which the solvent was removed under vacuum. The remaining material was dissolved in a mixture of ether and petroleum ether and cooled. There was obtained 2 g. (yield,
15.9%) of material melting at 140-142°, II. The remainder of the reaction product was an oil which resisted all attempts of crystallization. Compound, II, was analyzed for C_{85}H_{81}N. Calculated: C, 89.8; H, 6.1. Found: C, 90.0; H, 6.2.

To a 50 ml. Erlenmeyer flask containing 20 ml. of concentrated hydrochloric acid, 1 g. of II was added. Upon heating, the compound first dissolved and the crystals appeared which were filtered off and recrystallized from ethyl alcohol. The product melted at 136°, and when mixed with an authentic sample of diphenylacetophenone, m.p. 136°, the melting point was unchanged. The hydrochloric acid solution was made alkaline with sodium hydroxide and a few drops of benzoyl chloride was added. There was an immediate reaction and precipitation of a compound, which, on crystallization from ethyl alcohol, proved to be benzanilide, m.p. 163°.

**Action of Benzoyl Chloride on I.**—An ether solution of phenyl magnesium bromide was prepared from 4.6 g. (0.20 moles) of magnesium and 32 g. (0.20 moles) of bromobenzene, and a part of the ether was displaced with benzene until the boiling point of the mixture was 65°. To this reagent, 10 g. (0.036 moles) of diphenylketene phenylimine was added and the mixture refluxed for six hours, after which 23 g. (0.20 moles) of benzoyl chloride was added. The reaction mixture was refluxed for an additional three hours, and then hydrolyzed with ice and hydrochloric acid. The product of hydrolysis was extracted with ether and the ether solution dried
over sodium sulfate. The ether was evaporated on a steam bath and the benzene removed with reduced pressure; and then attempts were made to crystallize the remaining oil. The oily residue was repeatedly dissolved in small amounts of ethyl ether and precipitated with petroleum ether in an effort to remove impurities. Ether solutions and alcohol solutions of the oil were cooled in ice baths and dry ice baths, but no crystals were obtained.

**Action of Lithium Phenyl on Diphenylketene Phenylimine.**

Lithium phenyl was prepared in an atmosphere of nitrogen by reacting 1.3 g. (0.187 moles) of lithium with 14.6 g. (0.093 moles) of bromobenzene. This reagent was siphoned into a separatory funnel that had been previously dried and filled with nitrogen. In a 500 ml. three-necked flask, 5.0 g. (0.0186 moles) of diphenylketene phenylimine was placed and dissolved in 25 ml. of anhydrous ether. The lithium phenyl was dropped slowly into the flask, and there was an immediate reaction in which heat was generated and a deep red color formed. The reaction mixture was stirred for one hour after addition was complete, and the lithium complex, III,

\[
\text{either } (\text{C}_6\text{H}_5)_2\text{C} \equiv \text{C} \equiv \text{NCO}_6\text{H}_5 \text{ OR } (\text{C}_6\text{H}_5)_2\text{C} \equiv \text{C} \equiv \text{NCO}_6\text{H}_5
\]

\[
\text{Li} \quad \text{C}_6\text{H}_5 \quad \text{C}_6\text{H}_5 \quad \text{Li}
\]

was hydrolyzed with ice and hydrochloric acid. The hydrolysis mixture was extracted with ether and dried with sodium sulfate. The ether solution was evaporated and the residue crystallized from ethyl alcohol and then from methyl alcohol. There was obtained 4.2 g. (yield, 64.3%) of material, which
melted at 140-142°. A mixed melting point with diphenylacetophenone-anil showed them to be the same material.

Hydrolysis with concentrated hydrochloric acid gave diphenylacetophenone, m.p. 134°, and aniline, which was identified as benzanilide, m.p. 163°.

Action of Benzoyl Chloride on III.- Lithium phenyl was prepared in an atmosphere of nitrogen from 0.8 g. (0.115 moles) of lithium and 4.1 g. (0.026 moles) of bromobenzene. This reagent was siphoned into a separatory funnel and slowly added to 7 g. (0.026 moles) of diphenylketene phenylisimine contained in a 500 ml. three-necked flask. This mixture was stirred for two hours after addition of lithium phenyl was complete, and then 3.7 g. (0.026 moles) of benzoyl chloride in ether solution was added slowly. There was an immediate reaction in which lithium chloride was precipitated and the red color faded. After the solution had become colorless, the lithium chloride was filtered off and the filtrate evaporated to a few ml. The residue was crystallized from a mixture of ether and petroleum ether and then recrystallized from ethyl alcohol. There was obtained 7 g. (yield, 76.8%) of material, IV, melting at 161°. The compound was analyzed for C_{22}H_{15}ON.

Calculated:  C, 87.8; H, 5.7. Found:  C, 87.7; H, 5.6.

Oxidation of IV with Chromic Acid.- A solution containing 50 ml. of benzene and 2 g. of IV, was shaken for 24 hours with 0.6 g. of chromic anhydride and 0.3 g. of sulfuric acid in 50 ml. of water. No change was observed at the end of
this time and the mixture was then refluxed for four hours. No oxidation was observed and 80% of the starting material was recovered.

To 20 ml. of acetic acid containing 1.5 g. of IV, 0.5 g. of chromic anhydride was added. The mixture was refluxed for 30 minutes and then poured into ice water. The oxidation product was filtered off and washed with petroleum ether. The remaining solid was crystallized from ethyl ether and 0.3 g. of a compound, V, melting at 185° was obtained. The remaining oil resisted all attempts of crystallization. The solid material, V, was analyzed for the glycol of IV, C₉H₇O₃N₂.

Calculated: C, 81.7; H, 5.7. Found: C, 81.8; H, 6.0.

A solution containing 10 ml. of acetic acid and 1 g. of IV was placed in a 50 ml. round-bottom flask and 2 g. of CrO₃ was added in portions over a period of one hour. The solution was refluxed for 15 minutes and then poured into 100 ml. of ice water. The precipitate was filtered and washed with cold water, and then washed with warm potassium hydroxide solution. The remaining solid was steam distilled and the material which was volatile with steam was crystallized from alcohol and water. A mixed melting point with an authentic sample, m.p. 45-48°, and a phenylhydrazone derivative, m.p. 137°, proved the substance to be benzophenone.

The KOH solution used to wash the oxidation product was neutralized with hydrochloric acid and a precipitate was obtained, which upon crystallization from hot water, melted
at 120-121°. A mixed melting point with an authentic sample of benzoic acid proved its identity.

**Oxidation of IV with Potassium Permanganate.**—A solution of 20 ml. of acetic acid containing 1 g. of IV was shaken with 0.5 g. of KMnO₄ for thirty minutes. At the end of this time, the excess KMnO₄ was decolorized with NaHSO₃ and the solution poured into water. An oil was obtained which was steam distilled. A small amount of steam volatile material was obtained, which was not identified. Crystals were obtained upon cooling the water in the steam distillation flask, which melted at 163°. A mixed melting point with benzanilide, m.p. 163°, showed the compounds to be identical.

**Ozonization of IV.**—Four attempts were made to ozonize the compound without success. The apparatus used produced 6% ozone when analyzed with KI and sodium thiosulfate solution. The oxygen was dried by passing through activated alumina, and the apparatus was thoroughly dried before using.

A solution containing 50 ml. of ethyl bromide and 1 g. of the IV were cooled in an ice bath, and oxygen and ozone were passed through the solution for 8 hours. At the end of this time, the ethyl bromide was evaporated with reduced pressure and the remaining material dissolved in acetic acid. Water was added and the solution refluxed for 45 minutes. The material was then recovered by adding an excess of water and filtering off the precipitate and crystallizing from methyl alcohol. Eighty per cent of the starting material was recovered. The remaining material was steam distilled
in an effort to recover benzophenone if it were present, but none was obtained.

**Behavior of IV with Concentrated Hydrochloric Acid.**—To 10 ml. of concentrated hydrochloric acid, was added 0.5 g. of IV and the mixture was refluxed for one hour. No change in the material occurred and all of IV was recovered.

**Hydrolysis of IV with Alcoholic Potassium Hydroxide.**—To 5 g. of KOH dissolved in 20 ml. of 95% ethyl alcohol was added 1 g. of IV, and the mixture was refluxed for a period of 8 hours. Upon cooling the solution slowly, a yellow material separated which was filtered off, washed with water and crystallized from methyl alcohol. The compound melted at 142° and a comparison with diphenylacetophenone-anil showed the compounds to be identical. Concentrated hydrochloric acid gave two products, which were identified as diphenylacetophenone and aniline.

The alcoholic KOH solution was diluted to 200 ml. with water and filtered to remove the remainder of II. The filtrate was evaporated to a small volume on the steam bath, and acidified with hydrochloric acid. A precipitate formed which, upon crystallization from hot water, melted at 120-21°. A mixed melting point with an authentic sample showed it to be benzoic acid.
BIBLIOGRAPHY

2. Dimroth, O., A Synthesis for Derivatives of 1,2,3-Triazols, Ber., 35: 1029-38 (1902)


20. Staudinger, H., Preparation of Ketenes from Acid Chloride and A Tertiary Base, Ber., 44: 1619-23 (1911)


BIOGRAPHY
Mack Castlemain Fuqua was born in Monroe County Mississippi on October 20, 1914. He attended grade and high school at Becker, Mississippi, and was graduated from Becker High School in 1932. In the autumn of 1932 he entered East Mississippi Junior College, Scooba, Mississippi, and was graduated from there in 1934. The following autumn he entered Mississippi College, Clinton, Mississippi, and received his B. A. degree there in the spring of 1936. He taught in Woolmarket High School during the 1936-37 school session. From the spring of 1937 until the autumn of 1938 he was employed by the Mississippi State Highway Department. He entered Louisiana State University in 1938 and received his M. S. degree in chemistry in 1940. The following two years were spent working toward a Ph. D. in chemistry from the same institution. In June, 1942, he was married to Miss Carrie Nell Drake of Columbus, Mississippi. Since June, 1942, he has been employed by the Standard Oil Company of Louisiana. He is now a candidate for a Ph. D. in chemistry from Louisiana State University.
EXAMINATION AND THESIS REPORT

Candidate: Fuqua, Mack Castlemoan

Major Field: Chemistry

Title of Thesis: Part I. The Reactions of Beta Hydroxy Ketones with Phenyl Magnesium Bromide. Part II. Ketenesimines

Approved:

[Signature]
Major Professor and Chairman

[Signature]
Dean of the Graduate School

EXAMINING COMMITTEE:

[Signature]

Date of Examination:

May 6, 1943