

THE CONDENSATION OF SECONDARY MEXYL ALCOHOLS WITH PHENOL IN THE PRESENCE OF ALUMINUM CHLORIDE

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THE CONDENSATION OF SECONDARY HEXYL ALCOHOLS WITH PHENOL IN THE PRESENCE OF ALULINUA CHLORIDE

by

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Introduction

The work on condensation reactions, using aluminum chloride as a catalyst, was started in this laboratory in 1916 when Huston and Friedemann (3) reported the condensation of benzyl alcohol with benzene. Since that time Huston and co-workers have studied the condensation of saturated alighatic alcohols and several mixed alighatic-aromatic alcohols with benzene and benzene nuclei in the presence of this same catalyst.

In 1936 Huston and Hsieh (11) reported the condensation of some simple tertiary alcohols with phenol. This was followed closely by the work of Huston and Hedrick (16) in 1937, and of Huston and Guile (20) in 1938, who investigated the tertiary heptyl and tertiary octyl alcohols respectively.

The secondary anyl alcohols were condensed with phenol by Huston and Esterdahl (24) in 1940.

To further investigate the scope of this reaction the secondary hexyl alcohols have been condensed with phenol in the presence of aluminum chloride.

Historical

A review of the literature reveals that many papers have been written concerning the alkylation of phenols. There are three general methods for the preparation of alkyl phenols, all of them involving the use of a catalyst. First, the direct alkylation of phenols using alkyl halides, alcohols, acyl chlorides, and alkenes in the presence of a variety of catalysts. Second, the replacement of a variety of groups by hydroxyl in alkyl bensene derivatives. And last the rearrangement of alkyl phenyl ethers to yield alkyl phenols.

A great variety of catalysts have been used in these reactions; namely, concentrated sulfuric acid, acetic acid, perchloric acid, phosphoric acid, and magnesium and aluminum chlorides.

This paper deals with the alkylation of phenol, using alcohols and anhydrous aluminum chloride, so only those papers dealing with the same reagents will be included in this review. It must be mentioned, however, that in 1884 Auer (1), using a mixture of zinc and zinc chloride as a catalyst, condensed simple aliphatic alcohols with phenol and obtained yields of alkyl phenols. Several years later, in 1897, Nef (2) condensed benzyl alcohol with benzene in the presence of aluminum chloride and reported a small yield of diphenyl methame. This work was repeated in 1916 by Huston and Friedemann (3) and a thirty per-cent yield of diphenyl methane was reported. This work was followed by that of Huston (4) in which benzyl alcohol was condensed with phenol, anisole, and phenetole in a similar manner as with benzene. He reported yields of forty five to fifty per-cent of the alkylated products. This successful work led to further investigation concerning the possibilities of this reaction. Negative results were obtained by Huston and Sager (5) in 1926 when attampts were made to condense phenyl propyl and phenyl ethyl alcohols with benzene. These same workers reported that methyl, ethyl, propyl, iso-propyl, n-butyl, iso-butyl and iso-anyl alcohols did not condense with benzene under similar conditions. They found, however, that allyl alcohol did condense with benzene to give a sixteen per-cent yield of allyl benzene. Allyl alcohol was condensed with phenol by Huston and Newmann (6) in 1933. From this it was concluded that aluminum chloride favored condensation only when the alpha carbon of the alcohol was double bonded or the member of a benzene ring.

To substantiate this conclusion Huston and co-workers (7) condensed diphenyl carbinol, methylphenyl carbinol, and ethylphenyl carbinol with phenol and obtained good yields of condensation products. Diphenyl carbinol, in which both carbon atoms adjacent to the carbinol group are members of a benzene ring, gave a much larger yield of alkylated product than benzyl alcohol under the same conditions. This, they pointed out, was definite evidence that aromatic unsaturation has a great effect on the activity of the hydroxyl group.

In 1933 it was reported by Huston and Davis (8) that triphenyl carbinol did not condense with bensene. The product isolated was triphenyl methane and not the expected tetraphenyl methane.

The condensation of benzyl alcohol with o-cresol, p-cresol, and m-cresol in the presence of aluminum chloride was reported from this laboratory by Huston and co-workers (9). In each case, two monosubstituted and one disubstituted derivative was obtained. To investigate the effect of strain in cycloalkyl carbinols, Huston and Goodemoot (40) condensed cyclohexyl, cyclopentyl, and cyclobutyl carbinols with benzene. They found that the carbinols showed a progressive decrease in activity as the number of carbons in the ring was increased from four to six.

Investigation of several diaryl-alkyl and dialkyl-aryl carbinols by Huston and co-workers (10) showed that they did not condense with benzene, but were dehydrated, yielding the corresponding unsaturated products.

In 1936 Huston and Hsieh (11) investigated some saturated aliphatic alcohols and reported that primary alcohols did not condense with benzene or phenol, secondary alcohols did condense with benzene and phenol giving small yields, and tertiary alcohols condensed with phenol under the influence of aluminum chloride. These workers also condensed some tertiary alcohols with toluene, m-cresylmethyl ether and anisole.

Previous to this work, Sowa Hennton and Nieuwland (12) reported the condensation of several primary alcohols with phenol. However, they used boron trifluoride as the catalyst. The same year it was reported by Tsukervanik and Nazarova (13) that tertiary alcohols condensed with phenol in the presence of excess aluminum chloride to give good yields of alkyl phenols. Under the same conditions secondary alcohols condensed to give insignificant yields of the desired products.

In 1934 Huston and Fox (14) condensed tertiary butyl, tertiary amyl, and the three possible tertiary hexyl alcohols with benzene.

Further investigation in this field led to the condensation of the higher tertiary alcohols with benzene and phenol; namely the heptyls and octyls. Huston and Binder (15) condensed the tertiary heptyl alcohols with benzene. and Huston and Hedrick (16) condensed the same alcohols with phenol. Several workers have studied the condensation of the tertiary octyl alcohols with benzene. Huston and Anderson (18) condensed methyl ethyl n-butyl and methyl ethyl tertiary butyl carbinols with benzene and phenol. Huston and Sculati (17) studied the condensation of some dimethyl anyl carbinols with bensene. Huston and Cline (39) and Huston and Breining (19) worked with the methyl dipropyl and propyl disthyl carbinols respectively. The condensation of some dimethyl anyl carbinols with benzene was reported by Huston and Wasson (21) in 1940. The dimethyl anyl carbinols were condensed with phenol by Huston and Guile (20) in 1939, and it was reported that fragmentation of the carbon chain occurs when the anyl radical is highly branched. Some alkyl phenols of lower molecular weight were formed as a result of this fragmentation.

In 1940 Huston and Jackson (22) reported the condensation of some diphenyl alkyl carbinols with phenol, and Huston and Hughes (23) continued the investigation of dialkyl aryl carbinols in regard to their condensation with phenol.

The same year Huston and Esterdahl (24) condensed the secondary amyl alcohols with phenol and reported that a mixture of products was formed as a result of dehydration of the alcohol followed by condensation. At the present time the condensation of the methyl dipropyl carbinels with phenol, and the condensation of several secondary alcohols with benzene are being studied in this laboratory by Meloy and Kaye.

This work is a continuation of the study of secondary alcohols. It specifically deals with the condensation of the secondary hexyl alcohols with phenol under the catalytic influence of anhydrous aluminum chloride.

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Theoretical

The work of Huston and co-workers has shown that unsaturation of the alpha carbon atom, whether it was double bonded or the member of a bensene ring, favored condensation of alcohols with bensene or bensene nuclei in the presence of aluminum chloride. This strained condition results in an unstable bond between the oxygen and carbon atoms, greatly increasing the activity of the hydroxyl group.

This type of bond is present in benzyl (a) and allyl (b) alcohol, both of which condense easily with phenol and benzene. The electron pair between the OH group and C atom is attracted strongly by both groups, resulting in the type of bond found in a molecule of chlorine. :Cl:Cl: This bond is known to be unstable and very active. Extending this examination to the saturated primary (c), secondary (d), and tertiary (e) alighatic alcohols, a different electronic arrangement is found. The attraction of the carbon atom for the electron pair between C and O decreases progressively as we go from primary to secondary to the tertiary alcohols. This may be shown experimentally by the case of replacement of hydroxyl by halogen of a halogen acid, and the case of dehydration of tertiary alcohols. This same condition exists to a lesser extent in secondary alcohols, however, the type of bond present in both cases is similar to that found in a molecule of hydrogen chloride, H :Cl:. These conditions may be represented electronically by the following formulas.

In view of this tertiary alcohols should condense readily with bensene and phenol, secondary alcohols less easily and primary alcohols only under special conditions. Experimental evidence bears this out.

Although extensive work has been done in the field of condensation reactions, and several mechanisms proposed to explain the path of the reactions, no one mechanism has been conclusively established. The situation is further complicated due to the variety of catalysts and conditions employed by different workers. In discussing three of the proposed mechanisms, a tertiary alcohol will be used for convenience, pointing out each time the application of the mechanism to a secondary alcohol.

The mechanism proposed by Tsukervanik and Nazarova (13) may be presented by the following equations, using as an example tertiary butyl alcohol.

- (A) $(CH_3)_3 COH + AlCl_3 \rightarrow AlCl_2 OC(CH_3)_3 + HCl$
- (B) $Alcl_2OC(CH_3)_3 \rightarrow CH_3-C=CH_2 + Alcl_2OH$ CH₃
- (C) CH_3 -C=CH₂ + HCl \rightarrow (CH₃)₃C-Cl CH₃
- (D) $(CH_3)_3C-C1 + C_6H_6 \rightarrow (CH_3)_3C-C_6H_5 + HC1$

This theory proposes as intermediates an alkene (B), and an alkyl chloride (C) formed by the addition of HCl to the alkene. The chloride then condenses with the hydrocarbon (D) (Friedal-Craft reaction) in the presence of excess aluminum chloride to form the alkyl bensene. Applying this mechanism to a secondary alcohol, such as methyl sec-butyl carbinol, the reaction could proceed by the formation of the following intermediates.

$$\begin{array}{ccccc} H & CH_3 & H & CH_3 \\ CH_3 - C - CH_2 - CH_3 & + & AlCl_3 & \longrightarrow & CH_3 - C = C - CH_2 - CH_3 + & HCl & + & AlCl_2OH \\ OH & & H & CH_3 \\ CH_3 - C = & C - CH_2 - CH_3 & + & HCl & - \rightarrow & CH_3 - C - & C - CH_2 - CH_3 \\ H & Cl & H & Cl \end{array}$$

The HCl formed in the first equation would add to the dehydration product of the alcohol according to the rule of Markownikoff, and a tertiary alkyl chloride would result. This tertiary hexyl chloride would then condense with phenol or benzene to yield a tertiary alkyl derivative.

In criticism of this theory it seems unlikely that an aluminate would be formed as in equation (A), due to the fact that it is difficult to replace the hydroxyl hydrogen of a tertiary alcohol. However, the hydroxyl hydrogen of a secondary alcohol is more labile and could be replaced with less difficulty. Furthermore, if this mechanism is correct, HCl should not be liberated during the first three steps of the reaction. Hedrick (16), investigating this theory, found that heat and HCl were instantly evolved, and when phenol was added to the mixture no evidence of reaction was noted. A small yield of alkyl phenol was reported.

A similar mechanism is advanced by McKenna and Sowa (25), except that an alkene is the only intermediate formed during the condensation. They have shown that when benzene is alkylated with alcohols using boron trifluoride as a catalyst, the alcohol is first dehydrated and then the alkene condenses with the hydrocarbon.

CH3-CH2-CH2-CH2-OH + BF3 \longrightarrow CH3-CH2-C = CH2 + H2O H CH3-CH2-C = CH2 + C₆H₆ $\xrightarrow{\text{BF3}}$ CH₃-CH₂-C = C₆H₅ CH₃-CH₂-C = CH₂ + C₆H₆ $\xrightarrow{\text{BF3}}$ CH₃-CH₂-C = C₆H₅ As evidence for this mechanism they state that normal and secondary alcohols give identical products as do the iso and tertiary isomers.

A like mechanism is suggested by McGreal and Niederal (26) using sine chloride as the catalyst. This mechanism was extended to alcohole such as diphenyl carbinol by Welsh and Drake (27). They suggest that alcohole of this type may split out water from the OH of the carbinol group and a nuclear hydrogen of the bensene ring.

There is little evidence against this mechanism since it has been shown by many workers (28) that alkenes do condense with aromatic hydrocarbons in the presence of aluminum chloride.

In contrast to the work of McKenna and Sowa, Huston and Sager (5) reported that primary alcohols did not condense with bensene in the presence of aluminum chloride under ordinary conditions. However, McKenna and Sowa used ZnCl₂ as a satalyst and carried out the reaction at a higher temperature than employed in the Huston method.

There is some evidence to show that alkyl phenyl ethers rearrange in the presence of a catalyst to form alkyl phenols. Smith (29) reported the rearrangement of several alkyl phenyl ethers when treated in the cold with equal molecular portions of aluminum chloride. The ethers were prepared from alkyl halides and the alkali salt of the phenol.

 $C_6H_5ONa + R-C1 \rightarrow C_6H_5OR + NaC1$

C6H50R + Alc13 --- RC6H40H

Similar rearrangements have been reported by numerous workers (30), and it may be concluded that if others are formed during the reaction they may rearrange to alkyl phenols.

When allyl bromide and sodium phenolate are brought together in an alcohol medium a 90% yield of allyl ether is obtained, but in a bensene medium there is only a 30% yield of the ether and a 70% yield of o-allyl phenol. Thus Claisen (31) points out that an ether is not a necessary intermediate, for phenyl alkyl ethers do not rearrange to the phenols under the condition of formation.

This ether formation theory is also refuted in part by the work of Huston and co-workers (4) (11). Good yields of condensation products have been reported from reactions in which there is no possibility of ether formation.

Many addition products of aluminum chloride have been reported (32), and with this in mind Huston and Evert (33) began an investigation of similar complexes involving alochols and phenol. Briefly this theory is: A complex molecule is formed between the outer shell of electrons of aluminum chloride and the reacting substances. The resulting poly-molecule is not stable at the reaction temperature, and the atoms rearrange to form stable compounds. This theory, although promising, does not explain many of the results obtained in this laboratory.

Experimental

I Preparation of Alcohols

Four of the alcohols condensed were prepared by the following method (38).

(1) <u>3-methyl pentanol-2</u>

In a dry three liter triple necked flask equipped with reflux condenser, mercury sealed stirrer, and dropping funnel was placed 2.4 moles of dry magnesium turnings and 100 ml. of anhydrous ether. The reaction was protected from carbon dioxide and moisture in the air by soda-lime tubes on the condenser and dropping funnel. Two moles of secondary butyl bromide dissolved in 120 ml. of anhydrous ether was then added dropwise over a period of three hours.

After the reaction started the flask was cooled in a water bath to prevent loss of ether by vigorous refluxing.

The Grignard reagent thus prepared was allowed to stand overnight, cooled to -5° C. in an ice-salt mixture and then 1.8 moles of freshly distilled acetaldehyde (34) in 120 ml. of anhydrous ether was added as rapidly as possible keeping the temperature below 10° C..

After standing a short time the reaction mixture was filtered from unused magnesium and decomposed by pouring on 600 gms. of ice. The precipitated magnesium compounds were dissolved with dilute hydrochloric acid while the temperature was kept at 0° C. by the addition of ice. The resulting two layers were separated and the aqueous layer extracted with three portions of ether. The combined ether solutions were washed with dilute sodium carbonate solution, then with water and finally dried over anhydrous potassium carbonate for several hours. The ether was removed and the residue fractionated, using a modified Claisen flask.

Boiling range of fraction used, 134-137°C.

Yield was 46% of the theoretical.

(2) <u>3,3-dimethyl butanol-2</u>

This alcohol was prepared by the method described above except that tertiary butyl bromide was used.

Boiling range of fraction used, 119-121°C.

Yield was 27% of the theoretical.

(3) <u>Hexanol-3</u>

The same general procedure was followed except that the ethyl Grignard reagent was prepared from ethyl bromide, followed by the addition of normal butyraldehyde.

Boiling range of fraction used, 133-136°C.

Yield was 54.5% of the theoretical.

(4) <u>4-methyl pentanol-3</u>

Prepared from the ethyl Grignard reagent and iso-butyraldehyde.

Boiling range of fraction used, 125-128°C.

Yield was 63% of the theoretical.

<u>Hexanol-2</u> and <u>4-methyl pentanol-2</u> were obtained from the stock room and twice redistilled before using.

Alcohols condensed were:

- (1) 3-methyl pentanol-2
- (2) 3,3-dimethyl butanol-2
- (3) hexanol-3
- (4) 4-methyl pentanol-3
- (5) hexanol-2
- (6) 4-methyl pentanol-2

II Condensations with Phenol

The six secondary hexyl alcohols were condensed with phenol by the two general methods used by numerous workers in this laboratory.

(1) The first method employed by the writer was similar to the one used by Huston and Guile (20) except that the reaction flask was cooled only when the temperature exceeded 50° C. This method proved unsatisfactory due to the formation of a resinous complex between the phenol, alcohol and aluminum chloride that greatly hindered stirring of the mixture.

After preliminary investigation to determine the relative amounts of reactants necessary for a maximum yield, the following procedure was adapted and will be described in detail.

(2) A quarter mole (25.5 gms.) of the alcohol and a half mole (47 gms.) of molten phenol were weighed into a dry 500 ml. three necked round bottom flask. The flask was then fitted with a glycerine sealed stirrer and a reflux condenser with drying tube to protect the reaction from moisture in the air. To this mixture was then added .18 mole (24 gms.) of anhydrous aluminum chloride from a shaker

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bottle designed to protect the reagent from moisture during the transfer. The flask was cooled in a water bath if the temperature exceeded 35°C. during the two hour addition period.

The color of the reaction mixture changed from a light yellow to a brilliant red as the aluminum chloride was added and some hydrogen chloride was given off. The viscosity of the solution also increased, especially in the condensations where solid products were obtained. The reaction was stirred for four hours after the aluminum chloride was added and it was during this period that large volumes of HCl were evolved. The flask was warmed in a water bath (50-60°C.) if the solution became viscous enough to hinder stirring.

After standing overnight the semi-solid glass like reaction mixture was hydrolyzed by pouring on a 1:1 mixture of ice and hydrochloric acid. The resulting two layers were separated and the aqueous layer extracted with three portions of ether. The combined ether and organic layers were washed several times with dilute sodium carbonate solution to remove acid and then dried over anhydrous sodium sulfate for several hours. The ether was removed on the steam bath and the residue fractionated at reduced pressure using a Claisen flask.

The first distillation yielded three main fractions. A small amount below 85° at 15 mm. pressure which consisted mainly of uncondensed alcohol and traces of its chlorides; a second fraction between 85° and 115° at 4 mm. pressure consisting chiefly of phenol; and a third fraction between 115° and 130° at 4 mm. pressure that was the desired product. A small amount, 2 to 4 grams, of tarry residue remained in the flask at the end of the distillation.

The 115°-130°C. fraction was refractionated several times at 4 mm. pressure until a colorless alkyl phenol was obtained. The products that crystallized were separated from oily impurities by porous plate treatment, and when possible they were recrystallized from petroleum ether or a 50% mixture of alcohol and petroleum ether.

Table I shows the yields of alkyl phenols obtained by the two methods described above. It will be noted that the yields from the two methods are in the same approximate ratio, but much higher when the solvent is omitted.

Table II records the physical constants and analyses of the principal products isolated.

	With S	Solvent Without So		Solvent
Alcohol Condensed	Number of Condensations	Av. yield of Alkyl Phenols	Number of Condensations	Av. yield of Alkyl Phenols
4-methyl pentanol-3	2	23.1%	3	54.0%
3-methyl pentanol-2	3	26.4%	3	59.1%
3,3-dimethyl butanol-2	3	24.5%	3	54.3%
4-methyl pentanol-2	3	17.1%	4	41.0%
hexanol-2	4	8.5%	4	22.5%
hexanol-3	2	10.2%	2	25. 5%

Table I

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III Preparation of Derivatives

The benzoyl ester (35) and alpha-maphthylurethane (36) derivatives were prepared for all the alkyl phenols obtained by the method previously described.

(1) Bengoyl esters

Three grams of the phenol were dissolved in 4 ml. of pyridine in a 50 ml. Erlenmeyer flask and 3 ml. of bennoyl chloride was added. After the initial reaction had subsided the mixture was refluxed over a low flame for 1.5 hours, cooled, and then poured on ice. The oily product was then extracted with two portions of other. The other solution was washed with cold dilute sulfuric acid to remove pyridine, and then with dilute sodium carbonate solution to remove excess acid. After removal of the other on the steam bath the ester was distilled at reduced pressure using a modified Claisen flask. The crystalline esters were recrystallised to constant melting point from 85% alcohol solution. If the ester failed to crystallize on cooling and standing, it was redistilled and the boiling point carefully determined. See Table IV for data on these derivatives.

(2) <u>Alpha-naphthy lurethanes</u>

One gram of the alkyl phenol was placed in a clean dry test tube and an equal volume of alpha-naphthyl isocyanate added. The reaction was catalyzed with two drops of an anhydrous ether solution of trimethyl amine, the test tube fitted with a CaCl₂ tube and then heated on the steam bath until the contents of the tube solidified on sooling. The derivative was extracted with boiling ligroin, and the solution filtered while hot to remove insoluble material. The alpha-naphthylurethane

crystallised out when the filtrate was cooled in an ice bath. It was removed and recrystallised to a constant melting point from hot ligroin. The data on these derivatives are given in Table III.

IV Proof of Structure

During the course of this work it was observed that the melting points of the alkyl phenols prepared from 4-methyl pentanol-3, 3-methyl pentanol-2 and 3,3-dimethyl butanol-2, agreed closely with the melting points of the tertiary hexyl phenols prepared and identified by Hsieh (11). This suggested the possibility that the secondary hexyl alcohols, with branching on the carbon atom adjacent to the carbinol group, may have been dehydrated during the condensation reaction resulting in the formation of tertiary products. Following this lead, small samples of 2-methyl-2-p-hydroxyphenyl pentane and 2,3-dimethyl-2-p-hydroxyphenyl butane synthesized by Hsieh were obtained, and their alpha-naphthylurethane derivatives prepared.

The alkyl phenol obtained from the condensation of 3,3-dimethyl butanol-2 with phenol, was proven to be the tertiary 2,3-dimethyl 2-phydroxyphenyl butane.

Alkyl phenol	Welting point of alkyl phonol	Welting point of urethane
2,3-dimethyl 2-p-hydroxyphenyl butane	105-106	115-116
from 3,3-dimethyl butanol-2	104-105	115-116

Mixed melting points of the alpha-maphthylurethanes and of the alkyl phenols showed no depressions, proving that the compounds are identical. The rearrangement of 3,3-dimethyl butanol-2 will be discussed in another section of this thesis. (See discussion) The alkyl phenol obtained from the condensation of 4-methyl pentanol-3 with phenol, was proven to be the tertiary 2-methyl-2-p-hydroxyphenyl pentane.

Alkyl phenol	Melting point of alkyl phenol	Melting point of urethane
2-methyl 2 -p-hy droxyphenyl pentane	37-38	125.5-126.5
from 4-methyl pentanol-3 and phenol	32-33	124.5-125.5

A mixed melting point of the alpha-maphthylurethanes showed no depression, proving that the compounds are identical. Due to the low melting point and oily nature of the phenols a mixed melting point determination was not made. The latter product was purified by drying on a porous plate and was not recrystallized due to its extreme solubility in all solvents used. However, this does not greatly effect the melting point of the alpha-maphthylurethane as shown in the above table.

The structure of the alkyl phenol resulting from the condensation of 3-methyl pentanol-2 with phenol was proven in a similar manner. 3-methyl-3-p-hydroxyphenyl pentane was prepared from 3-methyl pentanol-3 and phenol by the method of Huston and Hsieh (11). The fraction distilling at 123-127°C. at 4 mm. pressure was refractionated several times, and then separated from oily impurities by drying overnight on a porous plate. Mixed melting points of the alphanaphthylurethanes and alkyl phenols showed no depressions, proving that the compounds are identical. The reported melting point of 3-methyl-3-p-hydroxyphenyl pentane is 59-60°C., however, this is the melting point of the recrystallised product. When the tertiary phenol is purified by the same treatment given the product from the secondary alcohol the melting points are identical.

Alkyl phenol	Melting point of alkyl phenol	Melting point of urethane
3-methyl 3-p-hydroxyphenyl pentane	54-55	147-148
from 3-methyl pentanol-2	54- 55	147.5-148.5

The structures of the alkyl phenols resulting from the condensation of hexanol-2, hexanol-3 and 4-methyl pentanol-2 with phenol were not proven, due to the fact that their alpha-maphthylurethane derivatives could not be recrystallized to a sharp melting point. This indicates that the products isolated were mixtures of isomers resulting from the condensation of phenol with the dehydration product of the alcohol.

As previously stated, the fractions distilling at 115-130°C. at 4 mm. pressure were redistilled several times to obtain the pure alkyl phenols. During this procedure, repeated attempts were made to isolate more than one product from the reaction, but due to the highly viscous character and the closeness of the boiling points of the phenols, this could not be done. Several techniques were used in these distillations, but in every case distinct fractions of different products could not be separated.

Two products are possible from each alcohol if an alkene is an intermediate in the reaction. Hexanol-2 could be dehydrated to form hexene-2, while hexanol-3 could form the alkenes hexene-2 and hexene-3. Inasmuch as the condensation products of these alkenes could not be separated it was not determined which phenol was present in the largest quantity. The alpha-maphthy lurethane derivatives of the same alkyl phenols, synthesized from the alkyl benzenes by Kaye, exhibited the same behavior and no definite conclusions could be drawn.

It may be pointed out, however, that the alkyl phenol from 4-methyl pentanol-2 appeared to be primarily 4-methyl-3-p-hydroxy phenyl pentane. This was not definitely proven, but is evident from a study of the derivatives of this product and of the alkyl phenols made from the alkyl benzenes of 4-methyl pentanol-3 and 4-methyl pentanol-2.

Alkyl phenol	of urethane
4-methyl pentanol-2 plus bensene alkyl phenol	108-112
from	
4-methyl pentanol-2	
and phenol	120.5-123.5
4-methyl pentanol-3	
plus benzene alkyl phenol	116-124
The alkyl benzenes from 4-methyl pentan	ol-2 and 4-methyl pentanol-3

were converted to the alkyl phenols by Kaye, using the method of Huston and Guile (20).

The para position is assigned to the substituted hexyl group in these phenols as a result of extensive work done in this laboratory with a variety of alcohols (11) (24).

Discussion

The results reported herein indicate that in the presence of anhydrous aluminum chloride, the secondary hexyl alcohols are easily dehydrated and condense with phenol to form products other than the ones expected. The alcohols with branching on the carbon atom adjacent to the carbinol group give the largest yields of alkyl phenols, showing that they are dehydrated more easily than the straight chain isomers. As would be expected, tertiary hexyl phenols were formed in every case where this structural arrangement was present. In contrast to this, no prediction could be made in regard to the alkyl phenols formed from the condensation of the dehydration products of the straight chain alcohols with phenol. Experimental evidence bears this out as shown in the preceding section of this thesis.

A detailed analysis of the molecular rearrangement noted in 3,3-dimethyl butanol-2 is beyond the scope of this thesis. Briefly, the rearrangement is similar to the pinasolone transformation in which an alkyl radical migrates during a process of dehydration. The dehydrating effect of the aluminum chloride brings about the interchange of two radicals on adjacent carbon atoms, namely CH₃ and OH, followed by the elimination of a molecule of water. The resulting symmetrical olefin then condenses to form the tertiary phenol.

The mechanism of aluminum chloride condensation reactions as proposed by Tsukervanik and Nasarova (13) suggests that an intermediate alkyl chloride is formed during the early stages of the reaction. The theory is not so plausible when applied to tertiary alcohols, but gains credence when secondary alcohols are being considered. During the course of several condensations it was observed that only insignificant amounts of HCl were liberated during the addition period of the reaction. However, after addition of aluminum chloride was complete large volumes of HCl were given off, indicating that the HCl formed during the initial stages of the reaction may have added to the alkene forming an alkyl chloride. With this in mind several low fractions from the condensations were refractionated in attempts to isolate traces of the alkyl halides, but negative results were obtained in every case.

Materials

Secondary butyl and tertiary bromides were prepared from the corresponding alcohols by the action of sulfuric and hydrobromic acids (37).

Acetaldehyde was prepared from paraldehyde (B.P. 21-26°C.)

Normal butyraldehyde - Eastman's (Practical). Redistilled before using. (B.P. 73-76°C.)

Iso-butyraldehyde - Eastman's (C.P. grade) B.P. 61-62°C.

Ethyl bromide (C.P. grade) B.P. 38-40°C.

Hexanol-2 - Eastman's (Technical) B.P. 137-140°C. Redistilled before using.

4-methyl pentanol-2 - Eastman's (Technical) B.P. 129-132°C.

Redistilled before using.

Phenol - Mallinkrodt's crystals. Redistilled before using.

Benseyl chloride - Eastman's (C.P. grade)

Alpha-naphthyl isocyanate - Eastman's (C.P. grade)

Magnesium turnings especially prepared for Grignard reactions, were dried in an oven at 40°C. before using.

Anhydrous ether - (C.P. grade) Dried over metallic sodium. Ligroin - (B.P. 60-90°C.) Dried over metallic sodium. Petroleum ether - (B.P. 30-65°C.) Dried over metallic sodium. Benzene used in molecular weight determinations was thiophene free, C. P. grade.

Aluminum chloride - Baker's anhydrous.

3-methyl pentanol-3 - Prepared by Hsieh (11) B.P. 120-123°C.

			TADIo 11					
Al cohol Condensed	Froducts	¥.Р.°С.	B.P.°C.	Specific Gravity 250 250	Refractive Index n ^{D25}	1401 -76-**	र २	Found A
4-methyl pentanol-5	2-methyl- 2-p- hyár ozy pheny l pentane	32-33	125-1 26 4 Ello	1	1	180 •03	81 . 07	10.14
3-methyl pentanol-8	3-met hyl-Sp- hydroxyphenyl pentane	54-55	124-127 4 mie	ŧ	ł	179 -5 0	80•79	10.18
5,5-dimethyl butanol-2	2,5-dimethyl-2-p- hydroxyphenyl butane	104-105	122 -125 4 ma.	8	1	178.00	80.53	10.12
4-methyl pentanol-2	4-methyl-3-p- hydroxyphenyl pentane 4-methyl-2-p- hydroxyphenyl pentane	l	249–251 745 mm. 126– 139 4 mm.	•96076	1.51 49	177 .96	80 •51	10.24
hexanol-2	2-p-hydroryphenyl herane 3-p-hydroryphenyl herane	I	251-255 745 mm 128-131 4 mm	•94969	1•5 08 1	178 .74	80 . 82	10•20
heranol-5	3-p-hydroxyphenyl herane 2-p-hydroxyphenyl hexane	1	252-256 745 mm. 126-150 4 mm.	92126°	1,5098	177 .31	80 .62	10 •21
*Calc. for Cl2	^н 180 с = 80.85% н∶	= 10.175	*	Cale. mole	cular weight	: = 178.26		

Alpha-naphthylurethanes of	M.P.°C	Analysis* 🔊
2-methy1-2-p- hydroxypheny1 pentane	124.5-125.5	4.05
3-methyl-3-p- hydroxyphenyl pentane	147.5-148.5	4.00
2,3-dimethy1-2-p- hydroxyphenyl butane	115-116	4.10
4-methyl-3-p- hydroxyphenyl pentane 4-methyl-2-p- hydroxyphenyl pentane	120,5-123,5	4.14
2-p-hydroxyphenyl hexane 3-p-hydroxyphenyl hexane	95-97	4.12
3-p-hydroxyphenyl hexane 2-p-hydroxyphenyl hexane	93-95 (77-80)	4.06
*Calc. for C23H2502N	N = 4.03%	

Table III

A] _ h

Table	TV
10.040	.

	Benzoyl Esters		
Benzoyl Ester of	M.P. or B.P. ^o C.	Analysi	s Found*
		<u> </u>	<u></u>
2-methy1-2-p-	185-187°C.	80.47	7,61
hydrexyphenyl pentane	B.P. 4mm.		
3-methy1-3-p-	75-76 °C.	80.54	7.61
hydroxyphenyl pentane	М.Р.		
2,3-dimethy1-2-p-	53.5-54.5°C.	80.75	7.77
hydroxyphenyl butane	M.P.		
4-methy 1-3-p-	188 -193⁰C.	80.84	8.10
hydroxyphenyl pentane	B.P. 4mm.	-	
4-methy1-2-p-			
hydroxyphenyl pentane			
2-p-hydroxyphenyl hexane	189-194°C.	81.10	7.91
3-p-hydroxyphenyl hexane	B.P. 4mm.		
3-p-hydroxyphenyl hexane	190-195°C.	81.04	7.75
2-p-hydroxyphenyl hexane	B.P. 4mm.		
Calc. for C19H22O2	C = 80.81%	H . 7.86%	

Summary

- 1. The six possible secondary hexyl alcohols have been condensed with phenol in the presence of aluminum chloride.
- 3-methyl pentanol-2, 4-methyl pentanol-3 and 3,3-dimethyl butanol-2 condensed with phenol to form the tertiary hexyl phenols 3-methyl-3-p-hydroxyphenyl pentane, 2-methyl-2-p-hydroxyphenyl pentane and 2,3-dimethyl-2-p-hydroxyphenyl butane, respectively.
- 3. Hexanol-2, hexanol-3 and 4-methyl pentanol-2 condensed with phenol to form mixtures of isomers that could not be separated.
- 4. The benzoyl ester and alpha-naphthylurethane derivatives have been prepared.
- Hexanol-3, 3-methyl[pentanol-2, 4-methyl[pentanol-3 and
 3,3-dimethyl[butanol-2 were prepared.

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