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THE CONDENSATION OF 2, 3, 3-  
TRIMETHYL 2-PENTANOL AND 2, 2, 3-  
TRIMETHYL-3-PENTANOL WITH  
PHENOL IN THE PRESENCE OF  
ALUMINUM CHLORIDE

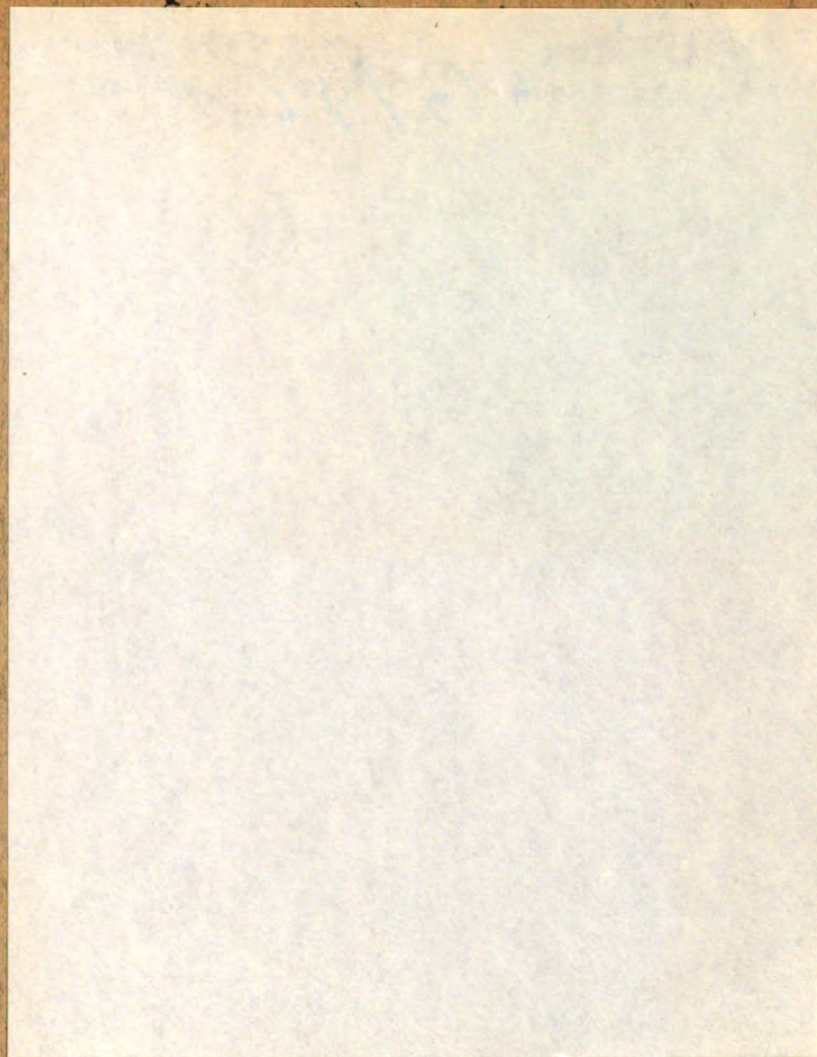
Thesis for the Degree of M. S.  
MICHIGAN STATE COLLEGE  
Samuel Breiter  
1946

*Ralph C. Huston*

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**The Condensation of 2,3,3-Trimethyl 2-Pentanol and  
2,2,3-Trimethyl-3-Pentanol with Phenol in the  
Presence of Aluminum Chloride**

**By**

**Samuel Breiter**

**A Thesis**

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ments for the degree of  
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## INTRODUCTION

Although previous workers in this laboratory have condensed 2,3,3-trimethyl-2-pentanol(1) and 2,2,3-trimethyl-3-pentanol(2,3) with phenol in the presence of aluminum chloride, the study of these condensations was still incomplete.

Proofs of structure were lacking for both condensation products isolated. In the case of 2,3,3-trimethyl-2-pentanol, only a small amount of the carbinol was available due to great difficulty of preparation and some doubt existed concerning the purity of the compound obtained. In the condensation of 2,2,3-trimethyl-3-pentanol, the previous workers obtained products whose physical constants differed greatly.

For these reasons, it was considered desirable to continue the study of the condensation of the two carbinols with phenol.



## HISTORICAL

A complete review of the literature dealing with alkylation of aromatic nuclei would obviously be beyond the scope of this paper and would be needlessly repetitious.

Many previous papers(4,5,6) have furnished brief and fairly complete surveys. In addition to these reviews, extensive surveys on the subject of aluminum chloride in organic chemistry have been made by Kramers (7) and Thomas (8).

Since this work is a study of the condensation of tertiary aliphatic alcohols with phenol in the presence of aluminum chloride, only those researches dealing with this subject will be summarized.

Alkylation of phenol by means of tertiary aliphatic alcohols using aluminum chloride, was first reported by Huston and Ksieh in September 1934 at a meeting of the American Chemical Society. Tertiary butyl, tertiary amyl, and the tertiary hexyl alcohols were condensed with phenol, and the results, published in 1936,(10) were as follows:

<u>Alcohol</u>	<u>Yield (%)</u>
1. 2-Methyl-2-propanol	40
2. 2-Methyl-2-butanol	54
3. 2-Methyl-2-pentanol	56
4. 3-Methyl-3-pentanol	50
5. 2,3-Dimethyl-2-butanol	47

In 1935, after the report made by Huston and Hsieh to the American Chemical Society, but prior to the formal publication of their results, Tsukervanik and Nazareva (9) reported the condensation of tertiary butyl and tertiary amyl alcohol with phenol, to obtain 60-70% the alkyl phenols.

The investigation was continued by Huston and Hedrick (11) who successfully condensed the tertiary heptyl alcohols with phenol.

<u>Alcohol</u>	<u>Yield (%)</u>
1. 3-Methyl-3-hexanol	31
2. 2-Methyl-2-hexanol	65
3. 2,3-Dimethyl-3-pentanol	41
4. 2,3-Dimethyl-2-pentanol	27
5. 2,3-Dimethyl-2-pentanol	44
6. 3-Ethyl-3-pentanol	30
7. 2,3,3-Trimethyl-2-butanol	26

In the meantime, the study of the octyl alcohols had been undertaken by Anderson (2) who condensed two of the methyl ethyl butyl carbinols with phenol to obtain rather low yields of condensation product.

<u>Alcohol</u>	<u>Yield (%)</u>
1. 3-Methyl-3-heptanol	25
2. 2,2,3-Trimethyl-3-pentanol	21

Snyder (3) repeated Anderson's work and then completed the investigation of the methyl ethyl butyl carbinols. In the case of the 2,2,3-trimethyl-3-pentanol, the condensation product obtained by these workers had different melting points.



Unfortunately, the same derivatives had not been prepared and it was impossible to ascertain whether the products were different, or the same, with varying degrees of purity.

<u>Alcohol</u>	<u>Yield (%)</u>
1. 3-Methyl-3-heptanol	80
2. 3,4-Dimethyl-3-hexanol	40
3. 3,5-Dimethyl-3-hexanol	61
4. 2,2,3-Trimethyl-3-pentanol	21

The study of the octyl alcohols was continued by Langdon (12) who condensed the dipropyl methyl carbinols.

<u>Alcohol</u>	<u>Yield (%)</u>
1. 3-Ethyl-3-hexanol	36
2. 3-Ethyl-4 methyl 3-pentanol	54

Huston and Guile (1) condensed the dimethyl amyl carbinols with phenol in an extension of the study of the octyl alcohols.

<u>Alcohol</u>	<u>Yield (%)</u>
1. 2 methyl 2-heptanol	70
2. 2,3-Dimethyl-2-hexanol	36
3. 2,4-Dimethyl-2-hexanol	59
4. 2,5-Dimethyl-2-hexanol	65
5. 2-Methyl-3-ethyl-2-pentanol	28
6. 2,4,4-Trimethyl-2-pentanol	65
7. 2,3,4-Trimethyl-2-pentanol	23
8. 2,3,3-Trimethyl-2-pentanol	2

A later publication by Huston and co-workers (13) corrected the yield of octyl phenol obtained in alkylation of phenol with 2,3,3-trimethyl-2-pentanol to 40%.

Huston and Meloy (14) completed the study of the octyl alcohols with the condensation of the methyl dipropyl carbinols with phenol.

<u>Alcohol</u>	<u>Yield (%)</u>
1. 4 Methyl 4-heptanol	65
2. 2,3 Dimethyl 3-hexanol	47
3. 2,3,4 Trimethyl 3-pentanol	60

Thus, a study of the alkylation of phenol with tertiary aliphatic alcohols initiated and developed fully by Huston and his co-workers in this laboratory, was completed through the octyl alcohols with the publication by Huston and Meloy in 1942. In the eight year period, twenty-nine tertiary aliphatic alcohols have been condensed with phenol, derivatives of the alkyl phenols were prepared, and the structures of all but three were proven by synthesis. The three alkyl phenols for which proof of structure is still lacking are: 2,2,3 trimethyl 3(para hydroxy) phenylmethane, 2,3,3 trimethyl 2(para hydroxy) phenylmethane, and 2,3,4 trimethyl 2(para hydroxy) phenylmethane.



## EXPERIMENTAL

### I. Preparation of Alcohols

#### A. 2,2,3-Trimethyl-3-Pentanol

This alcohol was first prepared by Clark and Jones (15) by the reaction of pinacolene and methyl magnesium bromide. Snyder (3) and VanDyke (6) also prepared the alcohol in the same manner. The procedure used in this work was quite similar with minor variations.

Six moles (144 grams) of dry magnesium turnings were placed in a five liter, three-necked flask equipped with a mercury-sealed mechanical stirrer, an Allihn condenser protected by a calcium chloride-soda-lime tube, and a Hershberg dropping funnel (16). About five milliliters of ethyl bromide were added, and after waiting a minute or two for the reaction to start, one hundred milliliters of ether were added. The remainder of six moles of ethyl bromide (654 grams) was diluted with five hundred milliliters of ether and added through the dropping funnel at the rate of two drops per second. When the reaction was proceeding satisfactorily as evidenced by brisk boiling of the ether, two liters of ether were added through the condenser. The remainder of the ethyl bromide solution was then added dropwise as rapidly as it was possible to do so without external cooling of the reaction flask. The time required to prepare the Grignard reagent was six hours.

The reaction mixture was analyzed by Gilman's (17) method, in which an aliquot was hydrolyzed with standard acid and back-

titrated with standard base. The yield of Grignard reagent obtained was 5.7 moles, 95% of theoretical.

A solution of five moles (500 grams) of pinacolene and five hundred milliliters of ether were then added to the stirred solution of ethylmagnesium bromide at the rate of one drop per second. The time for complete addition was ten hours. The reaction mixture was allowed to stand overnight before hydrolysis.

Hydrolysis was accomplished by pouring the mixture on ice. Sufficient 25% sulfuric acid was added (about 600 cc.) to dissolve the basic magnesium salts. The organic layer was separated and the aqueous portion extracted three times with 10% of its volume of ether. The ether extracts and the organic layer were combined and washed with water, 5% sodium carbonate solution, and water, and dried over anhydrous sodium sulfate.

The ether was distilled off through an eighteen inch Vigreux fractionating column and the residue fractionated by means of a heated Fenske column (250 x 16 mm.), packed with one-sixteenth inch glass helices, using a total condensation, partial take-off head.

Three hundred and twenty-five grams of the carbinol were obtained, a yield of 50%, based on the pinacolene used. The index of refraction of the carbinol was checked periodically as it distilled, to insure purity.

B.P. - 61-62° C./20 mm.

$n_D^{20}$  - 1.4358

Early runs in which the ketone was added more rapidly, gave only 35% yields as was obtained by VanDyke.

B. 2,3,3 Trimethyl-2-Pentanol

This alcohol was prepared by Horton and Hass (18) through the reaction of 2,3-dimethyl-2,3 epoxybutane (prepared in 15% yields from pinacolone) with ethylmagnesium bromide to obtain a yield of 38% based on the oxide. They also obtained the alcohol in 6% yields from acetone and tertiary amylmagnesium chloride. Huston and Guile (1) prepared the alcohol by synthesizing 3,3-dimethyl-2-pentanone and react it with methyl iodide, employing a modification of the Whitmore-Bradertscher procedure (19). Yields of 2-5% of the carbinol were obtained.

In 1904, Grignard (20) discovered the reaction of organic acids with alkylmagnesium halides which gives tertiary alcohols in satisfactory yields. Bailey (21) extended this work and prepared a large number of tertiary alcohols, using simple Grignards. These methods were applied in developing an improved method of synthesizing 2,3,3-trimethyl-2-pentanol in yields of 25%.

Briefly, the octanol was prepared in the following manner: Tertiary amylmagnesium chloride was prepared and carbonated by passing in carbon dioxide to yield the acid complex. Addition of excess methylmagnesium bromide yielded the carbinol complex which was hydrolyzed to obtain the carbinol. A detailed procedure for a two mole run of tertiary amyl chloride, yielding one-half a mole of carbinol, follows:



### 1. Preparation of Tertiary Amyl Chloride

The chloride was prepared by a procedure adapted from the preparation of tertiary butyl chloride (22). Tertiary amyl alcohol was shaken with excess concentrated hydrochloric acid for about ten minutes. Separation of the chloride, washing with sodium carbonate solution and water, drying over calcium chloride, and fractionation, gave a 60% yield of pure tertiary amyl chloride, B.P. 82-83° C./740 mm.

### 2. Preparation of Tertiary Amylmagnesium Chloride

The Grignard reagent was prepared in the usual manner. However, instead of using iodine as a catalyst, several milliliters of ethyl bromide were added to the magnesium, and when the reaction started, one hundred milliliters of ether were added through the condenser. Then addition of the amyl chloride was made, and when the reaction was proceeding satisfactorily, additional ether was added to the flask. For the two mole run, a total of nine hundred milliliters of ether was used. The rate of addition of the halide was critical and maintained at a rate of about two drops per three seconds. The time of reaction was four hours. The yield as determined by titration was 50-60%.

### 3. Carbonation of the Grignard Reagent

The procedure was taken from Organic Synthesis (23). Carbon dioxide, from a cylinder fitted with a needle-valve, was passed through a train consisting of a safety-flask, two concentrated sulfuric acid wash bottles, and a safety-flask, into the stirred Grignard reagent which had previously been cooled to 0°C. A solid carbon-dioxide-alcohol cooling bath was found more

efficient and convenient to handle than the ice-salt bath; recommended as a simple means of controlling the temperature of reaction. The time required to carbonate the Grignard reagent obtained in a two mole run was two to three hours.

#### 4. Preparation of Methylmagnesium Bromide (24)

Methyl bromide was generated in a three liter, one-necked flask, fitted with a condenser which was connected by glass tubing to a purification train. The train consisted of a safety-flask, three 25% sodium hydroxide wash bottles, a safety-flask, three concentrated sulfuric acid wash bottles, and a final safety-flask. The outlet was connected to a T-tube which served as the gas delivery tube. The other arm of the T-tube was fitted with a glass rod, to serve as a plunger to prevent plugging of the gas outlet tube. The plunger was held in place by a lubricated rubber sleeve, in much the same manner as a glycerine-sealed stirrer.

Seven hundred and fifty grams of sodium bromide were added to the generation flask which contained a solution of 235 grams of methanol, 540 grams of concentrated sulfuric acid and 50 milliliters of water. The flask and its contents were then heated gently on a sand bath.

The reaction flask was a three liter, three-necked flask, fitted with an Allihn condenser protected by a calcium chloride-soda lime tube, and a mercury-sealed stirrer. Eighty-four grams (3.5 moles) of magnesium turnings, sufficient to prepare slightly more than three moles of Grignard reagent, were placed in the flask, and three hundred milliliters of ether added. The gas

delivery tube was placed in the third neck of the flask with the end extending below the surface of the ether.

As an added safety measure, a two-way stopcock was inserted between the gas generator and the purification train, so that excess methyl bromide could be passed out of the system, if necessary, to control the reaction.

When the reaction started, an additional eight hundred milliliters of ether was added to the reaction flask. The reaction was completed when all the magnesium had been consumed. Time for completion was six hours.

#### 5. Addition of Methylmagnesium Bromide to the Acid Complex

Estimating the yield of acid to be about one mole, three moles of methyl Grignard provided an adequate excess, since only two moles were required theoretically.

The flask containing the acid complex was fitted with a "goose-neck" glass bend and a condenser set for distillation. The Grignard reagent was added through a dropping funnel quite rapidly, in a stream. There was only a slight reaction and the ether began to distil. Ether was removed by distillation until the reaction mixture was syrupy and the temperature had risen to 60°C. About one and one-half liters of ether were collected. Five hundred milliliters of anhydrous benzene were added to the residue and the solution refluxed at 65-70°C. for four hours. The addition of Grignard reagent, distillation of ether, and reflux was completed in a day. (Note- It was suggested by Dr. G. L. Geerner of this laboratory that it might be

safer and more convenient to add the benzene to the acid complex prior to the addition of the Grignard reagent. Then, after addition of the Grignard reagent, solvent may be distilled off until the proper temperature is reached.)

## 6. Isolation of the Carbinol

The complex mixture was hydrolyzed with ice and sufficient 25% sulfuric acid to dissolve the basic salts. About seven hundred milliliters of acid were required.

After the usual separation and extraction of the aqueous layer with benzene, the combined extracts were washed with water, 5% sodium hydroxide, water, and dried over anhydrous sodium sulfate. Neutralization of the alkali extract yielded a small amount of dimethyl ethyl acetic acid. The benzene was removed by distillation and the residue was fractionated by means of a Fenske column. The yield of carbinol was 25% of theoretical, based on the tertiary amyl chloride.

B.P. - 63-64°C./20mm.

$n_D^{20}$  - 1.4413

## II. Condensations

Most of the earlier workers in this laboratory who condensed tertiary alcohols with phenol used either of two methods. In the first procedure devised by Huston and Hsieh (10), the alcohol and phenol were dissolved in petroleum ether, and the aluminum chloride was added in portions. The second procedure developed by Huston and Hedrick (11), consisted of suspending the aluminum chloride in petroleum ether and adding a solution of phenol and



carbinol in petroleum ether dropwise from a dropping funnel.

Attempts to condense phenol with the carbinols under consideration, by the method of Huston and Hsieh (10), gave negative results, the phenol being recovered quantitatively and the alcohol lost through decomposition by aluminum chloride.

The method developed by Esterdahl (25) to effect condensation of some secondary alcohols with phenol, and later used by Huston and Meloy (14) in the condensation of tertiary alcohols, proved successful. In this method the aluminum chloride was added to a solution of phenol in the carbinol, no solvent being used.

#### A. 2,3,3-Trimethyl 2-Pentanol and Phenol

A one liter, three-necked flask was fitted with a glycerine-sealed mechanical stirrer and a two-necked addition tube bearing a calcium chloride tube and a thermometer reaching to the bottom of the flask. The third neck was closed with a well-rolled cork.

Two moles (185 grams) of phenol were dissolved in one mole (130 grams) of the carbinol. The solution was placed in the flask and .5 mole (67 grams) of aluminum chloride was added in portions. Initial additions were of the order of two grams. The temperature rose to 35°C. almost immediately and was maintained by controlling the rate of addition.

After some aluminum chloride was added, the solution became light brown, and with continued addition of the catalyst, it turned deep purple. Only small amounts of hydrochloric acid were evolved as revealed by testing with ammonia placed at the outlet.

After two-thirds of the aluminum chloride had been added, the reaction mixture became quite viscous, necessitating slower addition of catalyst. As stirring continued, after a portion of aluminum chloride was added, the mixture became considerably less viscous as the catalyst was incorporated into the reaction mixture and given the opportunity to react. The time required for complete addition was seven hours.

Heat was then applied by means of a water bath and a temperature of  $40^{\circ}\text{C}$ . was maintained for two hours. During this time, greater quantities of hydrochloric acid were evolved than were observed in the earlier stages of the reaction. After heating, the reaction mixture was a dark orange color.

After standing overnight, the mixture was hydrolyzed by pouring it slowly on cracked ice, with stirring. The organic layer was separated and the aqueous layer extracted twice with 10% of its volume of ether. The ether extracts were added to the phenolic layer and the solution washed with a 5% solution of sodium bicarbonate and then with water. The ethereal solution was dried over anhydrous sodium sulfate.

The ether was removed by distillation and the residue fractionated through a 10 inch Vigreux column bearing a 12 mm. side-arm. The wide sidearm helped prevent plugging due to crystallization. As a further aid in fractionation, the column was heated by means of a coil of Chromel wire.

The following fractions were obtained from 1.25 moles of carbinol:

- I. 80-120°C./12 mm. - 130 grams - phenol
- II. 120-150°C./12 mm. - 15 grams - mixture
- III. 150-175°C./12 mm. - 145 grams - alkyl phenol
- IV. residue - 10 grams

Fraction III was refractionated several times and the following fractions taken:

- I. 165-167°C./12 mm. - 40 grams
- II. 167-170°C./12 mm. - 74 grams
- III. 170-172°C./12 mm. - 24 grams

The total weight of material in these fractions was 138 grams and may be considered as the crude alkyl phenol, a yield of 53% of the theoretical.

The crude material was purified by recrystallization from hexane. It was extremely soluble in the solvent at room temperature and crystallization was accomplished by dissolving the phenol in about three milliliters of solvent per gram of solid and allowing it to crystallize in the icebox. There was only approximately 40% recovery, so that it was necessary to concentrate the mother liquor to about half its volume to take a second crop of crystals. A third crop was recovered in the same manner. Products having approximately the same melting point were combined and recrystallized in the same fashion. Gradually, two main fractions which were indicated in the first crystallization, were isolated; one melting at about 75°C. and the other at about 100-110°C. As the products became purer, more solvent was required, and in the last stages of purification, about 10 milliliters of hexane per gram

of solid was used with the lower melting product, and about 20 milliliters per gram for the high melting product. In all, a total of seventy crystallizations were required to separate the two products which crystallized as tiny white needles.

I. m.p. 80-81°C. Yield - 28 grams

II. m.p. 118-119°C. Yield - 6 grams

Fraction I is 2,2,3-trimethyl-3(para hydroxy) phenylpentane and fraction II, the normally expected product, is 2,3,3-trimethyl-2(para hydroxy) phenylpentane.

Some material melting below pure I remained and was undoubtedly impure I which would be further purified by additional crystallizations. Twenty-five grams of material melting in the range of 65-75°C. remained.

Material which boiled below 165°C./15 mm. on redistillation of the alkyl phenol fraction, was added to fraction II, boiling at 120-150°C./12 mm. and the combined fraction redistilled several times to give:

I. 123-130°C./12 mm. - 11.5 grams

II. 155-165°C./12 mm. - 5 grams

Fraction I was extracted five times with 500 milliliters of boiling water. The mixture was filtered hot, the insoluble oil remaining on the paper, being returned to the flask for the next extraction. On cooling, the water solution, fine needles of tertiary butyl phenol separated. The tertiary butyl phenol was isolated in very small quantities, only two grams being recovered.

### B. 2,2,3-Trimethyl-3-Pentanol and Phenol

The procedure used was identical to that used in Part A.

The fractions isolated were:

- |                        |                                  |
|------------------------|----------------------------------|
| I. 80-120°C./13 mm.    | Yield - 130 grams - Phenol       |
| II. 120-150°C./13 mm.  | Yield - 20 grams - mixture       |
| III. 150-175°C./13 mm. | Yield - 140 grams - alkyl phenol |
| IV. residue            | 12 grams                         |

Fraction III was redistilled several times and the following fractions taken:

- |                        |            |
|------------------------|------------|
| I. 164-168°C./13 mm.   | - 13 grams |
| II. 166-169°C./13 mm.  | - 98 grams |
| III. 169-171°C./13 mm. | - 21 grams |

Most of this material came over in a fairly narrow boiling range and the whole could be considered the crude alkyl phenol. The weight of product obtained, as indicated above, was 132 grams, a yield of 51% of the crude alkyl phenol, based on 1.25 moles of the carbinol.

The crude material was recrystallized as described in Part A, and two products were obtained as tiny white crystals from hexane.

- |                     |                   |
|---------------------|-------------------|
| I. m.p. 79-80°C.    | Yield - 31 grams  |
| II. m.p. 118-119°C. | Yield - 8.5 grams |

Fraction I is the normal product, 2,2,3-Trimethyl-3(para hydroxy) phenylpentane, and fraction II, the rearranged product, 2,3,3-trimethyl-2(para hydroxy) phenylpentane.



As in Part A, there was 25 grams left which melted somewhat lower than pure I, which could be further purified by additional recrystallizations.

Redistillation of the alkyl phenol fraction gave a small quantity of lower boiling material which was added to the 120-150° fraction, which was then redistilled several times to give two very impure fractions.

I. 118-143°C./13 mm. - 12 grams

II. 143-165°C./13 mm. - 12 grams

Fraction I was extracted five times with 500 milliliters of boiling water to obtain three grams of tertiary butyl phenol.

### III Preparation of derivatives

#### A. $\alpha$ Naphthylurethanes

The method of French and Wirtel (26) was used. To one gram of the alkyl phenol was added one milliliter of  $\alpha$  naphthyl isocyanate. A few drops of an ether solution of trimethyl amine were added to catalyze the reaction. The reaction mixture, protected from moisture by a calcium chloride tube, was warmed on the steam-bath for one-half hour. On cooling, it solidified. The solid was extracted several times with boiling ligroin (b.p. 90-120°C.), in twenty milliliter portions, and the insoluble material filtered off. The  $\alpha$  naphthylurethane crystallized as white plates and was recrystallized three times from about twenty-five milliliters of ligroin to a constant melting point.

#### B. 3,5 Dinitrobenzoates

The pyridine method of preparation was taken from Shriner and Fuson (27). The product crystallized in fine, white needles

from alcohol and was recrystallized twice to a constant melting point.

### C. Benzoates

The same method was used as in the preparation of the dinitrobenzoates. The product crystallized either as white needles or clusters from dilute alcohol.

Oiling occurred when the hot alcoholic solution was diluted with water to the proper extent and then allowed to cool. The difficulty was overcome by diluting a cold alcoholic solution of the product with water to incipient cloudiness. The cloudiness was discharged with a drop of alcohol and the benzoate crystallized in the ice-box. If oiling resulted, additional alcohol was added to clarify the solution.

The benzoate of tertiary butyl phenol crystallized easily as white plates, from alcohol or dilute alcohol.

Mixed melting points of the corresponding compounds isolated from each condensation, and of their derivatives, showed no depression. Tert butyl phenol and its benzoate checked with that which was reported by Husten and Ksieh (10).

### Analysis

The  $\alpha$  naphthyl urethanes were analysed for nitrogen by the semi-micro Kjeldahl method (26). Samples of fifty to sixty milligrams were used, and the ammonia evolved was absorbed in 4% boric acid and titrated with N/100 hydrochloric acid.

DERIVATIVESA. From Condensation of 2,3,3-Trimethyl-2-Pentanol

	M.P.	$\alpha$ Naphthyl- urethane		3,5 Dinitro- Benzoate		Benzoate	% N Found* in $\alpha$ Naphthylurethane
I	2,3,3-Trimethyl-2-(Para Hydroxy) Phenylpentane	118- 119	158-9	168-0	---	3.76	
II	2,2,3-Trimethyl-3-(Para Hydroxy) Phenylpentane	80-81	143-4	139-40	57-8	3.82 3.84	
III	2-Methyl-2-(Para Hydroxy) Phenylpropane	96-7			80-81		

B. From Condensation of 2,2,3-Trimethyl-3-Pentanol

	M.P.	$\alpha$ Naphthyl- urethane		3,5 Dinitro- Benzoate		Benzoate	% N Found* in $\alpha$ Naphthylurethane
I	2,2,3-Trimethyl-3-(Para Hydroxy) Phenylpentane	79-80	143-4	139-40	59-60	3.63 3.68	
II	2,3,3-Trimethyl-2-(Para Hydroxy) Phenylpentane	118-9	158-9	168-9	---	3.66 3.80	
III	2-Methyl-2 (Para Hydroxy) Phenylpropane	96-7			81-82		

\*Calculated for  $C_{25}H_{29}O_2N$  - N = 3.73%

### DISCUSSION

Several theories have been proposed in an attempt to explain the mechanism of alkylation of aromatic nuclei with alcohols in the presence of dehydrating catalysts, but no one theory seems completely satisfactory. These theories have been thoroughly discussed by previous workers in this laboratory and need only be mentioned here.

Huston and co-workers had observed in their early investigations that the alpha carbon atom of an alcohol must be under strain in order to create an active hydroxyl group. This generalization, as proven experimentally, holds true for aromatic alcohols and unsaturated aliphatic alcohols.

Saturated aliphatic alcohols exhibit varying degrees of activity, depending on their structure. Tertiary alcohols have the most active hydroxyl group and condense most readily; secondary alcohols condense less readily; while primary alcohols which are most acidic, do not condense at all under ordinary conditions.

Tsukervanik and Nazarova (29) proposed that an addition compound of the type  $AlCl_2OR$  and  $HCl$  were first formed. The ether decomposed to the olefin which then reacted with hydrochloric acid to form an alkyl halide. Thus, in the presence of excess aluminum chloride and an aromatic ring compound, all the components necessary for a typical Friedel-Crafts type reaction are present.

A dehydration mechanism was proposed by McKenna and Sowa (30) to explain the alkylation of benzene by alcohols. The alcohol was said to be dehydrated first, followed by addition of the ring nucleus to give the alkyl benzene.

In similar type alkylations, McGreal and Niederl (31) and Welsh and Drake (32) also proposed the dehydration mechanism.

Rearrangement of alkyl phenyl ethers has been proposed as a possible mechanism, since it is known that such rearrangements occur to give good yields of alkyl phenols (33).

In this laboratory, work carried out by Ewart (34) in 1938 led to the proposal that addition compounds of aluminum chloride, the alcohol, and phenol are first formed. This complex molecule being unstable, rearranges to a more stable configuration by splitting out aluminum chloride and water to yield the alkyl phenol.

These mechanisms all attempt to explain the formation of the alkyl phenols, but do not explain the rearrangement which apparently occurred during condensation of the alcohols used in this investigation.

In each condensation, two products were isolated. The compounds obtained in each case, which melted at 118-119°C. were identical as shown by their mixed melting point and that of their derivatives. The same was true of the compounds melting at 79-80°C. and 80-81°C. As further evidence, the analysis of the alpha naphthyl urethanes of all four compounds showed them to be isomeric.

A reasonable explanation of this phenomena may be developed, based on the work of Huston and Avuapara (35). They studied the fragmentation of alcohols by condensing highly branched alcohols with benzene. Alkyl benzenes of lower molecular weight were isolated and it was shown that only by rearrangement and fission of

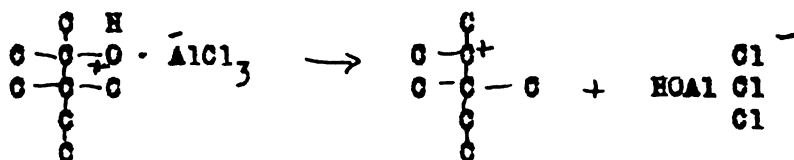
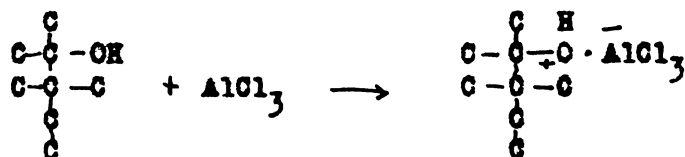


the original alcohol could these products be formed. A mechanism was proposed in which an initial reaction between aluminum chloride and the alcohol yielded a complex molecule which decomposed to produce an alkyl cation or carbonium ion. Some of the cation which failed to condense normally could form the alkyl halide or it could lose a proton to form the alkene. The alkene could then add a proton to give two carbonium ions in equilibrium, one of which had a tendency to rearrange to a tertiary butyl configuration. They further proposed that a tertiary butyl group adjacent to a positive carbon or an unsaturated carbon sets up a condition favorable to chain rupture. In this manner, the isolation of low molecular weight alkyl benzenes were very satisfactorily explained.

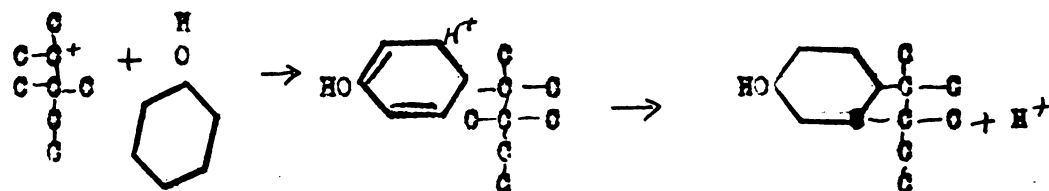
Subsequent investigations by Barrett (24) and VanDyke (6) supported this theory.

Applied to the alcohols under consideration, the mechanism proposed above would lead to the following series of reactions:

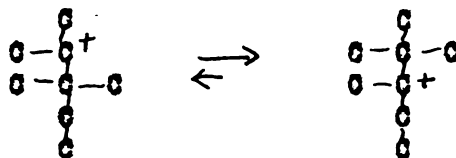
For 2,3,3-trimethyl-2-pentanol



In normal alkylations, the carbonium ion will react with phenol with the loss of a proton as shown by Price (36)



The portion which fails to condense normally (in this case practically all of it) would have a tendency to rearrange, as follows:



It might be considered that the methyl group migrates between the two forms, with a greater tendency to form the tertiary butyl configuration with its lower energy level and greater stability.

Then each carbonium ion reacts with phenol to form the alkyl phenol.

Isolation of tertiary butyl phenol was not unexpected in view of the findings of Huston and coworkers in the benzene condensations with branched alcohols. Undoubtedly, rearrangement to the tertiary butyl configuration followed by scission of the molecule led to formation of the tertiary butyl cation which condensed with phenol.

The same series of reactions may be applied to the condensation of 2,2,3-trimethyl-3-pentanol. The fact that the two products isolated were identical to those obtained in the condensation of 2,3,3-trimethyl-2-pentanol corroborates the belief that an equilibrium exists between the two carbonium ions. The fact that

rearrangement may occur with 2,2,3 trimethyl 3-pentanol was shown by Laughlin in an unpublished research (37). On dehydration of the alcohol, the normal product and a lesser amount of the rearranged product was obtained.

The structure assigned to each of the compounds isolated was based on the mechanism of reaction. Since the tertiary butyl configuration is the most stable, the product occurring in larger quantities would be 2,2,3-trimethyl-3 (para hydroxy) phenylmethane and the other product, as supported by this theory, would be 2,3,3-trimethyl-2 (para hydroxy) phenylmethane.

The para position was assigned to the alkyl groups by analogy. In all of the twenty-six tertiary alkyl phenols whose structures have been proven by synthesis in this laboratory, the alkyl group was substituted para to the hydroxyl group.

SUMMARY

1. 2,3,3-trimethyl-2-pentanol and 2,2,3-trimethyl-3-pentanol were condensed with phenol in the presence of aluminum chloride.

2. Isolation of 2,3,3-trimethyl-2 (Para hydroxy) phenylmethane and 2,2,3-trimethyl-3 (para hydroxy) phenylmethane from each condensation furnishes strong evidence of rearrangement of both alcohols.

3. Fragmentation of the alcohols to a slight degree was proven by isolation of small amounts of tertiary butyl phenol in each case.

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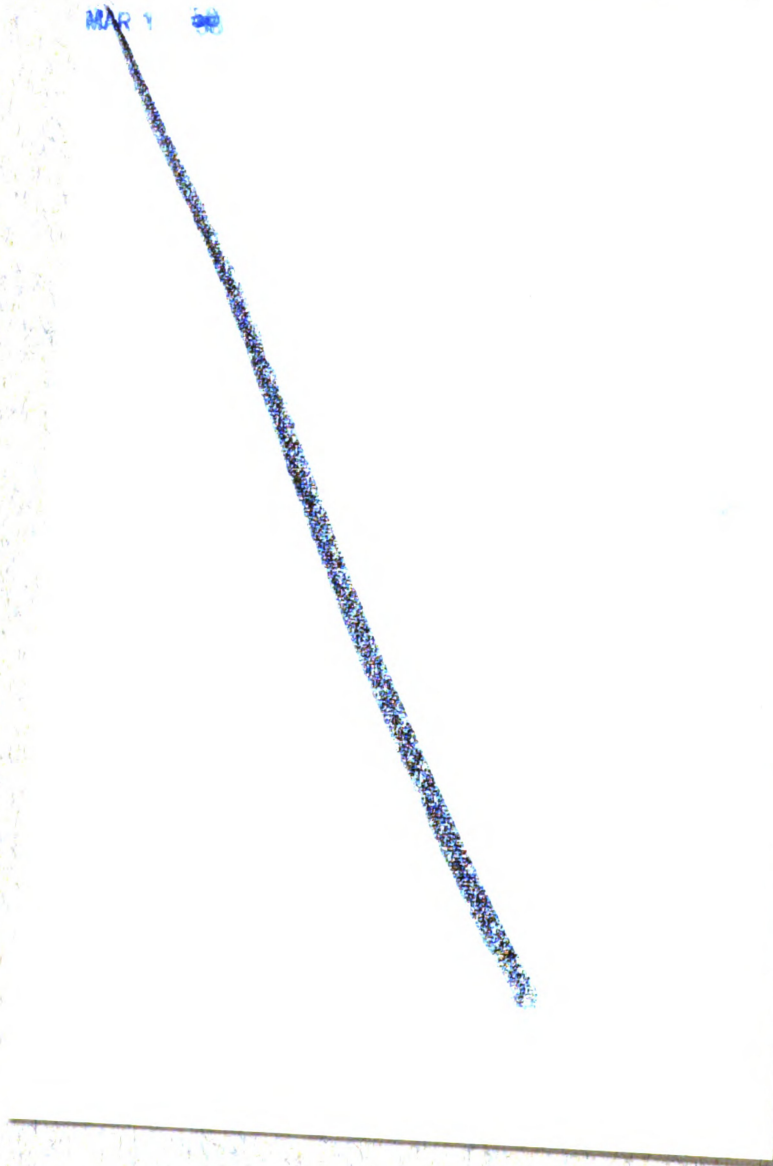
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