CONDENSATION OF PHENYL BUTYL CARBINOL WITH PHENOL IN THE PRESENCE OF ALUMINUM CHLORIDE

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THESIS

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By

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Condensation as Used in Organic Syntheses.

Condensation as applied to organic chemistry is defined by Cohen as "the union of two or more organic molecules or parts of the same molecule (with or without elimination of component elements) in which the new combination is effected between carbon atoms". As further explanation, it may be said that the union referred to is usually accompanied by unsaturation and consequently there would be a tendency for the unsaturated groups to saturate themselves. Such processes may therefore be divided into two groups: those which take place by separation of elements and those which take place by addition. In the present work we shall only be concerned with the first group.

The process of condensation by separation ofthe elements may be further divided into catalytic and dehydrative reactions. This is only a rough division, however for the reagent used may serve both purposes in the same reaction. Since this work has to do only with the elimination of water taking place in the main reaction, this discussion shall be confined to a review of condensation by dehydration.

In the condensation of aromatic alcohols with aromatic bases, Fischer (Ann. 206, 85, 1880) maintains that the reaction takes place with the elimination of water, the product formed being a combination of one mol of the alcohol with one mol of the base; and that the relative position of the amino or basic group to the combining carbon is always the same, viz., 1 : 4.

When the condensation is effected with phenol and aromatic alcohols, it is reasonable to assume that the relative position of the OH group is likewise in the 1 : 4 position with respect to the entering radical, from the fact that the OH group directs to the same position as the NH_2 group.

Substantiation of the above assumption is offered by Holleman (Chem. Rev. 1, 202, 1924) in which he maintains that the substituents already present in the benzene ring which direct entering substituents to the para or ortho position do so with varying velocities which are as follows:

$$OH > NH_2 > I > Br > Cl > CH_3,$$

thus showing that the OH has the strongest directing influence to the para or ortho position.

Review of Dehydrating Agents Used on Alcohols and Aromatic Compounds.

Dehydrating agents used before 1914 to bring about condensation of the alcohols with aromatic compounds were chiefly the following: zinc chloride, sulfuric acid, acetic acid, absolute alcohol, magnesium chloride, hydrochloric acid and phosphoric anhydride. A resume of the literature in which each of the above are used is as follows:

Zinc Chloride.

1. Benzhydrol + Anilinehydrochloride —> Aminotriphenylmethane (Fischer and Roser, Ber. 13,674, 1879).

2. (a) Butyl alcohol + Phenol —> Butyl phenol

   (b) Amyl alcohol + Phenol —> Amyl phenol

(c) Benzyl alcohol + Phenol → Benzyl phenol (Liebmann, Ber. 14, 1842, 1881. He also found the higher homologues of phenol failed to give the ferric chloride test).

3. Phenol → Diphenylether (Merz and Weith, Ber. 187, 1881).

4. Absolute alcohol + Phenol → Ethyl phenol (Auer. Ber. 17, 669, 1884).

Sulfuric Acid

1. Metanitrobenzylalcohol + benzene → Metanitrodiphenylmethane (Becker, Ber. 15, 2090, 1882).

2. Tetramethyldiaminobenzhydrol + Paratoluidine → Tetramethyltriaminodiphenyltolylmethane (Noelting, Ber. 24, 3126, 1891).

3. Paranitrobenzylic alcohol + Paranitrotoluene → Dinitrobenzyltoluene (Gattermann and Koppert, Ber. 26, 2810, 1893).

4. Phenol + Mandelic acid → Hydroxydiphenylacetic lactone (Bistrzycki and Flatau, Ber. 28, 989, 1895).

5. Phenol + Mandelonitrile → Alphahydroxydiphenylacetolactone (Bistrzycki and Simonis, Ber. 31, 2812,1898)

Sulfuric Acid and Acetic Acid (Mixed)

1. Benzyl alcohol + Benzene → Diphenylmethane (Meyer and Wurster, Ber. 6, 963, 1873).

2. Benzyl alcohol + Phenol → Benzylphenol (Paterno and Fileti, Gazz. Chim. ital. 5, 381, 1875).

3. Diphenylparatolylcarbinol + Phenol → Parahydroxytriphenylparatolylmethane (Bistrzycki and Gyr, Ber. 37, 655, 1904).

4. Mohlau and Klopfer (Ber. 32, 2147, 1899) were also successful in condensing benzhydrols with a paraquinone or derivative of the same with the mixture of sulfuric and acetic acids or in absolute alcohol.

Phosphoric Anhydride

1. Benzhydrol + Paraxylene → Diphenylparaxylymethane (Hemilian, Ber. 16, 2360, 1886).

2. Phenylhydroxyacetonitrile + Benzene → Diphenylacetonitrile (Michael and Jeanpretre, Ber. 25, 1615, 1892)

Magnesium Chloride

1. Propyl alcohol + Metacresol → Propylmetracresol (Mazzara, Gazz. 12, 505, 1882)

Stannic Chloride

1. Phenylhydroxyacetonitrile + Mesitylene → Phenyltrimethylphenylacetonitrile (Michael and Jeanpretre, Ber. 25, 1615, 1892).

2. Benzhydrol + Toluene → Diphenylparatolylmethane (Bistrzycki, Ber. 37, 659, 1904).

Acetic Acid

1. Khotinski and Patzewitch (Ber. 24, 3104, 1909) found that the triphenylcarbinols of the type triphenylcarbinol condense with pyrrole. But this same reaction does not hold true for primary or secondary alcohols.

2. Szeki (Acta. R. 2, 5, 1925) found that benzhydrol and various other aromatic carbinols condense readily with di- and trimethoxybenzenes in glacial acetic acid solution under the influence of hydrogen chloride.

Hydrochloric Acid.

1. Paranitrodimethyldiaminobenzhydrol + Metatoluidine → Paranitrodimethyldiaminodiphenyltolylmethane (Noelting, Ber. 24, 553, 1891).

2. Suais also did a meager amount of work in which hydrochloric acid was used as a condensing agent. (Bull. 1, 517, 1897).

Aluminum Chloride as a Dehydrating Agent

Aluminum chloride is probably best known in the Friedel-crafts reaction, although even there its mechanism is not thoroughly understood. It is also used as a dehydrating agent in reactions in which there is a subsequent splitting out of water.

Merz and Weith (Ber. 14, 187, 1881) used aluminum chloride on phenol and obtained a mixture of compounds of which benzene, diphenylether and methylenediphenyloxide were the chief constituents. Waas (Ber. 15, 1128, 1882) condensed dichlorethyl oxide with benzene using the same agent obtained triphenylethane. He maintains that such a reaction is due tothe action of the aluminum chloride converting the dichlorethyloxide into monochloraldehyde, which reacting with benzene, forms first monochlorodiphenylethane.

If such is the case the aluminum chloride undoubtedly serves not only as a catalyst, but also as a dehydrating agent. Graebe (Ber. 34, 1778, 1901) was able to obtain aniline by using hydroxylamine and benzene in the presence of aluminum chloride, but the percentage yield was small. Jaubert (Compt. Rend. 132, 41, 1901) carried out similar experiments using the hydrochloride of hydroxylamine, but he likewise obtained a rather poor yield.

In 1914 Frankforter and co-workers reported in a series of articles (J. Am. Chem. Soc. 36, 1511, 1529; 37, 385) the results of their investigations in which they used aluminum chloride as a condensing agent. They were successful in condensing chloral, chloral hydrate, bromal and trioxymethylene on various organic compounds in which there was an elimination of water. Many of the compounds prepared could not be obtained by the Baeyer or sulfuric acid reaction. Consequently he maintains that the aluminum chloride acts as a catalyst, at the same time, however, playing the part of a simple dehydrating agent.

Aromatic alcohols had not been condensed with aromatic compounds in the presence of aluminum chloride until Huston and Friedeman began their investigations in 1916 (J. Am. Chem. Soc. 38, 2527). They prepared diphenylmethane with anthracene as a by-product from benzene and benzyl alcohol in the presence of aluminum chloride. It was found that the amounts of reagents used and the temperature at which the reaction took place influenced the final yield. Later (J. Am. Chem. Soc. 40, 785) they extended their experiments to secondary alcohols with benzene and aluminum chloride, using methyl phenyl carbinol, ethyl phenyl carbinol and benzhydrol, obtaining diphenyl methane, diphenyl propane and triphenyl methane respectively. The reaction with the methyl phenyl carbinol took place much more smoothly and gave a higher percentage yield ofthe condensation product than did the ethyl phenyl carbinol. Consequently they concluded that the ethyl group probably had a greater retarding effect than the methyl group. In 1924 Huston condensed benzyl alcohol with phenol in the presence of aluminum chloride, obtaining parabenzyl phenol. The methyl and ethyl ethers were prepared in good yield by condensing benzyl alcohol with anisole and phenetol. It was noticeable that the phenolic hydroxyl group did not interfere with the substitution of the benzyl group in the benzene ring.

Preparation of Phenyl Butyl Carbinol

By the reaction of benzaldehyde on an alkyl magnesium halide secondary alcohols can conveniently be prepared if heat is not applied. In the preparation of phenyl butyl carbinol the following reagents were used:

Normal butyl bromide	3 mols
Magnesium	3.2 "
Benzaldehyde	2.7 "

There was obtained 1.9 mols of the carbinol, making a 70% yield of the theoretical.

The technique employed in the Grignard reaction was briefly as follows: the magnesium ribbon with a crystal of iodine was placed in a five liter balloon flask and during the course of three or four hours the butyl bromide dissolved in ether was added. Care was taken to have all reagents thoroughly dry. The butyl magnesium bromide was refluxed on a water bath for an hour to insure complete reaction. It was then cooled in an ice mixture and the benzaldehyde dissolved in ether was added during a period of one and one-half hours. The flask was removed from the ice mixture and allowed to stand at room temperature (22°) for three quarters of an hour, after which the complex compound was decomposed with ice and hydrochloric acid, extracted with ether and the extract distilled in vacuum. The yield on second distillation gave 280 grams coming over 94°-96° under 6 mm., most of it boiling at 94°-95°. The distillate from 90°-100° at 6 mm. made a total of 305 grams.

The boiling point of the carbinol corresponds very closely to that obtained by Fourneau and co-workers (Anales Soc. espan. fis. quim. 18, 323, 1920) of 120°-125° under 12 mm. and also that of Vernimmen (Bull. soc. chim. Belg. 33, 96, 1924) of 123° under 12 mm.

It may be well to mention at this time that Hess and Rheinboldt (Ber. 54, 2043, 1921) found that when an alkyl magnesium halide was refluxed with benzaldehyde in ether or benzene, gave a mixture of compounds due to the reducing action of the Grignard reagent. Benzyl alcohol was in every case one of the products formed. To avoid the side reducing action when alkyl magnesium halides (methyl excluded) are used heat should not be applied to the reaction mixture.

An analysis was made on the product obtained from butyl magnesium bromide and benzaldehyde on refluxing with the following results:

Substance, 0.1808 : CO_2, 0.5303; H_2O, 0.1444. Calculated for $C_{11}H_{16}O$: C, 80.43; H, 9.82. Found: C, 80.02; H, 8.94.

An analysis was also made on the product without being refluxed, but allowed to stand at room temperature for three quarters of an hour.

Substance, 0.1217 : CO_2, 0.3582; H_2O, 0.1069. Calculated for $C_{11}H_{16}O$: C, 80.43; H, 9.82. Found: C, 80.30; H. 9.83.

With such results we can be reasonably certain that there is a reaction of some kind when heat is applied to the complex compound of benzaldehyde with butyl magnesium bromide. This was further made evident from the fact that some benzylphenol was isolated in the condensation product.

Condensation of Phenyl butyl carbinol with Phenol in the Presence of Aluminum Chloride.

1. Method

In the two condensations that were made the following proportions were used:

Phenyl butyl carbinol	1 mol
Phenol	1.2 "
Aluminum chloride	.5 "
Petrolic ether	1500 cc.

The quantities that were actually used, however, were:

Phenyl butyl carbinol	50 grams
Phenol	34.4 "
Aluminum chloride	30.35 "
Petrolic ether	450 cc.

During the course of the first condensation the carbinol and phenol were suspended in petrolic ether and stirred constantly with a mechanical stirrer. Aluminum chloride was added in small portions over a period of two hours at such a rate that one third was added the first hour and the remainder the second hour. At the end of an hour and a half the temperature had risen to 30°. There was also a noticeable change in color, the milky appearance of the first few minutes giving way to a violet color, which deepened to a red on first noticeable evolution of hydrogenchloride. Approximately two thirds of the aluminum chloride had been added at this point. On further addition, the temperature gradually fell and by the time all of the chloride had been added the temperature had fallen to 24°. The stirring of the mixture was continued for one and one half hours after the final addition of the chloride, much hydrogen chloride being driven off in the meantime. When the stirring was discontinued the intermediate compound of a thick gummy consistency settled to the bottom. After standing overnight (21 hours) the mixture was decomposed with ice and a small quantity of hydrochloric acid, and extracted with ether. The ether extract was then fractionally distilled.

A second condensation was carried out using the same quantities and same technique as before, with the exception that the mixture was stirred for two and one half hours after the final addition of the aluminum chloride.

The distillation fractions were as follows:

1.	Up to 135° (petrolic ether and water)	discarded
	Up to 135° at 6 mm., ...	14 grams
	125° - 185° at 6 mm., ...	36 "
	185° - 230° at 6 mm., ...	26 "
2.	Up to 125°	discarded
	Up to 125° at 6 mm., ...	14 grams
	125° - 185° at 6 mm., ...	38 "
	185° - 230° at 6 mm., ...	24 "

The corresponding fractions from the above distillations were combined and redistilled yielding:

Up to 170°	2 grams
170° - 195° (recovered phenol)	23 "
Up to 160° at 6 mm., ...	10 "
160° - 180° at 6 mm., ...	66 "
180° - 230° at 6 mm., ...	50 "

The fraction 180° - 230° at 6 mm., was fractionated three more times yielding:

Up to 180° at 6 mm., ...	16 grams
180° - 245° at 6 mm., ...	26 "
Residue	8 "

The combined fractions 160° - 180° at 6 mm., making a total of 82 grams were subjected to two more distillations, yielding:

Up to 169° at 5 mm., ...	34 grams
169° - 172° at 5 mm., ...	32 "
172° - 180° at 5 mm., ...	16 "

An analysis was made on the fraction 169° - 172° at 5 mm., with the following results:

Substance, 0.1463 : CO_2, 0.4583; H_2O, 0.1206. Calculated for $C_{17}H_{20}O$: C, 84.95; H, 8.39. Found: C, 85.46; H, 8.31.

A five gram portion of the fraction 172° - 180° at 5 mm., was purified as follows: It was dissolved in Claissen's solution, (Ann. 442, 310, 1925) and shaken out twice with petrolic ether to remove any ethers that may have been formed in the condensation. The solution was then acidified and extracted with ethyl ether. After evaporation of the solvents, no residue remained from the petrolic ether, and that from the ethyl ether was carried thru two distillations; the second time practically the whole quantity (5 grams) came over 170° - 171° at 5 mm. On cooling the product, it solidified to a mass of paraffin-like consistency.

Small portions of the solid obtained above were used to seed the other fractions of the compound, but only two responded, 169° - 172° and 172° - 180° at 5 mm. Several attempts were made at recrystallization, but no solvent that was used seemed to be suitable. Furthermore, the product responds very slowly to being dried between filter papers, and when brought to room temperature began to melt. There

may be a possibility that it has no definite crystalline form, due to the comparatively long paraffin chain that is attached.

If we use that portion of the product which solidified as the compound sought for; we would then have a theoretical yield of 33%, which is somewhat in keeping with yields obtained by other condensations of a similar nature in which aluminum chloride was used as a condensing agent.

Attempt at Esterification

1. Schotten-Baumann Reaction.

As a means of recognizing compounds containing an OH group, the benzoyl derivative is often prepared. In the attempt at its preparation, one gram of the product was used with the calculated amount of potassium hydroxide and benzoyl chloride. Other attempts were made by varying the quantities of the benzoyl chloride and the potassium hydroxide, but none of the trials were successful. The chief cause of the difficulty was likely the fact that the product would not dissolve in either potassium or sodium hydroxide.

2. Carbonyl or Urethan Derivative.

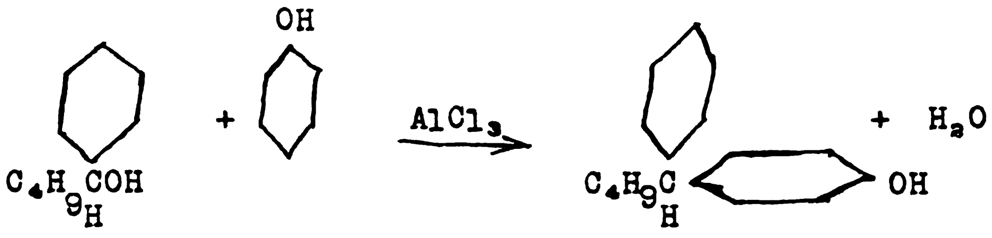
An attempt was also made to recognize the OH group by preparing the urethan according to the technique employed by Fourneau and co-workers (Anales. soc. espan. fis. quim. 18, 323, 1920) but no reaction took place and the product was recovered.

3. Qualitative tests.

The product failed to give the ferric chloride test for phenols, which might be expected from higher phenols of that type. It did, however, respond readily to the test for phenols described by Moir (J. S. African Chem. Inst. 5, 8, 1922).

Summary

1. Phenol reacts with phenyl butyl carbinol in the presence of aluminum chloride to produce parahydroxydiphenylbutylmethane according to the following reaction:



2. Attempt to prepare the benzoyl derivative and the urethan were unsuccessful.

BIBLIOGRAPHY

I. Condensation in Organic Syntheses.

   1. Cohen, Organic Chemistry, Vol. I.
   2. Fischer, Ann. 206, 85 (1880).
   3. Holleman, Chem. Rev. 1, 202 (1924).

II. Dehydrating Agents.

1. Zinc Chloride as a Dehydrating Agent.
   1. Fischer and Roser, Ber. 13, 674 (1879).
   2. Liebmann, Ber. 14, 1842 (1881).
   3. Merz and Weith, Ber. 14, 187 (1881).
   4. Auer, Ber. 17, 669 (1884).
2. Sulfuric Acid.
   1. Becker, Ber. 15, 2090 (1882).
   2. Noelting, Ber. 24, 3126 (1891).
   3. Gattermann and Koppert, Ber. 26, 2810 (1893).
   4. Bistrzycki and Flatau, Ber. 28, 989 (1895).
   5. Bistrzycki and Simonis, Ber. 31, 2812 (1898).
3. Sulfuric Acid and Acetic Acid (Mixed).
   1. Meyer and Wurster, Ber. 6, 963 (1873).
   2. Paterno and Fileti, Gazz. Chim. ital. 5, 381 (1875).
   3. Bistrzycki and Gyr, Ber. 37, 655 (1904).
   4. Mohlau and Kloppert, Ber. 32, 2147 (1899).
4. Phosphoric Anhydride.
   1. Hemilian, Ber. 16, 2360 (1886).
   2. Michael and Jeanpretre, Ber. 25, 1615 (1892).
5. Magnesium Chloride.
   1. Mazzara, Gazz. 12, 505 (1882).

6. Stannic Chloride.
    1. Michael and Jeanpretre, Ber. 25, 1615 (1892).
    2. Bistrzycki, Ber. 37, 659 (1905).
7. Acetic Acid.
    1. Khotinski and Patzewitch, Ber. 34, 3104 (1909).
    2. Szeki, Acta. R. 2, 5 (1925).
    3. Noelting, Ber. 24, 553 (1891).
    4. Suais, Bull. 1, 517 (1897).
8. Aluminum Chloride.
    1. Merz and Weith, Ber. 14, 187 (1881).
    2. Waas, Ber. 15, 1128 (1882).
    3. Gaebe, Ber. 34, 1778 (1901).
    4. Jaubert, Compt. rend. 132, 41 (1901).
    5. Frankforter and Kritchevsky, J. Am. Chem. Soc. 36, 1511 (1914).
    6. Frankforter and Kokatnur, J. Am. Chem. Soc. 37, 385 (1915).
    7. Huston and Friedemann, J. Am. Chem. Soc. 38, 2537 (1916).
    8. Huston and Friedemann, J. Am. Chem. Soc. 40, 785 (1918).
    9. Huston, J. Am. Chem. Soc. 46, 2775 (1924).

III Experimental

1. Gilman and McCracken, J. Am. Chem. Soc. 45, 2462 (1923).
2. Fourneau, Anales. soc. espan. fis. Quim. 18, 323 (1920).

3. Vernimmen, Bull. soc. chim. Belg. 33, 96 (1924).
4. Hess and Rheinboldt, Ber. 54, 2043 (1921).
5. Gattermann, Practical Methods of Organic Chemistry.
6. Moir, J. S. African Chem. Inst. 5, 8 (1922).