THE CONDENSATION OF TERTIARY AMYL AND TERTIARY BUTYL ALCOHOLS WITH ORTHO CRESOL IN THE PRESENCE OF ALUMINUM CHLORIDE

Thesis for the Degree of M. S.

MICHIGAN STATE COLLEGE

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1937

R. C. Huston.
5/27/37

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A Thesis

submitted to the faculty of Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the Master of Science degree

by

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August 1937

ACKNOWLEDGEMENT

I take this opportunity to acknowledge my indebtedness and to express my gratitude to Dr. R. C. Huston for the assistance and encouragement he has given during this work.

CONTENTS

INTRODUCTION

The condensation type of chemical reaction, wherein benzene or substituted benzene rings are reacted with aliphatic or aromatic alcohols or alkyl halides in the presence of a catalytic agent have constituted a large portion of the synthetic studies of modern organic chemistry. Some of the materials that have been used to catalyze these reactions have been sulphuric acid, phosphoric acid, phosphorous pentoxide, magnesium chloride, zinc chloride, phosphorous pentachloride, aluminum chloride, ferric chloride (both anhydrous and $FeCl_3 \cdot 6\ H_2O$) and bleaching earths (for example tonsil, filtrol, and other acid activated earths).

This laboratory has been very prolific in the study of the reactions using aluminum chloride as the condensing agent for aromatic compounds with various aliphatic and aromatic alcohols.

The material that follows is a contribution to this same field of work, and although it bears every ear-mark of the work of a beginner in the field of scientific research, I sincerely hope it may add something of value to our rapidly growing collection of knowledge.

HISTORICAL

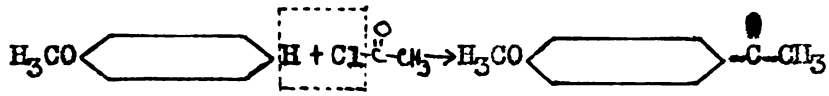
ALKYLATED PHENOLS

In 1881 Liebmann (1) prepared butyl, amyl and propyl phenol by condensing phenol and isobutyl alcohol, using molten zinc chloride as a catalyst.

In 1882 Mazzara (2) condensed propyl alcohol and m-cresol using magnesium chloride as a catalyst and a year later (3) he used the same catalyst to prepare methyl-butyl-phenol(butyl-m-cresol).

In 1894 Effronte (4) prepared isobutyl-o-cresol by diazotization and hydrolysis of o-toluidine. He obtained a reddish yellow oil boiling at 235-237°. This was described as a very thick aromatic oil which would not crystallize. He considered the butyl group to be in the para position and attempted to prove its structure by oxidation of the iso-butyl-o-methyl anisol to form a methoxy phthalic acid. He reported that the methylation (formation of the methyl ether) was extremely difficult, and although the product he obtained was not noticeably different from the expected product, it was of such a small quantity that he was forced to give up the study.

In 1899 Gattermann, Ehrhardt and Maisch (5) treated anisol and phenetol with acyl chlorides in the presence of aluminum chloride and obtained condensation products in which they proved the acyl group entered the ring in a position para to the OCH_3 group.



In 1891 Senkowski (6) strengthened the theory of Gattermann (5) by alkylating aniline and other aromatic compounds. He stated that the entering substituent always takes the para position on the ring, and that this is also true of the higher homologues of the phenols which are prepared by treating a mixture of phenol with the appropiate alcohol in the presence of zinc chloride.

In 1891 Baur (7) prepared o-amino-tert-butyl-toluene by the reduction of mono-nitro-butyl-toluene with zinc and hydrochloric acid. This product was a yellow oil with a boiling point of 245°, which gave the same acetyl and benzoyl derivatives as the amine used above by Effronte (4). He therefore considered the tertiary butyl group to be in the para position, although I could find nothing in this article about changing the amine to a phenol. Three years later he carried on a related study (8) and prepared butyl-ortho-cresol from o-cresol and iso-butyl alcohol with zinc chloride as a catalyst. He obtained a yellow oily product with a boiling point of 235-237°, which he considered to be p-tert-butyl-ortho-cresol, the same product as Effronte (4) had prepared from the amine. He expressed the strong probability that the iso-butyl was arranged to the tert-butyl group. A tri-nitro derivative was prepared which melted at 85-86°.

In 1899 Gurewitch (9) reported tert-amyl- and tert-butyl-phenols prepared by the action of the tert-alkyl chlorides with phenol in the presence of ferric chloride.

Clamenson (10) prepared alkyl phenols by the reduction of ketones with zinc amalgam and hydrochloric acid.

In 1907, three years later, Herzig and Wenzel (11) alkylated phenols by treating the phenol with alkyl iodide in an alkaline solution.

In 1909 Khotinsky and Patzewitch (12) called attention to the fact that aromatic tertiary carbinols may be condensed with many substances including phenols by the aid of acetic acid to which is added a little sulphuric acid or zinc chloride.

In 1911 Darzens and Rost (13) prepared p-tert-butyl-ortho-cresol by repeating the work of Effronte (4). This product was hydrogenated to prepare a methyl-butyl-hexahydrophenol.

In 1929 Meyer and Bernhauer (14) condensed o-cresol with isobutyl alcohol in the presence of 70% sulphuric acid at 80° C. They reported p-tert-butyl-o-cresol with a boiling point of 235-237°, which gave a nitro derivative with a melting point of 85-87°.

In 1934 Seymour (15) used hydrated ferric chloride as a catalyst for the condensation of tertiary alkyl halide with phenol, by refluxing at 80-90° for twenty-four hours.

In 1934 Dietzler, Lundquist and Perkins (16) obtained a patent on a process for preparation of alkylated phenols by the action of the alkyl halide with the phenol in presence of aluminum chloride and other catalysts at temperatures from 50-200°. They reported a 63.7 % yield of 4-tert-butyl-6 methyl phenol with a boiling point of 138-139°/25 mm.; a 20 % yield of 2,4 di-tert-butyl- 6 methyl phenol, boiling at 135.5°/25 mm. and an estimated 1 to 2 % of 2-tert-butyl-6 methyl-phenol with a boiling point of 156.5-157.5°/25 and with a melting point of 50.9°.

In 1935 Tchitchibabine (17) prepared alkyl and benzyl derivatives of phenols and cresols by heating the phenol with secondary and tertiary alcohols in the presence of phosphoric acid. He showed that the product of the condensation of m-cresol and tertiary butyl alcohol could be nitrated to produce musc ambrette (1-methoxy 2-tert-butyl-3 methyl-4,6-dinitro benzene). This was to prove that in the case of the butyl-m-cresol the butyl group is ortho to the hydroxyl group. He also condensed tertiary butyl alcohol with o-cresol and obtained about a 78 % yield of a product boiling at 122.5/14 mm. which formed colorless crystals melting at 27°. He assumed that the tertiary butyl is ortho to the hydroxyl group in this compound because it was in the case of the compound obtained from m-cresol.

Thus far I have given some history of the preparation of butyl and amyl cresols and related compounds by various methods. The previous articles from this laboratory have covered them quite thoroughly but I do wish to present a few of the steps in the development of the condensations of phenols with alcohols in the presence of aluminum chloride. Prior to 1915 there were several references (18) to the use of aluminum chloride as a dehydrating agent or catalyst but not by the present procedure.

The literature contains many articles regarding the Freidel and Craft's synthesis. In these an alkyl halide reacts with an aromatic substance by formation of an intermediate addition product which then rearranges and regenerates the aluminum chloride for continued reaction. Here we can consider aluminum chloride as a true catalyst. However, in most of our syntheses the aluminum

chloride must be in a relatively large and quite definite quantity to have the reaction yield satisfactorily. This fact would indicate no regeneration and it is questionable whether we can call it a true catalyst.

In the present Huston method the alcohol is used rather than an alkyl halide and definite quantities of aluminum chloride are needed. This method was begun by Huston and Friedemann (19) in 1916. They found that primary and secondary aromatic alcohols condense with benzene. When triphenyl carbinol was reacted with benzene the expected tetraphenyl methane was not received but triphenyl methane resulted.

In 1924 Huston (20) condensed benzyl alcohol with phenol and obtained p-benzyl phenol in a 45 % yield.

Two years later Huston and Sager (21) were unable to condense phenyl-ethyl-, phenyl-propyl- and other normal- and iso-alcohols. They did condense allyl alcohol with benzene. From this they concluded that only those alcohols condense in which the alpha carbon is a member of a benzene ring or is double bonded.

In 1927 Huston and Swartout (22) condensed benzyl alcohol with o-cresol and later work in this laboratory included the condensation of benzyl alcohol with p-cresol (23) and m-cresol (24). In each of these cases they obtained a di-alkyl- substituted and two mono-alkyl- substituted products.

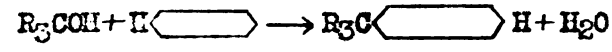
In all of these works the results have agreed with the theory of Gattermann (5) and Senkowski (6) that the most of the substitution

in the ring is para to the hydroxyl group, so we could expect this to be the probable structure of the alkyl cresols of the present study.

THEORETICAL

As shown in the historical review the use of aluminum chloride as a catalyst is not of recent development, although the improved and cheaper methods of production of recent years have probably increased greatly its industrial uses.

The mechanism that the reaction follows is not definitely established but the most accepted idea is one of a dehydration process. As in the general formula :



This procedure however does not give any idea of an intermediate formation, which we would strongly expect as indicated by the color produced during reaction.

Tzubervanik (25) reported the alkylation of benzene and toluene by the use of secondary and tertiary alcohols in the presence of aluminum chloride. He considered the formation of an aluminum alcoholate, which decomposes to an alkene. The alkene then takes up hydrochloric acid to form the alkyl halide which reacts with the hydrocarbon.

Although the evidence of ether formation by the use of aluminum chloride is not plentiful it is possible that we might explain the reaction by the formation of an intermediate ether followed by rearrangement to the phenol. It was reported by Herz and Weith (18) that aluminum chloride reacted with phenol to give a diphenyl ether, although the first step in the process was

considered to be dehydration.

Hedrick (26) has offered a mechanism which seems quite possible although like each of the others does not have enough evidence to be conclusive. He considers first the formation of a hydro-aluminum phenolic acid (I) which then reacts with the alcohol (II) to form an intermediate addition product which rearranges to give the substituted phenol and aluminum phenolate (III). The water formed in step II then reacts with the aluminum phenolate to produce the phenol and aluminum hydroxide (IV).

I— 6  $+ AlCl_3 \rightleftharpoons 5(H)^+ + (Al\ (OC_7H_7)_6)^- + 3\ HCl$

II— $H_3Al\ (OC_7H_7)_6 + 3\ R_3COH \rightleftharpoons Al\ (OC_7H_7)_6.(-CR_3)_3 + 3H_2O$

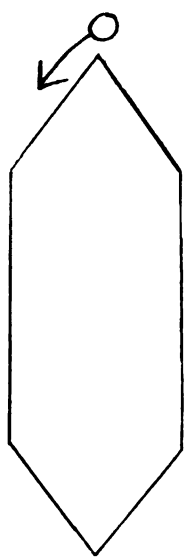
III— $Al\ (OC_7H_7)_6.\ (-CR_3)_3 \rightleftharpoons Al\ (OC_7H_7)_3 + 3\ HO.C_7H_6.CH_3$

IV— $Al\ (OC_7H_7)_3 + 3\ H_2O \rightarrow Al(OH)_3 + 3$ 

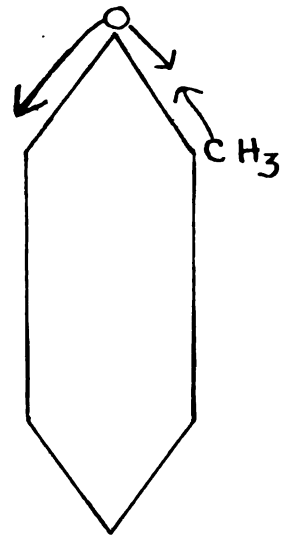
The history of the reactions of this type has shown that there is a general tendency to condense with the alkyl group entering the ring para to the hydroxyl group. If we notice the forces acting this is what we should expect. The directive influence of the following groups is considered to be to the ortho or para position, usually para predominating. The order of the relative directive powers of the groups is $OH > NH_2 > I > Br > Cl > CH_3$. Thus in o-cresol we can consider the directive power of hydroxyl as greatly predominate over the methyl group. We could expect then from the hydroxyl group alone to receive mainly a para substitution. However the small amount of ortho influence would be dissipated because to have a group enter ortho to hydroxyl it would be meta to methyl and this would not be very probable.

If we consider the electrical effects present in phenol (I, below) the negative field (general effect) of the phenolic oxygen will tend to repel the negative field of an alkyl group and we should expect to find the group entering the para position most easily. In the case of o-cresol (II below) where alkyl and hydroxyl groups are already present their negative fields will repel each other and increase the steric hindrance effect on the 2-position and decrease the amount of expected ortho substitution.

I



II



DISCUSSION

The resulting percentage yields (pages26 and26a) are calculated on crude products, basing calculation on the theoretical amount to be expected from a given quantity of alcohol used. Although individual runs gave large variations I consider the average yield of pure product for tert-butyl-o-cresol is 55 % and for tert-amyl-o-cresol 50% .

The proportion of reactants seems to be an optimum at about one mole of the alcohol to two moles of cresol and one-half mole of aluminum chloride. In the butyl run the better method is to add the alcohol-cresol-petroleum ether solution to the suspension of aluminum chloride in petroleum ether. I tried several runs by adding dry aluminum chloride to the alcohol-cresol-petroleum ether mixture but there seemed to be a tendency for the formation of a solid complex where there was excess of reactants and a deficiency of aluminum chloride present. This red jelly-like solid would form after the reaction was underway and by increasing aluminum chloride and solvent I found it could be stopped on some occasions. In other cases the solid formed so rapidly that the mass was too heavy to stir and the additional aluminum chloride and petroleum ether only remained on top. The time of this jelly formation was apparently the end of condensation because, in those cases which had solified early in the reaction the yield was practically nil. When the solvent and excess cresol were

removed from these runs which had solidified practically nothing was left but a dark gummy mass which decomposed and left a dry char in the flask.

In the case of the amyl alcohol the condensation reaction seemed to proceed more slowly, and by adding aluminum chloride to the alcohol-cresol less jelly formation was noted and the yield was better than by the same procedure for butyl condensations.

In the butyl runs the reaction mixture usually developed a bright blood to a very red color, and this coloration seemed to indicate something of the amount of condensation. However, in the amyl reaction the color formation was much slower and in some cases only a straw color resulted after two days stirring, but in spite of this the yield was quite good. In the first two runs of the butyl condensation the aluminum chloride was added to the cresol and then the alcohol dropped into this mixture but the yield was very poor. This may have been caused because the alcohol was added to the cresol and aluminum chloride but more probably because the ratio of aluminum chloride used was very small in comparison to the ratio used in later condensations which gave better yields.

EXPERIMENTAL

A 500 c.c. round bottom three necked flask was fitted with a mechanical stirrer with a mercury seal, dropping funnel, and a reflux condenser closed with a calcium chloride tube and having a thermometer extending through the air condenser into the solution. Dry air was forced through the empty apparatus for some time to make it as dry as possible. The solvent used in all runs was petroleum ether dried over calcium chloride. The alcohols were dried over anhydrous potassium or sodium sulfate. The o-cresol was redistilled at atmospheric pressure. The size of runs was varied but for most part $\frac{1}{2}$ mole (18.5 g) of tertiary butyl alcohol and from $\frac{1}{2}$ to $1\frac{1}{2}$ moles of ortho cresol were dissolved in 100 c.c. dry petroleum ether and placed in the dropping funnel. Varying proportions of aluminum chloride were used but usually 1/8 mole (16.7 g) of anhydrous aluminum chloride was added to 100 c.c. petroleum ether in the reaction flask. The stirrer was started and the aluminum chloride formed a white to yellow suspension in the solvent. The alcohol-cresol-petroleum ether solution was dropped into the flask over a period of about two hours at such a rate that the temperature remained from 25-30°, regulating the addition and cooling the flask with water and ice bath if necessary. Hydrogen chloride fumes escaped from the mouth of the reflux condenser and were led to the surface of a beaker of water or allowed to escape through a hood.

As the reaction progressed a coloration, usually dark blood red appeared in the flask. The stirring was continued about two to three hours after all of the material had been added and then allowed to stand at room temperature overnight. The next day the contents of the flask was poured into 300 c.c. of a 50 % ice hydrochloric acid mixture in a liter beaker. After stirring and standing one-half hour or longer, the beaker contents was transfered to a liter separatory funnel and the water layer drawn off the bottom. The red oil (upper layer) was collected in a round bottom flask. The water was again returned to the separatory funnel and extracted with di-ethyl ether two or three times. This extract was added to the main oil in the flask and anhydrous sodium sulphate added. The flask was left stoppered with occasional shaking over a period of twenty-four hours or longer and the extract then filtered or decanted from the sodium sulphate. The solvent was removed by distillation on a steam bath and the product distilled in a claisen flask and the distillate collected in a water cooled wurtz flask under reduced pressure (about 15 mm.). Three main fractions were obtained, (1) a low boiling fraction consisting of petroleum ether, alcohol, its chloride and unsaturated derivatives, (2) the excess cresol, and (3) the alkylated cresol. The crude fractions were then fractionated in vacuo in a modified claisen flask having a two and one-half foot column.

BROMINATED P-TERT-BUTYL-O-CRESOL

I placed 27.4 grams of the p-tert- butyl-o-cresol, boiling at 124-126°/15mm. in a 200 c.c. three necked round bottom flask equipped with a mercury seal stirrer, reflux condenser, and dropping funnel, and dissolved it in 100 c.c. of chloroform. The flask was placed in an ice bath, and 26.6 grams of bromine in 50 c.c. of chloroform was added slowly over a period of two hours with constant stirring. Much hydrogen bromide was given off and the flask was kept cold until the evolution stopped and was allowed to warm slowly to room temperature. The chloroform was then driven off and the product fractionated, giving the following fractions:

2 grams ——————————124-126°/11mm.

24 grams ——————————126-129°/11mm. N_{20}^{D} = 1.5436

7 grams ——————————129-134°/11mm. N_{20}^{D} = 1.5437

4 grams ——————————134-138°/11mm.

The fourth fraction decomposed quite easily. I expected the 126-129 fraction to be 1-hydroxy-2 methyl-4 tert-butyl-6 bromo benzene but analysis indicated a dibromo compound. Thinking that there was a possibility that two moles of bromine had been added, the work was repeated as above except for solvent, using carbon tetrachloride in this run.

The original distillation gave 42 grams of product 130-138°/15 and redistillation gave

20 grams—— 123-126°/11mm. N_{20}^{D} = 1.5440

16 grams—— 126-129°/11mm.

The index of refraction showed that I again had the same compound

but still the analysis indicated a dibromo compound. Aryl oxy-acetic acid (27) was made and melted at 74-75°.

BROMINATED P-TERT-AMYL-O-CRESOL

This material was prepared by the same procedure as above. I used 20 grams of p-tert-amyl-o-cresol with a boiling point of 255-257°/740 mm. in 100 c.c. of carbon tetrachloride and cooled to zero. I added 12 grams of bromine and stirred until no more hydrogen bromide was given off. The following fractions were obtained :

10 grams ———— 125-136°/12mm.

24 grams ———— 136-145°/12mm.

4 grams ———— 145-160°/12mm. Residue

When the above was purified I obtained the following fractions :

4 grams ———— 136-138°/11mm.

6 grams ———— 138-140°/11mm. N_{20}^{o} = 1.5423

12 grams ———— 140-142°/11mm. N_{10}^{o} = 1.5435

3 grams ———— Residue

A diphenyl urethane was prepared (29) from the 140-142 fraction of the above product. The fine white granules were very hard to dissolve but recrystallized to the melting point of 178.5-179.5°.

Analysis of C_{25} H_{26} O_2 N Br

Calculated Br 17.70 %

Found 18.69 %

6-BROMO-O-CRESOL

This compound was prepared by the method of Neeley(28). O-cresol was sulfonated to block the 4-position and brominated, followed

by distillation with super heated steam. Redistillation gave the following fractions :

28 grams ——— 197-203°

65 grams ——— 203-210°

10 grams ——— 210-220°

The high boiling material crystallized and was probably di-bromo-o-cresol. The main fraction used in the following condensations boiled at 203-206°.

4-TERT-BUTYL-6 BROMO-O-CRESOL

The 6 bromo-o-cresol prepared above was condensed with tertiary butyl alcohol by the same method as the o-cresol had been. The main portion of the yield boiled at 129-131°/11mm. It showed the index of refraction equal to 1.5241. Aryl oxyacetic acid derivative (27) of this product melted at 92-93°. Analysis of this compound indicated only one bromine to be present.

Since this product agreed in boiling point (129°/11mm.) with the brominated p-tert-butyl-o-cresol I thought they were the same but the index of refraction and the derivative melting points did not agree.

4-TERT-AMYL-6 BROMO-O-CRESOL

The 6 bromo-o-cresol prepared above was condensed with tert-amyl alcohol and the following fractions were collected :

9 grams ——— 131-136°/11mm.

20 grams ——— 136-143°/11mm.

5 grams ——— 145°/11mm.

These were further purified and the main part of the product boiled at 140-142°/11mm.

The diphenyl urethane of this compound was prepared by the method of Kamm (29) and melted at 177-178.5°.

Analysis of C_{25} H_{26} O_2 N Br.

Calculated Br 17.70 %

Found ----- 17.58 %

This checked very closely with the diphenyl urethane of the brominated p-tert-amyl-o-cresol 178.5-179.5°. These diphenyl urethanes were quite insoluble in alcohol and the available low boiling ligroin and therefore recrystallization was difficult. However, the melting points agree so closely that the possibility of their being different compounds is very slight.

PRODUCTS OF TERTIARY BUTYL ALCOHOL CONDENSATION

The products of this condensation, theoretically, should consist of three alkylated cresols (1) 1-hydroxy-2 methyl-4 tert-butyl benzene, (2) 1-hydroxy-2-methyl-6-tert-butyl benzene and (3) 4,6-di-tert butyl-2 methyl-1 hydroxy benzene. The work of Dietzler (16) recorded each of these products.

I distilled the main portion of my product many times at various pressures and found the boiling point to be 124-126°/15mm., 138-139°/25mm. and 236-237°/740mm.

This product was a colorless oil, very viscous and reminding one of glycerine. After standing in an ice-salt bath for several hours it formed crystals. These were transfered to a filter paper and dried in the ice box. Although they were thus formed by freezing the oil it was impossible to find a solvent from which

they would recrystallize. Even in the ice box they melted when touched with a spatula to transfer them to a tube. Therefore some of the oil was put in a small glass tube and placed in an ice bath and a seed dropped in. The next morning all was frozen. The tube was placed in a beaker of ice water and allowed to come to room temperature. In this way I found a melting point of 22-23°.

Although the product is one of the substituted phenols, the characteristic phenolic odor was not noticeable; it had only a faint rubber like smell which probably was due to materials taken up during distillation but could not be removed.

There being a slight possibility of ether formation during the reaction, the product was treated with Claisen alcoholic potassium hydroxide (30) but no indication of an ether was given.

When the oil was exposed to the sunlight for a length of time it took on a light yellow cast. When it was distilled at atmospheric pressure it boiled at 255-257° but soon took on a reddish yellow color. This probably was due to oxidation and decomposition.

Usually we find ortho, and di-substituted phenolic compounds are insoluble in a five percent potassium hydroxide solution. The lower boiling materials 225-255° which should have contained the 6-tert-butyl-o-cresol were poured into this solution but all seemed to be completely dissolved. This mixture was extracted with ether and a small portion of oil was found on driving off the ether. This material however boiled at the same point as the material which had not been extracted from the solution with

ether and which was reclaimed as a substituted cresol by acidifying the solution. Thus if any 6-tert-butyl-o-cresol was present it was in a very small quantity.

I was unable to get a mono-brominated derivative of the material which I could check with the 6-bromo-4-tert-butyl-o-cresol prepared by the condensation of 6-bromo-o-cresol with tertiary butyl alcohol. The boiling point, 124-126°/15mm., and melting point, 22-25° agree somewhat closely with the boiling point and melting point of the material which Tchitchibabine (17) prepared by phosphoric acid condensations having a boiling point of 122.5°/14mm. and a melting point of 27° and which he called o-tert-butyl-c-cresol. However, in spite of the above facts I consider that my product is p-tert-butyl-o-cresol since (a) it comprises such a high percentage of the total yield and since all of the past works on substituted phenols have shown the largest amount of substitution to be para to the hydroxyl. (b) My product checks in boiling point, appearance, and melting point of the nitro derivative with that of Effronte (4), Baur (7),(8) and Meyer and Bernhauer (14) and with the boiling point of the p-tert-butyl-o-cresol of Dietzler, Landquist and Perkins (16). (c) The bromination of the tert-amyl condensation product proved the alkyl group to be in the para position.

Analysis for $C_{11} H_{16} O$

Calculated C = 80.42 % ; H = 9.83 %

Found —— C = 79.84 % ; H = 9.94 %

Aryl oxyacetic acid derivative was prepared by the method of Koelsch (30) and white fleecy crystals were obtained with a melting point of 94-95°.

Analysis for $C_{13}H_{18}O_3$

Calculated C = 70.27 %; H = 8.105 %

Found------ C = 70.45 %; H = 8.094 %

I prepared diphenyl urethane by the method of Kamm (27). I obtained white fleecy needles from alcohol with a melting point of 113.5-114° and then analyzed for nitrogen by the Micro Kjeldahl method.

Analysis for $C_{27}H_{25}O_2N$

Calculated N = 3.900 %

Found ------ N = 3.801 %

Attempts to nitrate the product at room temperature resulted in decomposition and only a black tarry mass was obtained. I then tried cooling nitric acid in an ice bath and dissolving the cresol in glacial acetic acid. This solution was also cooled and the cold acid added drop by drop. If no action resulted a little sulphuric acid was added and the solution warmed carefully. A strong reaction then did set in. The mixture was poured into water and the yellow needles were recrystallized from alcohol, they had a melting point of 85-86°.

4. 6 DI-TERT-BUTYL-O-CRESOL

The combined black tarry residues from all the distillations of each condensation were collected and refractionated. From these residues I obtained about 28 grams of clear thick (even more viscous than the main product number (2) page 13) oil boiling at 156-161°/25mm. which probably was the product number (3)

(27)

on page 19. This product was cooled in an ice bath for about two hours and when it did not crystallize it was placed in the ice box and seeded with one of the above mentioned crystals, but could not be made to crystallize.

This product was poured into a five percent potassium hydroxide solution and although its density was about the same as that of the solution, preventing a layer formation, undissolved droplets of oil were visible. This solution was extracted with petroleum ether and after driving off the petroleum ether from the extract 23 grams of product boiling at 156-161°/25mm. was recovered. This quite definitely indicated the product was the di substituted cresol, as given by Dietzler (16).

PRODUCTS OF CONDENSATION OF TERT-AMYL ALCOHOL WITH O-CRESOL

This reaction seemed to progress somewhat slower and did not produce such a deep red coloration although it gave good yields.

The original product was fractionated after the hydrolysis of each condensation. These products were then combined and refractionated at different pressures to give the following results:

12 g ——————————————— 110-122°/10mm.

24 g —— 242-252°/740mm.——— 122-130°/10mm.

22 g —— 252-254°/740mm.

45 g —— 254-257°/740mm.——— 130-134°/10mm.

7 g —— 255-256°/740mm.——— 130-132°/10mm.

10 g —— 258-260°/740mm.——— 130-133°/10mm.

The main fraction above was redistilled and the pure product boiled at 130°/10mm. or 255°/740mm.

This product was a viscous colorless oil which soon took on a reddish amber color when exposed to sunlight. This could not be made to crystallize in an ice-salt bath, but when seeded with the p-tert-butyl crystals and left in the ice box several days did solidify, but melted as soon as it was placed in the room.

This product was brominated and the product obtained boiled at 140-142°/11mm, the same as the product obtained by the condensation of 6-bromo-o-cresol with tertiary amyl alcohol. These boiling points and the melting points of their diphenyl urethanes showed quite conclusively that the products were of the same structure and that the tert-amyl group was para to the hydroxyl of the cresol.

The black tarry residues from all the condensations were combined and refractionated. The following results were obtained:

4 grams ———— 132-134°/10mm.

8 grams ———— 134-138°/10mm.

6 grams ———— 138-200°/10mm.

The 134-138°/10mm. may have contained a di-alkylated cresol but I could not be sure that it was not more of the p-tert-amyl-o-cresol. The 138-200°/10mm. fraction was very thick and had a slight yellow coloration.

The low boiling fractions were distilled and a fraction of oil boiling at 123-126°/10mm. was obtained which I thought might be the o-tert-amyl-o-cresol. However this dissolved in a give

percent potassium hydroxide solution and crystallized when seeded with p-tert-butyl-o-cresol crystals, so it probably was more of the p-tert-amyl-o-cresol.

The 255-256° fraction was analyzed for carbon and hydrogen.

Analysis of $C_{12} H_{18} O$

Calculated C = 80.90 %; H = 10.11 %

Found C = 80.51 %; H = 10.18 %

Aryl oxyacetic acid (27) was prepared and gave a melting point of 99-100°.

Analysis of $C_{14} H_{20} O_3$

Calculated C = 71.19 %; H = 8.475 %

Found C = 71.22 %; H = 8.392 %

Diphenyl urethane (29) was prepared and gave a melting point of 121.5-122.5°.

Analysis of $C_{25} H_{27} O_2 N$

Calculated N = 3.49 %

Found N = 3.75 %

MOLECULAR REFRACTION

STUDY OF P-TERT-BUTYL-O-CRESOL

N_{20}^{o} = 1.5228

D = .97195

M = 164.125

$$M = \frac{M}{D} \times \frac{N^2 - 1}{N^2 + 2}$$

$$\frac{164.125}{.97195} \times \frac{1.3189}{4.3189} = 51.57 \text{ (Observed reading)}$$

C = 2.501 x 11 = 27.511

H = 1.051 x 16 = 16.816

O = 1.521

Double bond = 1.707x3 = 5.121

50.969 (Calculated reading)

STUDY OF P-TERT-AMYL-O-CRESOL

N_{20}^{o} = 1.5239

D = .9691

M = 178.144

$$M = \frac{M}{D} \times \frac{N^2 - 1}{N^2 + 2}$$

$$\frac{.9691}{178.144} \times \frac{1.3222}{4.3222} = 56.23 \text{ (Observed reading)}$$

C = 2.501 x 12 = 30.012

H = 1.051 x 18 = 18.918

O = 1.521 x 1 = 1.521

Double bond = 1.707x3 = 5.121

55.572 (Calculated reading)

TERTIARY BUTYL CONDENSATIONS

Trial	Used			Obtained/16mm.			% yield based on alcohol	% yield based on o-cresol
	$AlCl_3$	Alcohol	O-cresol	85 to 100	100 to 120	120 to 130		
1	5.5	18.5	81			5	12	4
2	7.3	24.7	72			7	13	6.5
3	33.4	37	54	6	5	41 (125-30)	50	50
4	16.7	18.5	27	5	6	20	50	50
5	16.7	18.5	81	30	30	23	56	19
6	34	37	162		30	56	68	22
7	34	37	162	52	37	48 (120-30)	58	19.5
8	33	32	108	45	26	23	39	17
9	33	37	108	24	5	65	78	38
10	33	74	135	65	14	no product		

TERTIARY AMYL CONDENSATIONS

Trial	Used			Obtained/16mm.					% yield based on alcohol	% yield based on o-cresol
	$AlCl_3$	Alcohol	O-cresol	75 to 105	105 to 131					
1	16.7	22	54	18	16				36	18
2	16.7	22	67.5	48	25				57	23
3	25	33	101	30	35				53	21
4	67	88	162	(75-85) 32	(85-95) 27	(95-134) 12	(134-138) 82	(138-150) 10	46	31
5	34	44	108	25	23	5	55		62	31

SUMMARY

1 - Tert butyl and tert aryl alcohols were condensed with o-cresol in the presence of aluminum chloride.

2 - The products were practically all p-substituted o-cresol.

3 - Aryl-oxyacetic acid and diphenyl urethanes were prepared.

4 - The yields varied in the neighborhood of fifty percent.

5 - The use of large excess of cresol increases the yield.

6 - Addition of the alcohol-cresol mixture to the aluminum chloride-petroleum ether suspension produces better results.

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NOTES ON INDIVIDUAL RUNS OF TERTIARY BUTYL CONDENSATION

Trial 1 -- The aluminum chloride was added to the cresol and petroleum ether mixture, and then the alcohol was dropped in over a period of two hours, and stirred three hours more. It was let stand over night and then hydrolyzed. The aluminum chloride used was in very low proportion and the yield was the lowest of any run.

Trial 2 -- I added the alcohol to the cresol-aluminum -chloride-petroleum ether mixture during one-half hour. It was stirred two and one-half hours and then stood overnight. It formed a red jelly-like mass.

Trial 3 -- The alcohol and cresol mixture was added to the aluminum chloride in petroleum ether and was stirred for four hours and let stand for three days. There seemed to be an excess of aluminum chloride left in the bottom of the flask.

Trial 4 -- I added the white anhydrous aluminum chloride to the petroleum ether and it turned to a light yellow solution or suspension. I dropped in the alcohol-cresol mixture slowly and stirred for four hours afterwards.

Trial 5 -- The cresol-alcohol mixture was added to the aluminum chloride-petroleum ether mixture over one hour period. It was stirred two and one-half hours and then left over night. A deep red solution resulted.

Trial 6 -- I added the alcohol-cresol petroleum ether mixture to the aluminum chloride suspension over a period of one

hour and allowed it to stand ten days before hydrolysis.

Trial 7 -- Aluminum chloride was suspended in 100 c.c. petroleum ether and I added the alcohol-cresol in 50 c.c. petroleum ether mixture to this suspension.

Trial 8 -- I added the dry aluminum chloride to the alcohol and cresol mixture in petroleum ether. The result was the formation of a gummy mass and a lower yield.

Trial 9 -- I suspended the aluminum chloride in 100 c.c. petroleum ether and added the alcohol-cresol-petroleum ether over a two hour period. It was stirred four hours and left over night. The product was bright red.

Trial 10 - I added dry aluminum chloride to the alcohol cresol mixture and the whole mass became almost solid at once. It was too solid to stir and when hydrolyzed and distilled only unreacted cresol was reclaimed as an oil. Over sixty percent of the material was left as a solid charred mass.

In all the condensations the temperature was kept between twenty and thirty degrees, and conditions were kept as anhydrous as possible.

NOTES ON INDIVIDUAL RUNS OF TERTIARY AMYL CONDENSATION

Trial 1 -- I added dry aluminum chloride to the alcohol-cresol mixture over a period of two hours. The mixture was stirred two days, then let stand over night and hydrolyzed. No bright red color was visible, but slowly a faint pink color appeared.

Trial 2 -- I added dry aluminum chloride to the alcohol-cresol mixture. The mixture was stirred three days, let stand over weekend and then hydrolyzed.

Trial 3 -- The aluminum chloride was added to the petroleum ether in the flask and I dropped in the alcohol-cresol-petroleum ether mixture.

Trial 4 -- I added the alcohol-cresol mixture quite rapidly to the aluminum chloride suspension. This was stirred four hours and then allowed to stand over night. It was hydrolyzed the next day but I left the product in the hydrolysis solution for ten days before extraction.

Trial 5 -- I added the aluminum chloride to the alcohol-cresol mixture and after two days stirring only a faint pink color was present. I then added about two grams of anhydrous zinc chloride and the color deepened, indicating more reaction was taking place. This showed the highest yield of any of the amyl condensations and might indicate that work with aluminum chloride-zinc chloride mixture might be a method to improve yields still further.