THE SYNTHESIS

OF

UNSYMMETRICALLY DISUBSTITUTED ETHANES

A Thesis

by

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THE SYNTHESIS OF UNSYMMETRICALLY DISUBSTITUTED ETHANES

The condensation of acetaldehyde with a variety of aromatic and heterocyclic ring compounds in the presence of sulphuric acid has been studied to determine its versatility as a method for the synthesis of unsymmetrically disubstituted ethanes. Such ethanes are source materials for vinyl compounds, useful for the manufacture of synthetic rubbers and plastics. A number of new compounds have been reported and a number of older syntheses have been improved.

In general, it has been found that benzene, alkyl- and alkoxyl-substituted benzenes give satisfactory yields of ethanes, whereas the more reactive phenols, amines, and heterocyclic compounds give only resinous products, and the less reactive halogenated benzenes, nitrobenzene, benzoic acid, and fused-ring aromatics fail to react.

Some preliminary work has been carried out with catalysts other than sulphuric acid.

INTRODUCTION

There has occurred recently a renewed interest in the synthesis of unsymmetrically disubstituted ethanes. This renewed interest dates from 1941 when the Dominion Tar and Chemical Company of Montreal announced the successful conversion of such ethanes into vinyl compounds, suitable for synthetic rubber and plastic manufacture, by pyrolysis in the vapour phase over clay catalysts. This discovery was confirmed and its limits extended by further work carried out by members of this Department, using bentonite catalysts.

During the months following this announcement, particular attention was given to the development of a satisfactory method for the synthesis of 1,1-diphenylethane, which on pyrolysis yields styrene. 1,1-Diphenylethane has been prepared by the Dow Chemical Company of Midland by an undisclosed method and is available in experimental quantities. Boyer and Gurd, working in this Department, directed their attention to its synthesis from benzene and acetaldehyde, and Winkler and Douglas to its synthesis from benzene and acetylene. The work described in this thesis was undertaken, not so much to find ways and means of improving the yields of the acetaldehyde reaction, but to determine its limits. Concerning this question little information is available in the literature. Accordingly, a number of condensations were carried out using a variety of unsubstituted and substituted aromatic and heterocyclic compounds of types available in commercial quantities. Some of these condensations were repetitions of and improvements on those already reported in the literature; others have been attempted for the first time.

HISTORICAL INTRODUCTION

CONDENSATION REACTIONS OF ACETALDEHYDE

I Aromatic Hydrocarbons

1. Benzene

One of the first reports of a condensation of an aromatic hydrocarbon with acetaldehyde to yield a 1,1-diarylethane compound was that of Bayer(1) who succeeded in condensing paraldehyde with benzene at low temperature using concentrated sulphuric acid as the catalyst

$$CH_3CHO + 2C_6H_6 \longrightarrow CH_3CH(C_6H_5)_2 + H_2O$$

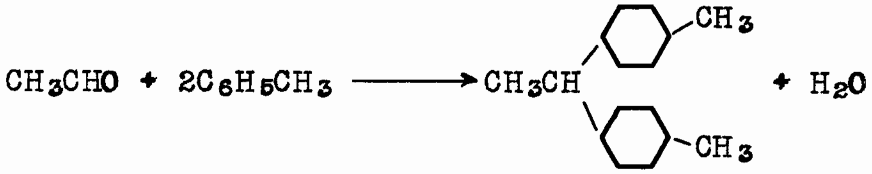
The product of the above reaction, 1,1-diphenylethane, was a colourless liquid, b.p. 268-70°C. The yield was very low and a large amount of tar was formed.

The only other catalyst(2) reported in the literature to be used in the condensation was aluminium chloride. By saturating the mixture of benzene and aluminium chloride with hydrogen chloride at 0°C. and heating it with acetaldehyde, a 48 per cent yield of 1,1-diphenylethane was obtained. Other identified products of this reaction were a 4 per cent yield of ethylbenzene, and a 3 per cent yield of 9,10-dimethyl-9',10'-dihydroanthracene.

Further investigations with a view to improve the yield of the reaction based on Bayer's method were recently carried out by Dr. Boyer and his co-workers in this department(3). Changes in relative quantities of reagents and catalyst used, as well as in technical details of procedure, resulted in an increase of yield up to 40 - 50 per cent.

2. Toluene

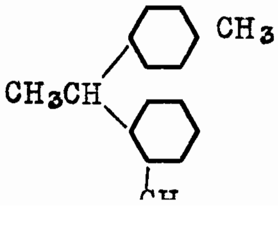
Condensation(4) of toluene with acetaldehyde, using concentrated sulphuric acid as catalyst, was the first successful condensation of that type and gave much better yields that of benzene.



The main product, 1,1-di(4'-methylphenyl)ethane, was a colourless liquid, b.p. 295-298°C. A higher boiling compound was also formed, having the empirical formula, $C_{25}H_{28}$

$$2CH_3CHO + 3C_6H_5CH_3 \longrightarrow C_{25}H_{28} + H_2O$$

Further work(5) on this condensation showed that optimum results were obtained when 78 per cent sulphuric acid was used. Paraldehyde was found to give the same results as acetaldehyde. More precise(6) analysis of the condensation products showed that besides the main product, 1,1-di(4'-methylphenyl)ethane, a large amount of 1,1-(4'-methylphenyl-2'-methylphenyl)ethane was formed.



3. 2,4,5-Trimethylbenzene

Low-temperature condensation(7) of paraldehyde and 2,4,5-trimethylbenzene, using concentrated sulphuric acid as catalyst, gave a crystalline product soluble in all organic solvents. No properties of this compound were reported.

II Phenolic Compounds

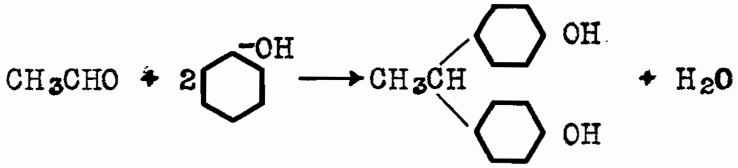
Condensation of an aliphatic alcohol and aldehyde leads to the formation of acetals(8 to 12). In phenol-aldehyde condensation, such links are not formed. Two crystalline products of this condensation were found to be formed in the same way as the alkyl benzene condensation products, i.e., by interaction of the aldehydic oxygen and the para hydrogen on the benzene ring.

Phenolic compounds condense with acetaldehyde under the influence of much milder catalysts than the ones used in acetaldehyde-hydrocarbon condensation. More drastic reaction conditions bring about resinification.

1. Phenol

The first one to work in this field was again Bayer(13). By condensing acetaldehyde and phenol in the presence of concentrated sulphuric acid, he obtained a white cement-like product, which he classified as a phenyl dye. Condensation reactions with naphthol,resorcinol and pyrogallol were also attempted but no products were identified.

It was Claus and Trainer(8) who first assigned a structure to the condensation product and showed it not to be a phenyl dye. The compound synthesised in ether solution using hydrogen chloride as a catalyst, separated in the form of a hard brittle resin but could be converted into one of crystalline form by heating the resin with alkali.



1,1-Di(4'-hydroxyphenyl)ethane was slightly soluble in water, benzene, soluble in alcohol, ether, chloroform and acetone.

An identical crystalline product(14) was obtained by condensing acetaldehyde and phenol in the proportion of one to four at low temperature, using concentrated hydrochloric acid as catalyst. The melting point was found to be 122°C. and Zinke's investigation(15) of the product confirmed Trainer's solubility observations, while Braun(16) determined the boiling points, obtaining b.p. 265°C.(12 mm.) and b.p. 218°C.(1 mm.)

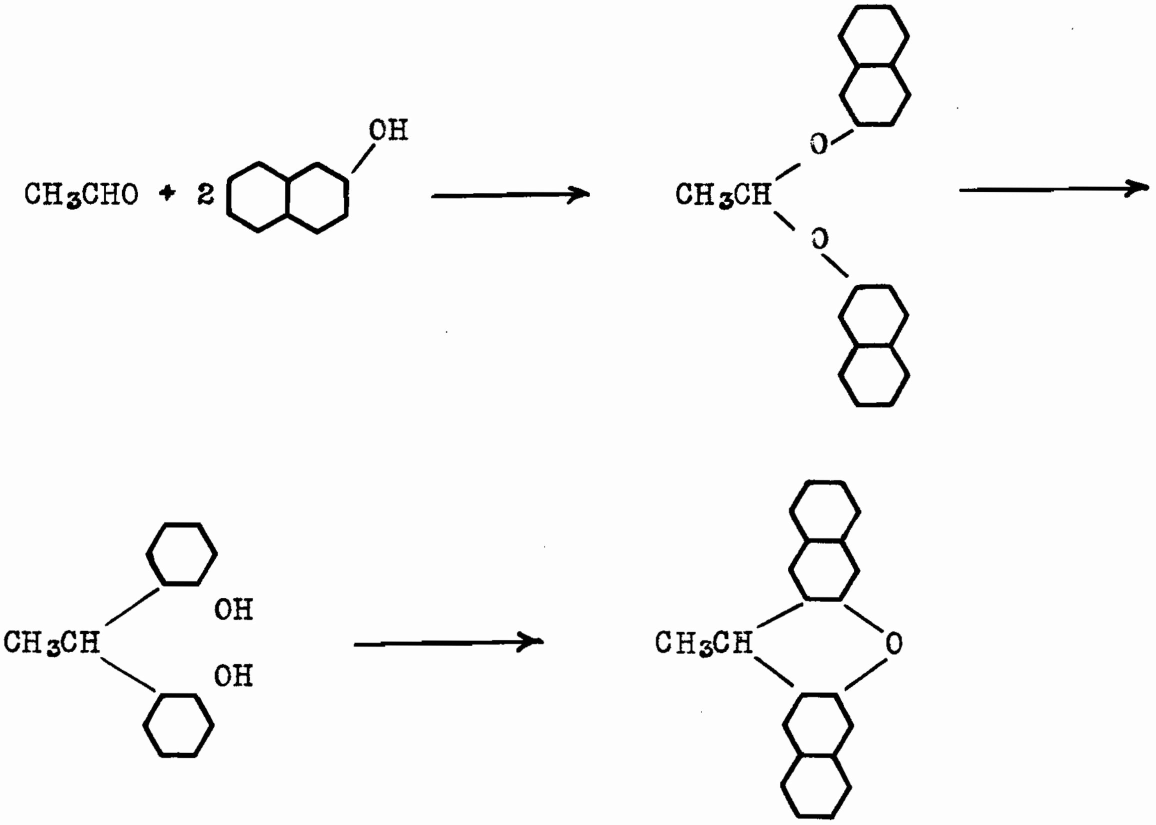
Fabinyi(17) obtained the compound b.p. 225-230°C.(5-10 mm.) by condensing at low temperature paraldehyde and melted phenol by dropwise addition of tin chloride.

The same(18) product was obtained when condensation took place in alcohol solution in the presence of dilute sulphuric acid.

2. Naphthols

The analysis of condensation products of acetaldehyde and α - and β-naphthol reactions(8) showed a definite difference in the mode of reaction of both compounds, the first one reacting like phenol itself, the second forming an acetal link and thus showing its aliphatic nature.

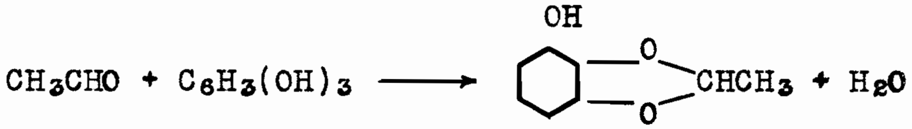
Claisen's investigation(19, 20) of β-naphthol condensations lead to the determination of the mechanism of the reaction, the first step being an acetal formation, followed by a rearrangement to a di-hydroxy molecule, which in turn by intermolecular loss of water gave an internal ether.



Depending on reaction conditions the condensation can give the final or the initial product. The final product was obtained by heating the starting material to 200°C. in acetic acid. It crystallized in colourless prisms, m.p. 173°C., soluble in chloroform and carbon disulphide. The initial product formed on condensation of paraldehyde and an excess of β-naphthol in acetic acid at 80-90°C. This acetal, m.p. 200-201°C., was insoluble in most solvents and rearranged itself to the second intermediate only under the influence of high temperature or addition of acid and mild heating.

4. Pyragallol (1,2,3-Trihydroxybenzene)

Acetaldehyde and pyrogallol in water solution at 80-100°C., using sulphuric acid as catalyst(22) gave a crystalline product of acetal structure.

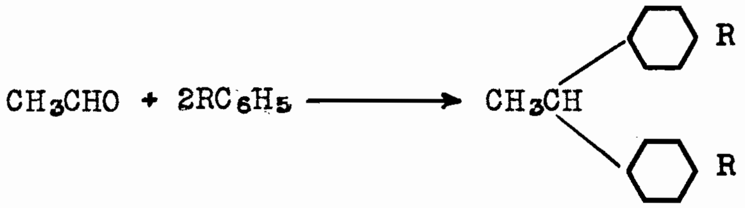


Kahl(23), using concentrated hydrochloric acid as catalyst, obtained two products depending on the amount of aldehyde used. With equal quantities of reagents a crystalline compound was formed, which, on analysis, showed that two molecules of acetaldehyde had reacted with two molecules of pyragallol with loss of two molecules of water. The author suggested a fluorone structure for that compound. When an excess of aldehyde was used in the reaction, an amorphous substance was produced.

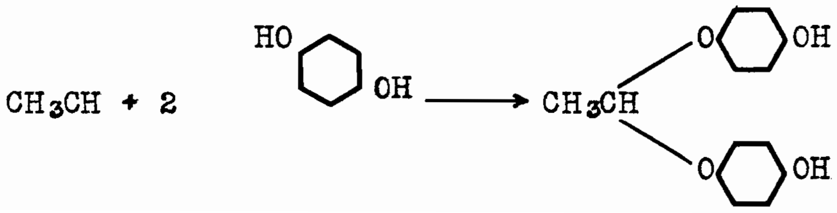
Condensations of paraldehyde and pyrogallol(24) gave a yellow syrup as product, which was found to possess therapeutic properties, but the structure of which was not determined.

5. Resorcinol (1,3-Dihydroxybenzene)

Condensation of acetaldehyde and resorcinol is the most interesting from the theoretical point of view, as it gives a good indication of the structure of 1,1-diphenylethanes, substituted on the benzene ring, showing that the acetaldehyde-phenyl link forms in the para position to the substituted group on the ring, i.e.,

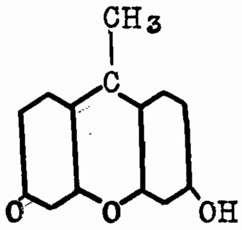


Condensation reactions carried out by Michael and Comey (25), in alcohol solution in the presence of hydrochloric acid, gave a gelatinous product which could not be identified. Condensation in water solution(26) using sulphuric acid as catalyst gave a yellow crystalline product, which decomposed at 300°C. without melting and was insoluble in water, ether, chloroform and benzene, but soluble in alcohol. The author assigned an acetal structure to the product.



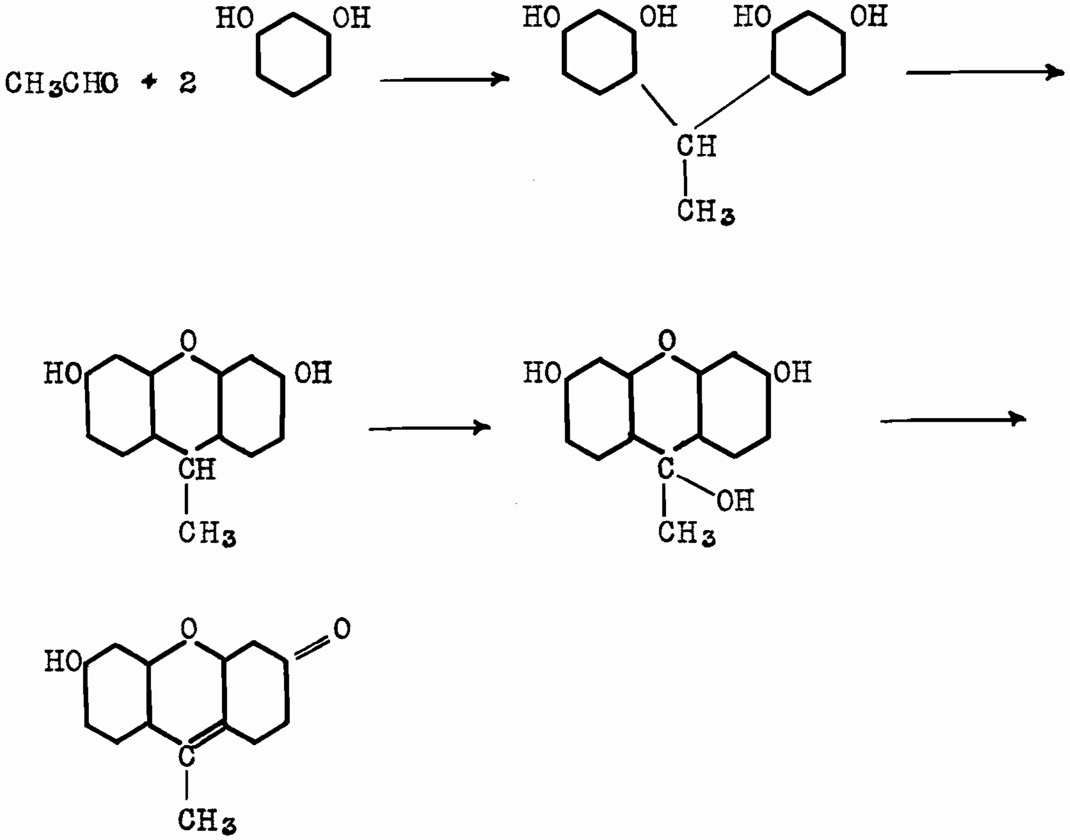
However, already the early work(27) on condensation of aldehydes and phenolic compounds showed that oxyfluorones were obtained as final products in all the cases where the primary condensation products had at least four hydroxyl groups, two in the para and two in the ortho position, to the aldehyde residue.

Carrying out a condensation in water solution using hydrochloric acid as catalyst, acetaldehyde was shown to combine with two molecules of resorcinol and the final product was identified as a fluorone.



That theory was confirmed in more recent years by other workers(28) who succeeded in condensing the acetaldehyde and resorcinol in the presence of concentrated sulphuric acid and in determining the mechanism of this reaction. The first step of the condensation was found to be elimination of a water molecule by interaction of two hydrogen atoms of the phenolic compound, in ortho position to one hydroxyl group and in para position to the other, with the aldehydic oxygen. The second step caused the formation of xanthene by the elimination of a second molecule of water through interaction of the two ortho hydroxyl groups. The xanthene in turn became oxidized by sulphuric acid and a fluorone was obtained.

This gave the final product by loss of a molecule of water.

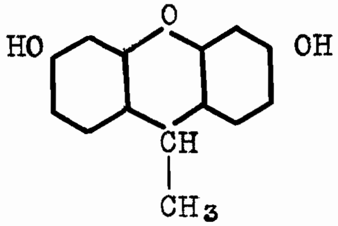


The product, a quinoid compound, was obtained in the form of black microcrystalline powder, which did not melt or decompose below 290°C., was soluble in alcohol, giving an orange solution, insoluble in ether, benzene and was found to be a good orange-coloured dye for wool and silk.

Niewland's and Flood's(29) work, based on acetaldehyde-resorcinol as well as acetylene-resorcinol condensation, caused a revision of the mechanism showing vinyl recorcinol to be the primary condensation product. The following equation shows how the authors explained the products obtained

$$2(HO)_2C_6H_4 + CH_3CHO \longrightarrow (HO)_2C_6H_3CH(CH_3)C_6H_3(OH)_2 + H_2O \longrightarrow$$

$$(HO)_2C_6H_3-CH(CH_3)-C_6H_3(OH)_2 \rightleftharpoons (HO)_2C_6H_3CH=CH_2 + (HO)_2C_6H_4$$



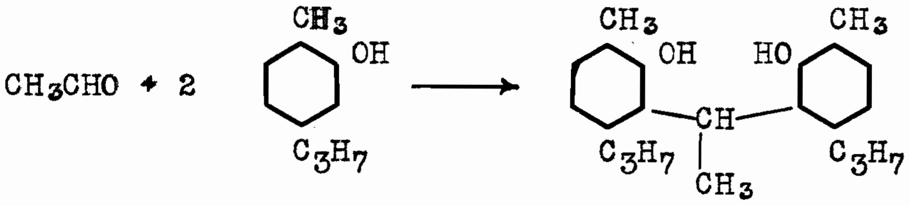
The vinyl recorcinol was separated and identified.

6. Orcinol (1-Methyl-3,5-dihydroxybenzene)

Condensation of acetaldehyde and orcinol was first investigated by Michael and Comey(30) who wrongly assumed a reaction between two molecules of acetaldehyde and two of the orcinol. Claisen(31) was the one who showed that the condensation took place in the same manner as resorcinol, i.e., between one molecule of the aldehyde and two of the phenolic compound. This was confirmed by Mohl and Koch(27) who, on analysis of the product, obtained the formula $C_{16}H_{18}O_4$.

7. Thymol (1-Methyl-4-isopropyl-2-hydroxybenzene)

Low-temperature condensation of paraldehyde(27) with an excess of thymol(32) in chloroform medium using tin chloride as catalyst gave a crystalline product of diarylethane structure.



1,1-Dithymolylethane was found to have a melting point of 185°C in contrast to Jäger's determination of 180°C.; it was soluble in cold alcohol, ether and chloroform. Use of sulphuric acid as catalyst was proved unsuccessful, as only tar and resinous material were obtained.

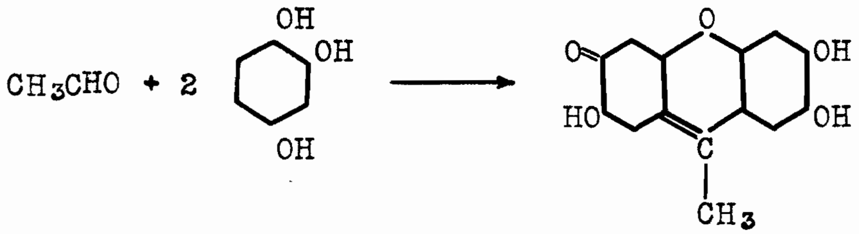
8. Phloroglucinol (1,3,5-Trihydroxybenzene)

The product of acetaldehyde and phloroglucinol(33) condensation in alcohol solution and, using hydrogen chloride as catalyst, was found to have the composition $C_{22}H_{22}O_9$ but the structure was not determined.

$$2CH_3CHO + C_6H_3(OH)_3 \longrightarrow C_{22}H_{22}O_9 + 2H_2O$$

9. Hydroxyquinol (1,2,4-Trihydroxybenzene)

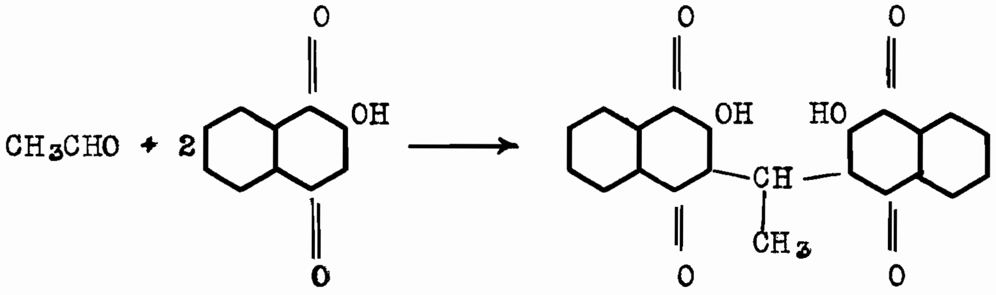
Condensation reactions of hydroxyquinol can be compared to those of resorcinol. A series of condensation reactions of acetaldehyde or paraldehyde with this trihydric phenol(34) carried out in 90 per cent alcohol solution,using different concentrations of sulphuric acid as condensing agent,lead in all cases to the formation of fluorones as final products.



The 9-methyl-2,3,7-trihydroxyfluorone separated as dark red needles, insoluble in water. It was found to be a dye.

10. 2-Hydroxynaphthaquinone

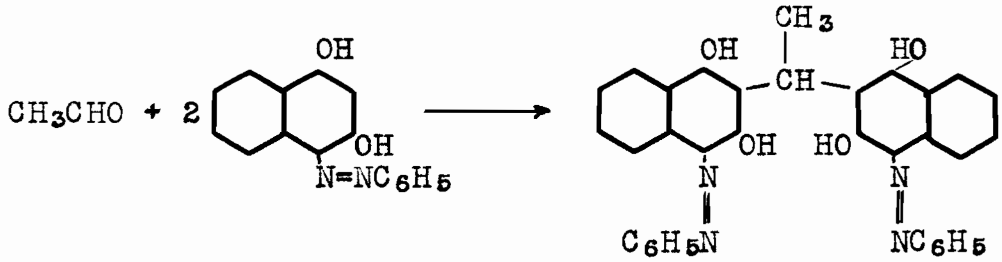
The condensation of 2-hydroxynaphthaquinone and acetaldehyde(35) was found to take place in the usual fashion to form the unsymmetrical disubstituted ethane, m.p. 190°C.



Some difficulty was encountered in purifying the compound.

11. 1,3-Dihydroxynaphthalene

The condensation of acetaldehyde and a derivative of 1,3-dihydroxynaphthalene(36) took place in a similar manner to the above condensation.



12. Resin-forming Reactions

The discovery of the industrial value of phenol-formaldehyde resins led to an extensive investigation of similar condensation reactions and their products. The many different forms of phenol-acetaldehyde resins(37) were found to be of such importance that it was deemed advisable to discuss the reactions employed in these condensations separately. Their innumerable applications make them almost as useful as the formaldehyde resins.

As early as 1900(38) a method of condensation of paraldehyde and phenol in the presence of methyl alcohol was patented as the resinous product of this condensation was resistant to most chemical substances and adapted for electrical insulations as well as for cells, boxes, etc. A different product(39), a fusible and soluble resin for the lacquer industry, was obtained by using an excess of phenol, high temperature, and a trace of hydrochloric acid as catalyst.

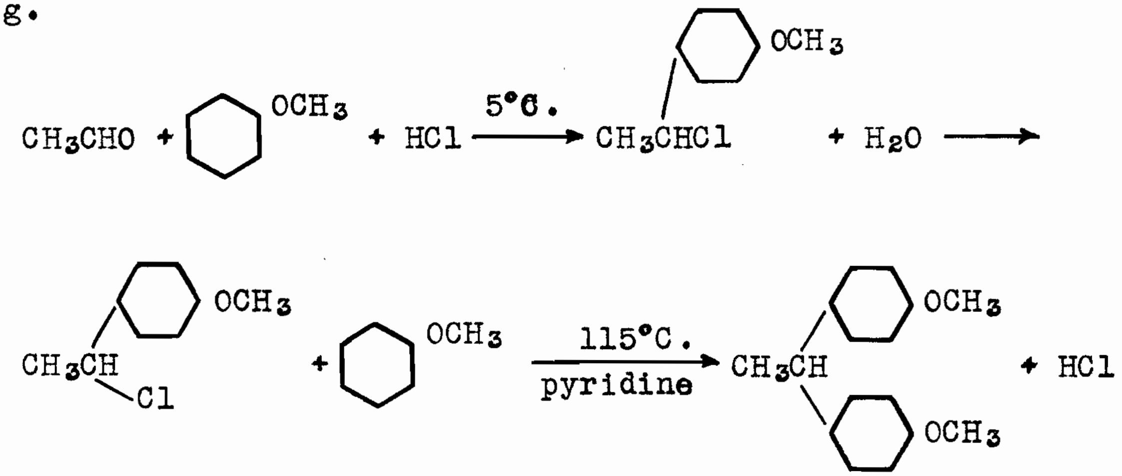
Also other aromatic oxy-compounds, as cresols and xylols, gave resins on condensation with acetaldehyde. Condensation of acetaldehyde and phenols, carried out at room temperature in solvents(40) such as carbon tetrachloride, ethylene trichloride and with condensing agents like hydrochloric acid, sulphuric acid and sulphonyl chloride, gave yellow resins, soluble in the usual organic solvents, insoluble in aqueous sodium bicarbonate. Depending on the relative quantities of phenols and acetaldehyde used, different hardnesses of resins were obtained. Paraldehyde, as well as technical phenol and cresol, could be substituted for pure reagents. Light-coloured, oil-soluble resins(41) were also obtained when phenolic compounds, phenol, cresol, and xylenol were heated with oxalic acid and treated with gaseous acetaldehyde, and then heat washed at 180°C. The same product was obtained (42, 43) by condensing acetaldehyde or paraldehyde with the molecular equivalent quantity of the phenolic compounds at low temperature and using concentrated hydrochloric acid as condensing agent. Thermoplastic resins (44, 45) were obtained by condensation of acetaldehyde or paraldehyde with phenol or cresol in the presence of sulphuric acid and with or without the addition of small quantities of nigrosin black or zinc chloride to speed up the reaction.

Non-catalytic condensation of acetaldehyde and polyvalent phenols(45) at normal or higher pressures, also gave resinous products. Condensation of phenol and acetaldehyde with naphthalene sulphonic acid(47) gave a "novo-lac" resin, which could be converted into a "resol" type of resin by special treatment.

Resins were also obtained when acetaldehyde was condensed with aromatic acids, as cresonic acid, in the presence of such chloride at a temperature of 130-140°C.

III Phenolic Ethers

Quelet(48) found that passage of dry hydrogen chloride through a mixture of a phenolic ether and an aliphatic aldehyde,in the presence or absence of a dehydrating agent, gave a chloroalkyl derivative by substitution in the para position to the ether group or in the ortho position in para substituted compounds. In the presence of dehydrating agents, diarylethane compounds were formed by loss of hydrogen chloride from the condensation product and the unchanged ether, e.g.



An 18 per cent yield of 1,1-di(4'-methoxyphenyl)ethane m.p. 72°C. was obtained. The crude product had a boiling point of 203-4°C.(10 mm.) Nearly quantitative yields of 1,1-di (3',4'-dimethoxyphenyl)ethane, m.p. 77-77.5°C., were obtained(49) by condensing acetaldehyde and veratrol at 0°C., using concentrated sulphuric acid as catalyst.

$$CH_3CHO + 2C_6H_4(OCH_3)_2 \longrightarrow CH_3CH\left[C_6H_3(OCH_3)_2\right]_2$$

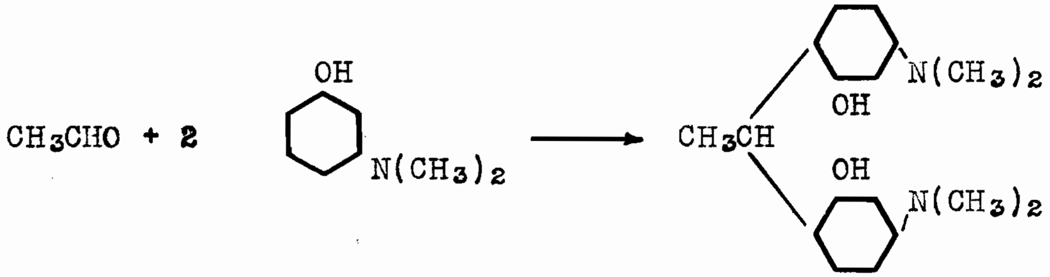
IV Aminophenols

Aminophenols, a group of compounds,having properties of both phenols and aromatic amines, were found to condense with acetaldehyde(50). Aminophenols or their hydrochlorides were used, the latter with sodium acetate and acetic acid as catalyst.

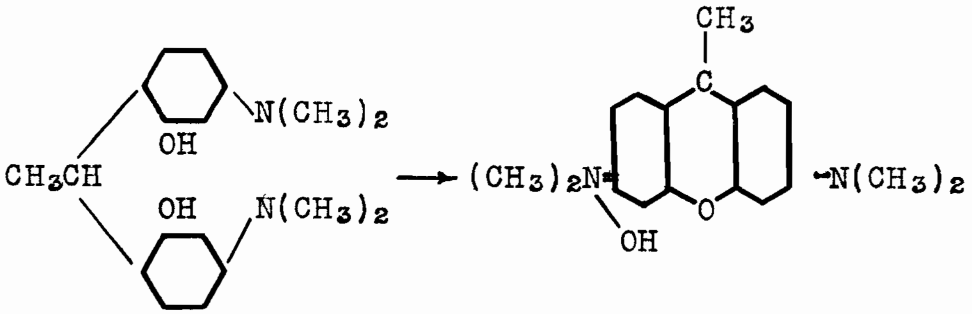
$$CH_3CHO + 2\text{-},3\text{- or }4\text{-}HOC_6H_4NH_2 \longrightarrow 2\text{-},3\text{- or }4\text{-}HOC_6H_4N{=}CHCH_3$$

The products, brown, infusible powders, were probably polymers of the above substituted azomethine compound and can be compared with the 4-alkyl substituted aniline condensation products(68).

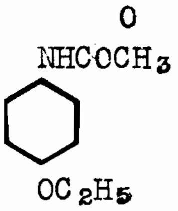
Condensation(51) of 2-dimethylaminophenol with acetaldehyde, using hydrochloric acid as catalyst, gave a 1,1-disubstituted ethane compound



The structure of 1,1-di(4'-dimethylamino-2'-hydroxyphenyl) ethane, m.p. 140°C., was determined by conversion of the compound to a fluorone under the influence of concentrated sulphuric acid.



A special case would be worth noting here(52), acetaldehyde or paraldehyde with a derivative of 4-aminophenol, phenacetin,



gave, in the presence of concentrated sulphuric acid, a characteristic, coloured compound. The formation of this compound allows identification of acetaldehyde.

V Aromatic Amines

Similarly to the case of phenol compounds, the condensation of amines and acetaldehyde was found to lead to both resinous and non-resinous products, the former being of great importance in the rubber industry. The nature of the products depends on conditions of reactions and catalyst used, resin formation being favoured by high temperature and long duration of reaction, by excess of aldehyde, presence of a catalyst, especially acid, and by increasing the complexity of the amine molecule.

In the non-resinous products, distinction between three types of compounds could be made:

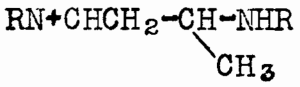
(1) 1,1-diaminoethane molecule in which the acetaldehyde and amine are condensed by the interaction of the aldehydic oxygen and the hydrogens of the amino group. The only exception in this case was the one in which no amino hydrogen was available, i.e., in dialkylanilines. In this case, condensation took place in the same manner as in alkyl substituted benzenes.

(2) quinoline ring compounds formed in the presence of a strong acid catalyst.

(3) so-called Eckstein's and Schiff's bases which formed

in neutral or basic media, and were considered by some authors as products of secondary changes only.

$RN=CHCH_3$



1. Aniline

Schiff(53) obtained two products when condensing pure acetaldehyde and aniline, an oil, which on analysis showed composition corresponding to a 1,1-disubstituted ethane,

$$CH_3CHO + 2C_6H_5NH_2 \longrightarrow (2C_6H_5)(C_2H_4)(N_2H_2) + H_2O$$

and a crystalline product of composition corresponding to a combination of two molecules of aldehyde with two molecules of the amine.

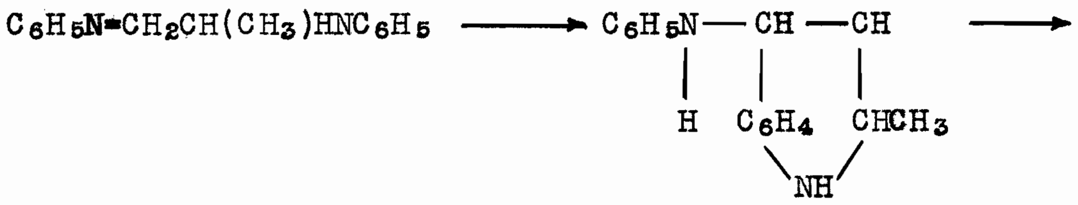
$$2CH_3CHO + 2C_6H_5CH_2 \longrightarrow (C_6H_5)_2(C_2H_2)_22N + 2H_2O$$

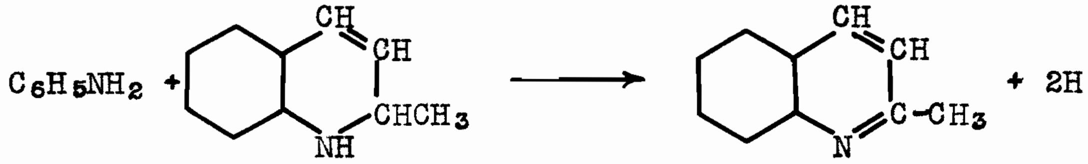
Aniline(54) dissolved in 90 per cent alcohol and, condensed with acetaldehyde below 10°C., gave a dark yellow oil, which turned red on standing. If dissolved in ether, a white crystalline powder, m.p. 126°C., b.p. 300°C., slightly soluble in benzene and alcohol, and soluble in ether, could be separated. Eckstein suggested two structures for this product.

$C_6H_5N=CH_2CH(CH_3)HNC_6H_5$

$C_6H_5NHCH(CH_3)C_6H_4NCHCH_3$

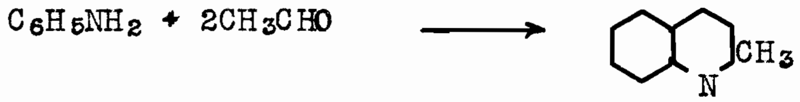
Addition of acetic acid or hydrochloric acid gave a 20 per cent yield of quinaldine.

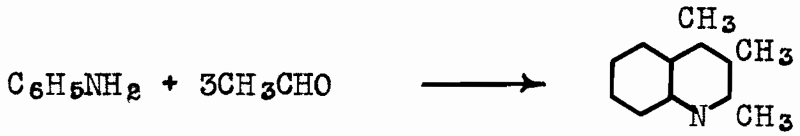




Eibner's and Koch's work(55) showed that the condensation of acetaldehyde and aniline chloride at 0°C gave, when the product was neutralised immediately, a white resin, which, when recrystallized from ether, showed to be a crystalline compound, m.p. 126°C., and identical with Eckstein's base. If, however, the reaction mixture was allowed to stand, a resin was formed which, on acidification with hydrochloric acid, gave quinaldine but no Eckstein base.

Condensation of an excess of paraldehyde and aniline(56) in the presence of sulphuric or hydrochloric acid, gave quinaldine and also some trimethyl quinoline.

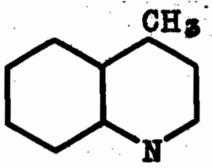




V. Braun(57) obtained quinoline ring compounds by using other acids and therefore stated that, in general, the condensation of an aliphatic aldehyde with a primary aromatic amine in the presence of an acid as condensing agent, would lead to quinoline ring compound.

That general statement was in agreement with experimental results obtained by other workers. Condensation of acetaldehyde or paraldehyde(58) with aniline at 360-420°C., using aluminium oxide as condensing agent, gave lepidine, 4-methylquinoline, as product. Higher temperature condensation gave similar results.

$CH_3CHO + 2C_6H_5NH_2 \longrightarrow$



The first one to separate and identify the 1,1-di(phenylamino)ethane was Eibner(59) who obtained the product, m.p. 51°C., by treating the water solution of aniline with acetaldehyde at room temperature.

$$CH_3CHO + 2C_6H_5NH_2 \longrightarrow CH_3CH(NHC_6H_5)_2 + H_2O$$

The product was found to be very soluble in alcohol, ether, benzene and chloroform.

The 1,1-disubstituted ethane compound, m.p. 49°C., condensed later again by Miller and Wagner(60) at low temperature, using very pure reagents, was shown to be stable at low temperature only, higher temperature condensation producing oils.

Study of the mechanism of the aniline-acetaldehyde condensation led Miller and Plöchl(51) to the conclusion that primary condensation products of neutral-medium, high-temperature condensation were azomethines, $C_6H_5N=CHR$, which changed into dimeric molecules due to alcohol-like condensation, giving an Eckstein base.

$$C_6H_5NHCH(CH_3)CH_2CH=NC_6H_5$$

Miller's and Wagner's(60) extensive work showed, however, no evidence for intermediate formation of azomethine. The high-temperature condensation gave so-called Eckstein's bases. Also the di-imine which, on standing at room temperature, liquefied and became coloured, presumably changed gradually to the Miller and Plöchl "dimer". However, every effort to force azomethine formation was unsuccessful, the product being in every case the di-imine as reported previously by Eibner(62). The authors concluded, therefore, that acetaldehyde and aniline did not yield isolable azomethine either as monomer or as true polymer. "Dimers" were products formed by secondary changes, the primary product being the unstable di-imine, 1,1-di(phenylamino)ethane.

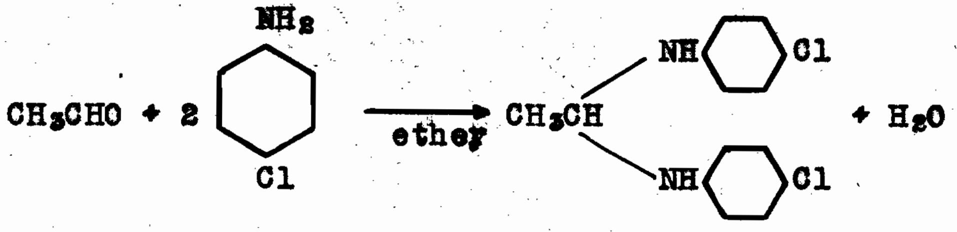
Resinous products of acetaldehyde-aniline condensation were found to have a variety of uses. Condensation at 0°C. in anhydrous medium(63) gave a resinous product, a rubber preserver without any vulcanization accelerating properties. Condensation at 135-140°C. in very slightly acid medium(64) produced a rubber vulcanization accelerator. A rubber vulcanization accelerator(65) under the name "K-1" was also obtained by condensing three molecules of acetaldehyde with two of aniline at room temperature.

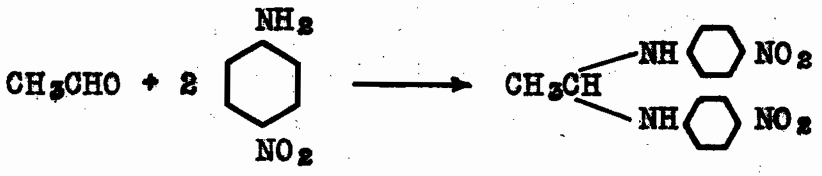
Condensation at 80°-100°C. in varnish solvents(66) with subsequent treatment with oxalic acid gave varnishes of very good drying properties, bright surface and stability to water and alkali. Finally, condensation in aqueous solution in the presence of sodium acetate and glacial acetic acid(67) at a temperature of 40-50°C. gave an industrially-used resin.

2. Substituted Anilines

(a) Substituted in the benzene nucleus

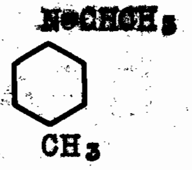
Products of non-catalytic condensation of acetaldehyde and chloro- and nitro-substituted aniline were investigated by Eibner(62). They were found to be crystalline compounds of definite melting points .



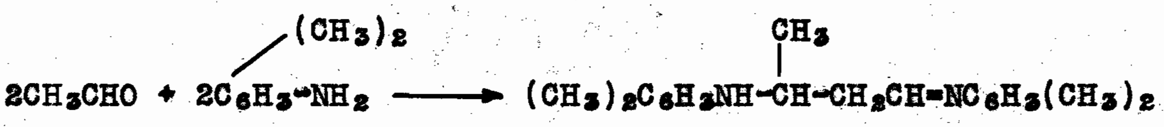


1,1-Di(4'-chlorophenylamino)ethane, m.p. 64-65°C., decomposed on recrystallization, while 1,1-di(4'-nitrophenylamino)ethane, m.p. 167°C., was more stable, soluble in benzene, and chloroform, but insoluble in ether.

Alkyl substituted anilines were not found to form monomeric ethane derivatives. Non-catalytic condensation of acetaldehyde and 4-methylaniline(68) gave warty crystals of melting point around 60°C., to which Schiff ascribed the azomethine structure:



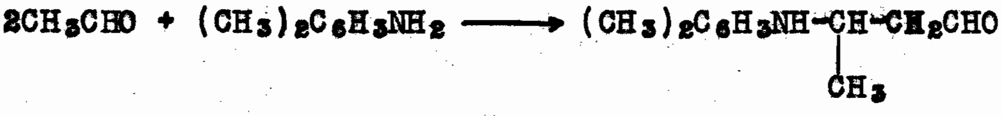
Further work(69) showed that Schiff's bases were obtained during condensations in alkaline or ether medium only, e.g., water solution condensation of acetaldehyde and a xylidine gave a dimolecular 1,1-dixylidinylethane, m.p. 147°C. --an Eckstein's base.



$$2CH_3CHO + 2\overset{(CH_3)_2}{C_6H_3}-NH_2 \longrightarrow (CH_3)_2C_6H_3NH-\overset{CH_3}{\overset{|}{C}}H-CH_2CH=NC_6H_3(CH_3)_2$$

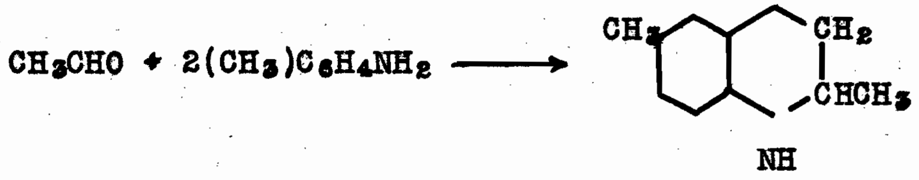
This result was comparable with the one obtained during aniline dondensation in neutral media.

Condensation in acid medium was reported incorrectly to give two isomeric straight chain compounds of m.p. 102°C. and 131°C.



$$2CH_3CHO + (CH_3)_2C_6H_3NH_2 \longrightarrow (CH_3)_2C_6H_3NH-\underset{CH_3}{\underset{|}{C}}H-CH_2CHO$$

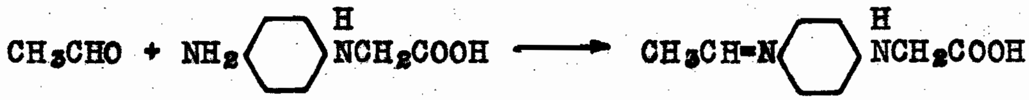
Edwards, Garred and Jones(70) proved the structure of the above condensation product to be a quinoline ring compound. They isolated the two cis and trans forms in the case of 4-methylaniline condensation.



These results are again comparable to the ones obtained in aniline condensation and confirm Braun's(57) generalization. The only reported resin formation(66) took place at 80-100°C. in solvents like benzene and its homologues.

Two special cases are noted also in the literature. Condensation of acetaldehyde with 4'-amino-1-phenyl-5-methyl-benzothiozole(71) was found to take place by interaction of the hydrogens of the amino groups with the aldehydie oxygen to form an unsymmetrical ethane derivative.

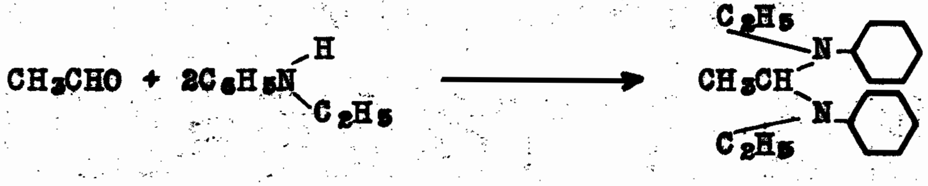
The product separated in the form of brownish yellow crystals. No analytical data or physical properties of the compound were given. In the condensation of acetaldehyde and (4-amino-phenyl) glycine(72) the primary amino group took part in the reaction, giving a product of a structure similar to Schiff's bases.



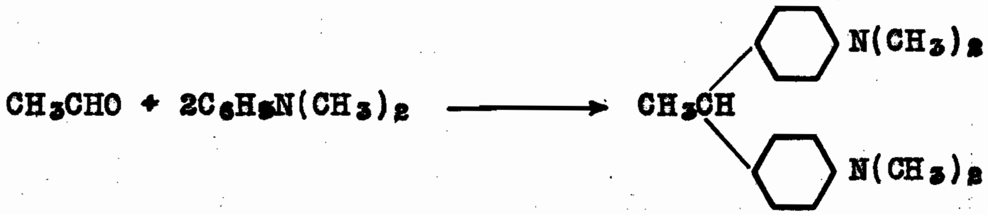
The condensation took place on heating or using concentrated hydrochloric acid as a catalyst. The product was a brown powder, which decomposed at 280°C. without melting.

(b) Substituted in the amino group

Replacement of one amino hydrogen(73) did not change the mode of reaction and an unsymmetrical ethane compound was formed through loss of the available hydrogen in two amino groups.



The replacement of both hydrogens in the amino group(74) did not, However, permit the formation of the usual link and it was found that the condensation took place through the interaction of the hydrogens on the benzene ring with the aldehydic oxygen, giving a product of similar structure to that of alkylbenzene condensation.



The condensation was carried out at low temperature, in alcohol medium and freshly prepared acetaldehyde was used. The product, 1,1-di(4'-dimethylaminophenyl)ethane, m.p. 68-69°C., separated in white crystals, insoluble in water, but soluble in ethyl alcohol, ether and carbon tetrachloride. Identical results were obtained by v. Braun(18) by using 20 per cent sulphuric acid as catalyst.

3. Naphthylamines

Condensation of acetaldehyde and α - or β-naphthylamines was found to lead to the formation of resins. German patents(66, 75) gave an industrial procedure for condensation of acetaldehyde and β - or a mixture of α - and β-naphthylamines in solvents like benzene and its homologues, to form resins similar to natural balsams, e.g., using an equimolecular mixture of both amines a product resembling Canada balsam was obtained.

Acetaldehyde with an equimolecular mixture of both amines in the presence of hydrochloric acid, gave a resin which, when added in small quantities to rubber compounds, imparted good ageing properties. Also condensation of two molecules of acetaldehyde with one molecule of α-naphthylamine(77) in inert solvents gave a resin which was found to protect rubber against heat-induced oxidation.

Paraldehyde and β-naphthylamine hydrochloride(78) gave yellowish brown crystals, which, however, were not identified.

4. Diamines

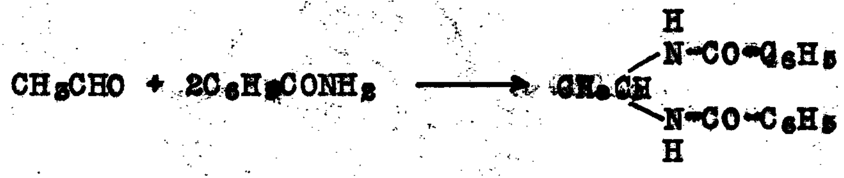
Condensation of acetaldehyde or paraldehyde and 1,3-diaminobenzene(79) in alcohol solution, in the presence of a few drops of concentrated hydrochloric acid, gave a fluorescent product of unsymmetrically substituted ethane structure.

Condensation of acetaldehyde with 3,5-aminotoluene(80) gave a yellow resin which could be converted into paint.

VI Aromatic Amides

Condensation of acetaldehyde and amides was found to take place in a similar manner to amine-aldehyde condensation, i.e., by the formation of a link through the amino group.

Condensation of acetaldehyde and benzamide(71), using dilute hydrochloric acid as condensing agent, gave 1,1-diphenylamidoethane, m.p. 188°C., slightly soluble in hot water, soluble in ether and hot alcohol.



$$CH_3CHO + 2C_6H_5CONH_2 \longrightarrow CH_3CH\left\langle\begin{array}{l}\overset{H}{N}-CO-C_6H_5\\ \underset{H}{N}-CO-C_6H_5\end{array}\right.$$

Similar results were obtained when benzylic amide was used instead of benzamide(82).

$$CH_3CHO + 2C_6H_5CH_2CONH_2 \longrightarrow CH_3CH(NHCOCH_2C_6H_5)_2$$

The product, m.p. 227-228°C., was found to be slightly soluble in ether and hot water, soluble in boiling alcohol.

VII Sulphur-containing Aromatic Compounds

Condensation of acetaldehyde and benzyl mercaptan(83) in acetic acid solution, using hydrogen chloride as condensing agent, was found to take place by the interaction of the aldehydic oxygen with the hydrogen of the thio group.

$$CH_3CHO + 2C_6H_5CH_2SH \longrightarrow CH_3CH(SCH_2C_6H_5)_2$$

1,1-Dibenzylmercaptylethane, b.p. 200-205°C. (5mm.), was also obtained using zinc chloride in hydrochloric acid as condensing agent(84).

VIII Heterocyclic Compounds

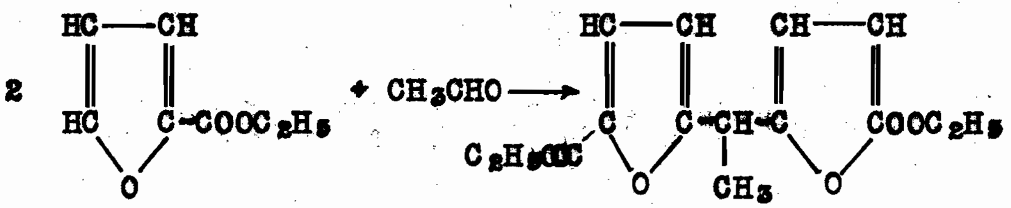
Condensation of acetaldehyde and the heterocyclic compounds in a variety of solvents, and under different temperature and catalytic conditions, leads, in the great majority of cases to unsymmetrically substituted ethane compounds, which form through the elimination of a molecule of water by the interaction of the aldehydic oxygen and two hydrogens from two molecules of the starting material. It would seem that the hydrogen adjacent to the non-carbon atom has the greatest tendency to be removed.

In the case of fused rings, the aromatic ring does not take part in the reaction.

1. Five-membered Rings

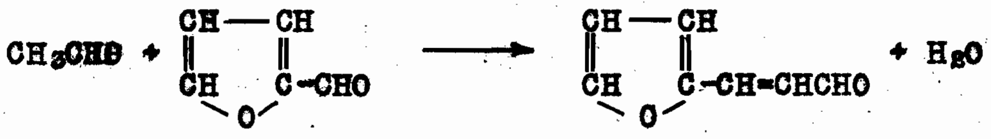
Furane Ring

Condensation of paraldehyde and a 2-substituted furane(85) at 0°C., using concentrated sulphuric acid as condensing agent, gave a 1,1-difurylethane by elimination of a water molecule through the interaction of the aldehydic oxygen and the hydrogen in the free 2 position.



The product was a pale yellow viscous liquid, b.p. 210°C. (5 mm.).

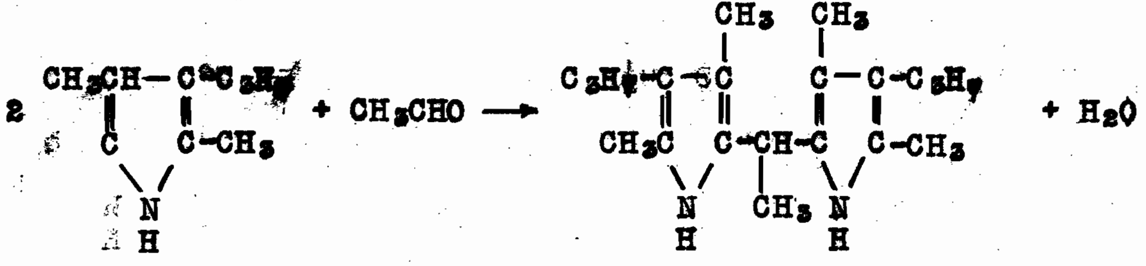
Condensation of furfural and acetaldehyde(86) in the presence of hydrogen chloride, gave a resin, insoluble in common solvents. However, using a 40 per cent solution of acetaldehyde, a very pure furfural and sodium hydroxide as catalyst, and keeping the reaction mixture at 0°C., fufuracrolein was obtained.

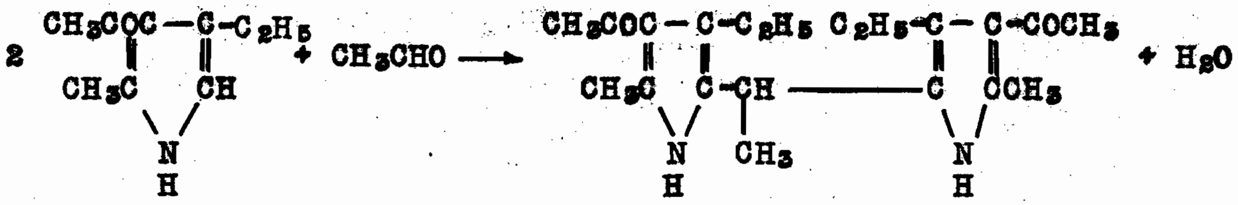


Pyrrole Ring

Condensation of acetaldehyde and pyrroles(87) was carried out in ethyl alcohol, using a few drops of concentrated hydrochloric acid as catalyst.

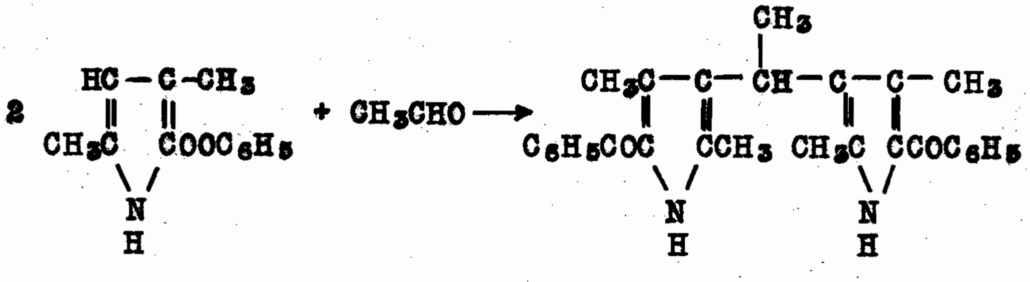
All attempts to condense 2-unsubstituted pyrroles failed; the 2-substituted compounds gave unsymmetrically substituted ethanes with 40 per cent solution of acetaldehyde, but tars only when a pure reagent was used.





Both condensation products were crystalline: 1,1-di(3'-propyl-2',4'-dimethylpyrryl)ethane, m.p. 150°C., and 1,1-di(3'-acetyl-2'-methyl-4'-ethylpyrryl)ethane, m.p. 248°C.

Paraldehyde and 2,4-dimethyl-5-benzoyl pyrrol(88) condensed on using zinc chloride as catalyst, giving similar results.



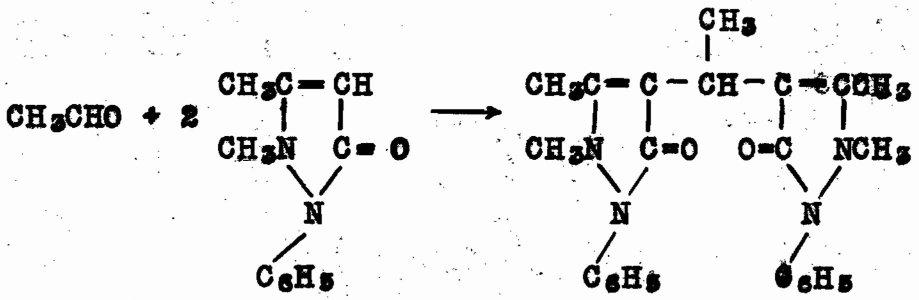
Condensation of paraldehyde and "hämopyrrolcarbonsäure" (89) in acetic acid, using hydrogen bromide as condensing agent, gave a crystalline product which melted with decomposition at 283°C. Analysis of this compound led the author to determination of its formula as

$$C_{32}H_{48}N_3O_5$$

but the structure was not determined.

Pyrazole Ring

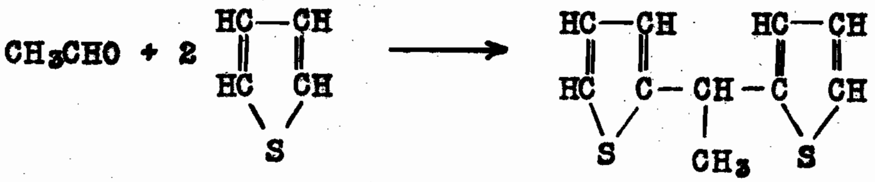
Condensation of antipyrine (1-phenyl-2,3-dimethylpyrazolone) with acetaldehyde(84, 90) at 120°C. took place through elimination of the only available hydrogen on the ring.



The product, 1,1-di(1'-phenyl, 2'-3'-dimethylpyrazolonyl)ethane, m.p. 153°C., was found to be soluble in alcohol, ether, chloroform, and insoluble in water.

Thiophene Ring

Paraldehyde and thiophene(91) in chloroform solution, condensed by phosphorus oxide , gave a product similar to the furanes.

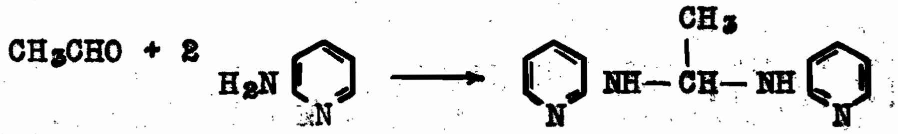


1,1-Dithiophenylethane, B.P. 270°-280°C., a yellow oil, was found to be soluble in ether, benzene and alcohol.

2. Six-membered Ring

Pyridine

Non-catalytic condensation of acetaldehyde and an amino derivative of pyridine(92) took place by elimination of a water molecule through the interaction of the aldehydic oxygen with the hydrogen of the amino group (see amines).

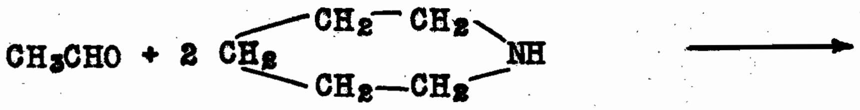


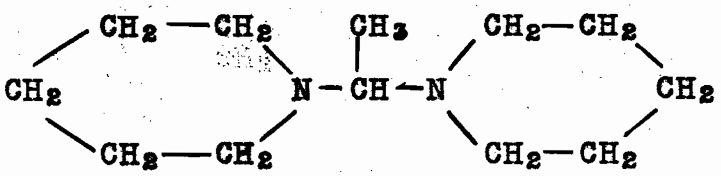
The product, m.p. 112.5°C., was formed in nearly quantitative yield.

Piperidine

Mannich and Davidson(93) found that, when an aldehyde is brought together with a secondary amine in the presence of solid potassium carbonate, at low temperature, a diamine with both amines residing on the same carbon atom was readily formed. When the aldehyde had at least one hydrogen atom on the carbon atom adjacent to the aldehydic group, an enamine $RCH=CRNH_2$ was formed subsequently.

In the case of acetaldehyde and piperidine, the reaction stopped on the first step.





1,1-Dipiperidinoethane, b.p. 58-60°C.(3 mm.), could be distilled at very low pressures; on distillation at higher pressures, piperidine and vinylpiperidine formed, but they distilled together and recombined in the receiver to the ethane compound again.

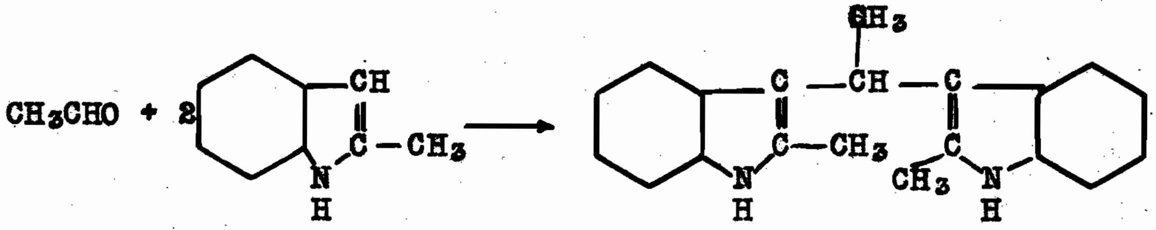
3. Fused Ring Compounds

Carbozoles (dibenzopyrrole)

Condensation of acetaldehyde and mono or polyalkylated carbozoles in the presence of sulphuric or hydrochloric acid gave transparent resins.

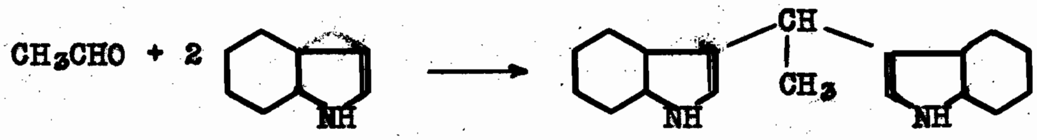
Indole (benzopyrrole)

Paraldehyde and 2-methylindole(95, 96) in the presence of zinc chloride at 80-100°C. gave a crystalline product.

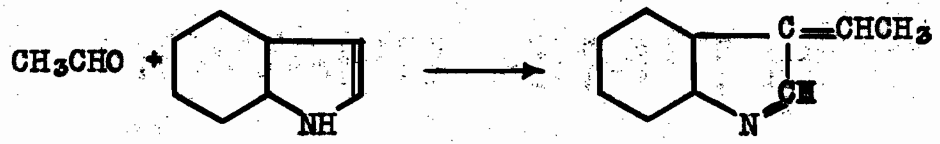


The 1,1-di(2'-methylindolyl)ethane, m.p. 191°C., was formed in the same way as 2,4,5-substituted pyrrol-acetaldehyde condensation product. The benzene ring did not take part in the condensation reaction.

Further work by Freund and Leubach(97) showed that in general two products were formed simultaneously, the trimeric-1,1-di-indolylethane,



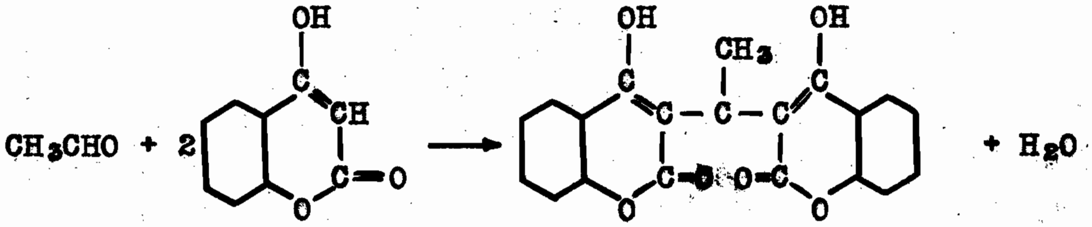
and at the same time also a dimeric indolyl derivative



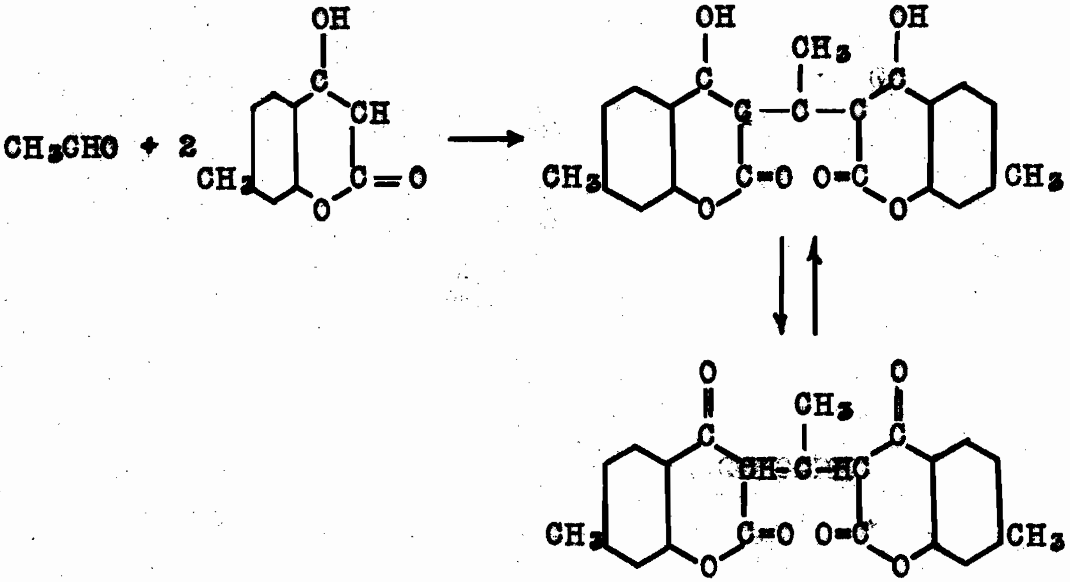
Both the above compounds were found to have application as dyes.

Cumarin

Condensation of acetaldehyde with 2-hydroxycumarin(98,99) in hot water solution, gave 1,1-di(2'-hydroxycumarino)ethane, m.p. 115°C.



Condensation of acetaldehyde and 5'-methyl-2'-hydroxycumarin (100) in hot methyl alcohol solution gave a similar compound, m.p. 206°C., to which the authors ascribed two alternative structures.



These two structures were suggested for all compounds of that type.

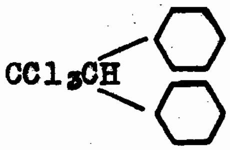
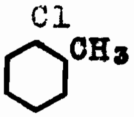
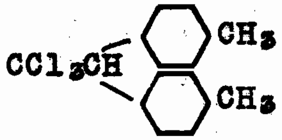
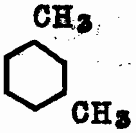
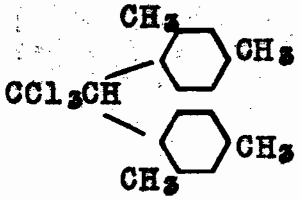
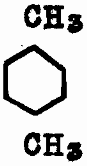
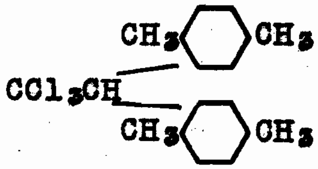
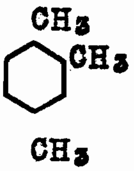
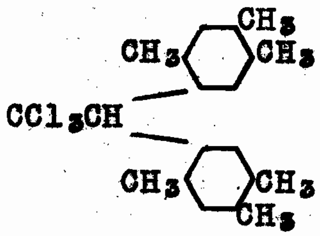
CONDENSATION REACTIONS WITH OTHER ALDEHYDES

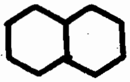
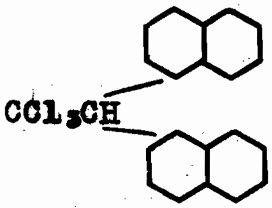
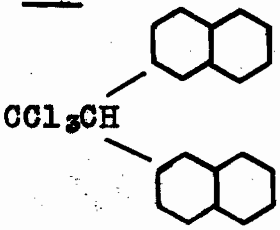
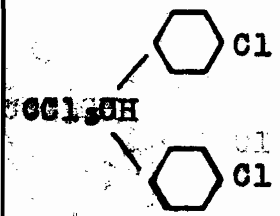
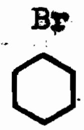
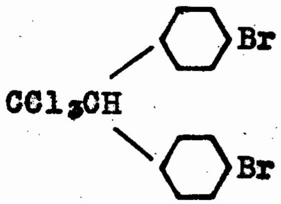
1. Chloral

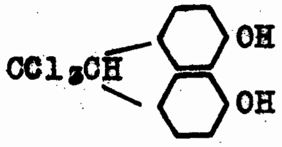
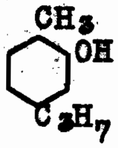
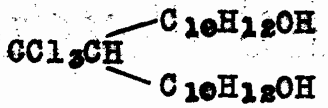
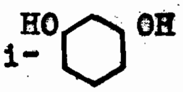
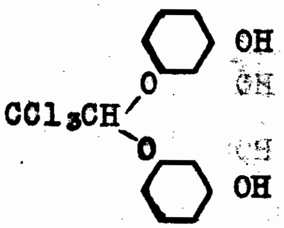
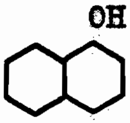
Condensation reactions of trichloroacetaldehyde with aromatic hydrocarbons, phenols, amines and other similar compounds, was much easier to study than the aldehyde condensation, due to the fact that easily purified, crystalline products could, in most cases, be obtained. As the mechanism of the reaction was identical with that of the acetaldehyde condensation a large number of valuable experiments was conducted. It should also be noted that many condensations which refused to take place with acetaldehyde, took place smoothly with the chloral.

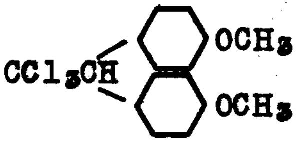
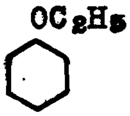
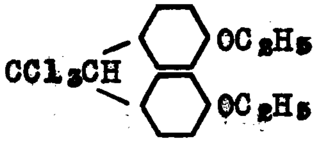
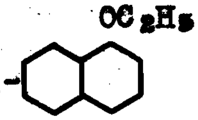
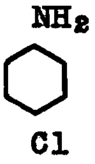
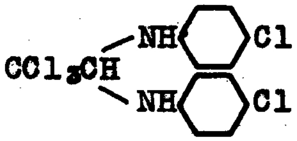
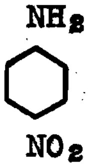
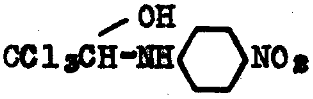
The following table gives a list of the 1,1-disubstituted trichloroethanes obtained by the workers in this field.

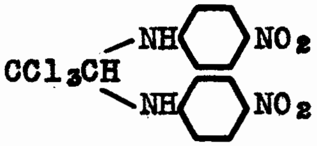
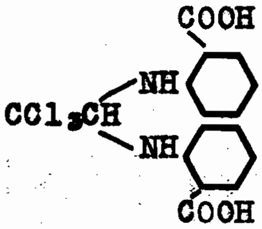
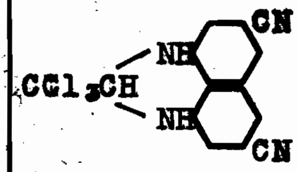
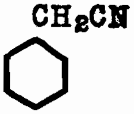
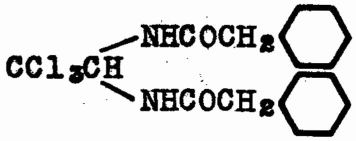
CHLORAL CONDENSATION PRODUCTS

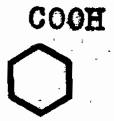
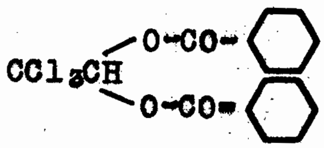
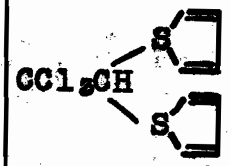
Starting Material Hydrocarbons	Catalyst	Product	m.p.	Ref.
benzene 	conc.H_2SO_4 $AlCl_3$		64°	101 102. 102,103
toluene 	H_2SO_4 $AlCl_3$		89°	104 102
xylene (1,3) 	conc.H_2SO_4		106°	105,106
xylene (1,4) 	conc.H_2SO_4		87°	106
pseudo-cumene 	conc.H_2SO_4		143°	106

Starting Material Hydrocarbons	Catalyst	Product	m.p.	Ref.
naphthalene 	Fuming H_2SO_4		136° s.alc.	107,108
		and		
			ins. alc.	107
chloro-benzene 	conc.H_2SO_4		105°	109
bromo-benzene 	conc.H_2SO_4		139-41°	109

Starting Material Phenols	Catalyst	Product	m.p.	Ref.
	K_2CO_3	chloral ethers at 4- position		110
phenol 	conc.H_2SO_4 CH_3COOH		202°	111,112
	$AlCl_3$		212°	102
thymol 	CH_3COOH + conc.H_2SO_4			113
resorcinol 				114
		$C_{14}H_8O_5$		115
	H_2O	$C_8H_6O_5$ + CCl_3COOH + 3HCl		116
1-naphthol 	CH_3COOH + H_2SO_4	$CCl_3CH(XC_{10}H_6OH)_2$	chars 200°	117

Starting Material	Catalyst	Product	m.p.	Ref.
Phenolic ethers				
anisole 	CH$_3$COOH + H$_2$SO$_4$		92°	111
	conc.H$_2$SO$_4$		78°	112
	AlCl$_3$			112
phenatol 	CH$_3$COOH + H$_2$SO$_4$		105°	102,108
	AlCl$_3$			
ethyl naphthyl-ether 	CH$_3$COOH + H$_2$SO$_4$	CCl$_3$CH(XC$_{10}$H$_6$OC$_2$H$_5$)	198-200°	111
Aromatic amines and nitriles				
4-chloro-aniline 			143°	119
4-nitro-aniline 	cold		128°	119

Starting Material Aromatic amines and nitriles	Catalyst	Product	m.p.	Ref.
	heat		216°	119
2-carboxy-aniline 	heat in benzene		165° (from ether) 240° (from [illegible])	120,121 122
3-cyano-aniline 	heat in toluene		165-7°	123
benzylic cyanide 	CH_3COOH + conc.H_2SO_4		257°	124
	conc.H_2SO_4			126

Starting Material		Catalyst	Product	m.p.	Ref.
Aromatic Acids					
benzoic acid		trace conc. H_2SO_4		65-5°	126
Heterocyclic Cmpds.					
thiophene		CH_3COOH + H_2SO_4		76°	127

II. Benzaldehyde

Benzaldehyde was found to behave similarly to acetaldehyde in presence of concentrated sulphuric acid (128) but only with homologous of benzene containing eight or more carbon atoms to the molecule. Condensations reactions of benzaldehyde with phenols, amines (25,129,130,131) and more complex aromatic molecules (126,132, 133) as well as when using catalysts other than sulphuric acid show close resemblance to the acetaldehyde condensations.

III. Cyclohexanone

The same phenomenon was observed in cyclohexanone condensations using cyclohexanone itself as well as substituted compounds and condensing them with phenols, (134 - 136) aromatic amines (137, 138).

CONDENSATION REACTIONS OF ACETYLENE

The easy formation of acetaldehyde from acetylene in presence of concentrated sulphuric acid and a trace of mercuric ions led some workers to the belief that substitution of acetaldehyde by acetylene in condensation reactions when using above mentioned catalyst should lead to parallel results. That belief was confirmed by experimental data obtained by Niewland and his coworkers, although some of his results seem to be doubtful in view of the recent experiments in this department.

The simplest picture of the acetylene-acetaldehyde transformation would be represented by the following equation:

$$HC\equiv CH + 2H_2O \longrightarrow CH_3CH(OH) \longrightarrow CH_3CHO + H_2O$$

Proof was also found that acetylene forms first complex intermediate compounds with water and the mercuric salt, with simultaneous formation of acids. Acetaldehyde is formed by reaction of that intermediate with acid. As however some reactions were carried out in anhydrous media, Niewland suggested that acetylene acted as anhydrous acetaldehyde (139,140).

It was also found that condensations catalysed by other reagents than concentrated sulphuric acid led to products identical with the products of the acetaldehyde condensation.

I. Aromatic Hydrocarbons

1. Benzene

According to Niewland (141) condensation of acetylene and benzene in the presence of concentrated sulphuric acid and mercuric sulphate carried out at 10-20°C. gave 40 - 50 per cent yield of 1,1-diphenylethane. These results, however, were not duplicated when identical condensation was recently carried out (142). Under various conditions using the highest commercially obtainable purity of acetylene the condensations gave very low yields, the highest being 16 per cent, generally about 6 to 10 per cent with large amount of solid by-products and tar. A series of catalyst promoters was added but the yields kept in the above range.

Condensation of acetylene and benzene in presence of aluminum chloride was also tried by some workers. Varet and Vienne (143) obtained an 80 per cent yield of styrene and 15 per cent yield of 1,1-diphenylethane, while Cook, and Chambers (144) found only traces of above products, the main product being mesidomethyldihydroanthracene, which was probably formed by the reaction between the 1,1-diphenylethane and an excess of acetylene. Boeseken and Adler (145) obtained results similar to Cook's, when amalgamated aluminum was used. With aluminum chloride, however, he assumed formation of a compound which he called polyprostyrene , formed from a very reactive primary product prostyrene C_8H_8.

The latest work in this field (146) gave again different results: a 30 per cent yield of 1,1-diphenylethane and a 20 per cent of ethylbenzene was obtained.

2. Alkyl Benzenes

The condensation of a series of substituted benzenes was investigated using sulphuric acid and mercuric sulphate as catalysts. It was found that mono- and dimethyl substitution aids the condensation reaction, while polysubstitution and monosubstitution with larger groups inhibits it markedly. 1,1-Ditolylethane, b.p. 295-300°C., 1,1-di(4'-ethylphenyl) ethane, 1,1-dixylylethane, b.p. 322-26°C., 1,1-dimesitylethane, b.p. 344-348°C.(141) were synthesised. All compounds boiled without decomposition and the last two were found to be fluorescent. Also a series of 1,1-di(monoalkylsubstitutedphenyl) ethanes was synthesised (147),

$$CH\equiv CH + C_6H_5R \longrightarrow CH_3CH(C_6H_4R)_2$$

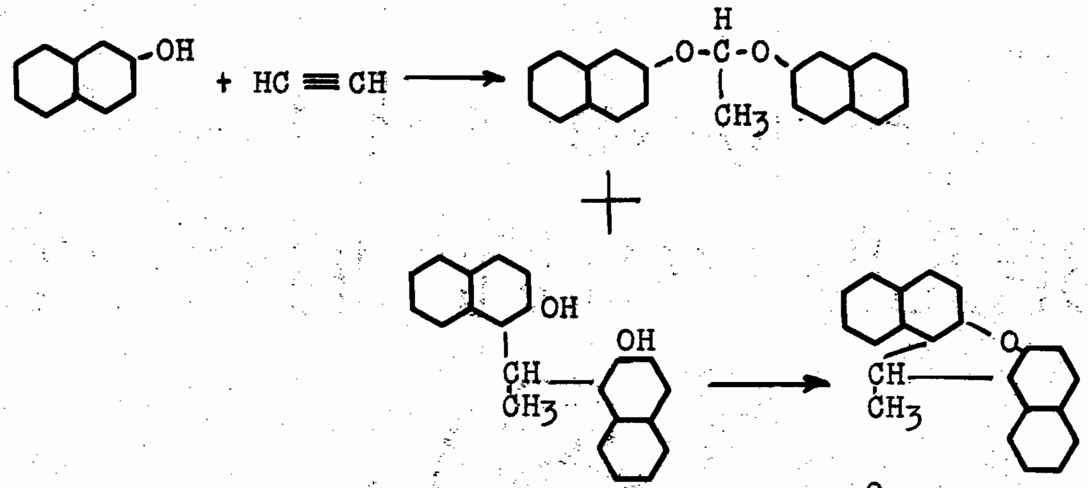
R symbolizing a propyl, isopropyl, butyl or isobutyl group. All products were viscous, amber-coloured liquids, of high boiling point, best distilled under reduced pressure. Polynuclear hydrocarbons, such as diphenyl, diphenylmethane, triphenylmethane and naphthalene did not react with acetylene under these conditions.

1,1-Ditolylethane was also obtained using aluminum chloride as catalyst (144). By the same method 1,1-di(4'-chlorophenyl) ethane, b.p. 319-21°C. was synthesised, while nitrobenzene refused to react.

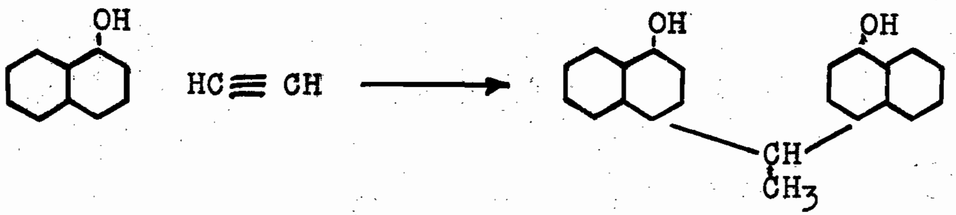
II. Phenolic Compounds

Similarly to acetaldehyde, acetylene has been shown to condense with aliphatic alcohols (139) to form acetals, and with phenolic compounds to form unsymetrically-substituted ethanes or resins.

Phenol and cresols condensed to give mixtures of products, which were found impossible to purify; β-naphthol gave some acetal and some 1,1-di(2'-hydroxynaphthyl) ethane (148):



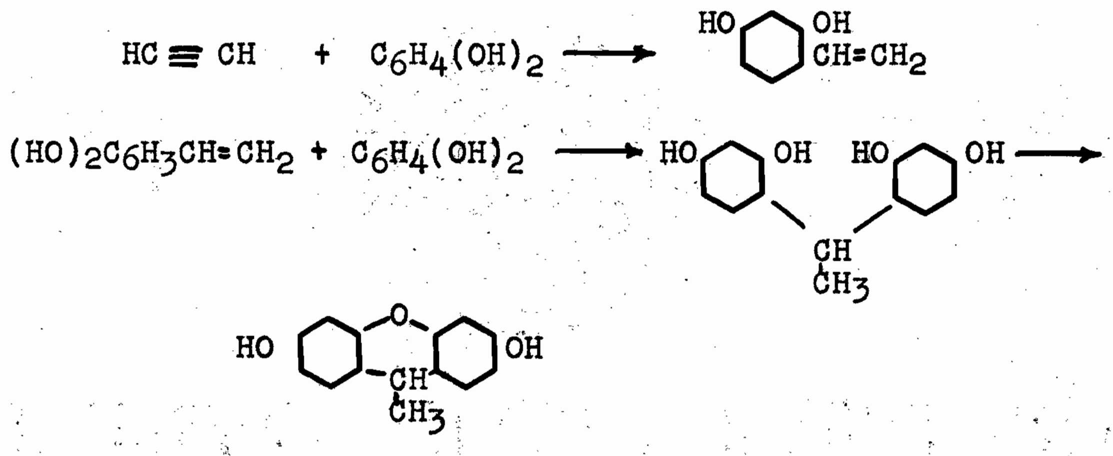
The 1,1-di(2'-hydroxynaphthyl) ethane, m.p. $168.5^{\circ}C$. changed through loss of a molecule of water into an internal ether: ethylidine di-β-naphtholyl oxide, m.p. $173^{\circ}C$. That mechanism is different than the one given by Claisen (1920) for the acetaldehyde-β-naphthol condensation.



a-naphthol gave the 1,1-di(1'-hydroxynaphthyl) ethane only (139)

Pyragallol and phloroglucinol reacted even more readily than did phenol, giving products soluble in alkali.

A great amount of work has been done on the acetylene-resorcinol condensation. The first mechanism (148) suggested, assumed the formation of the ethane compound as the first step of the reaction, with subsequent spontaneous change to dihydroxymethylxanthane. Later work, however, (29) led to a new mechanism. Vinylresorcinol, which was isolated S from the reaction mixture, was given as a primary product:



This mechanism is the one accepted nowadays.

No products were obtained when 2- or 4-nitrophenol were used (148). The authors explained that by the fact that the nitro group is 3- directing, while the tendency of the ethylidine group is to enter the 4- position. Instead of occupying a position 3- to the side chain the acetylene did not react at all. The lack of results in phenatol, ethylphenylether, condensation was explained by the inhibiting influence of the replacement of a hydroxyl group by an alkoxy group.

Resins were obtained when phenol and acetylene condensed in glacial acetic acid solution (148) using sulphuric acid and mercuric sulphate.

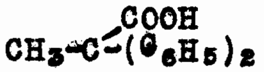
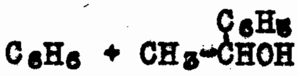
III. Aromatic Amines

Condensation of aromatic amines and acetylene has been carried out with a variety of catalysts. With a sulphuric acid - mercuric sulphate catalyst (141) quinaldine and 2,3,4-trimethylquinoline were obtained. The optimum results were obtained with 40 per cent sulphuric acid and a temperature of 60°C. When perchloric acid and mercuric perchlorate were used only trimethylquinoline was formed. With aluminum chloride as catalyst (144), aniline united with the catalyst and did not react further. Dimethylaniline gave a small yield of 1,1-di(4'-dimethylaminophenyl) ethane.

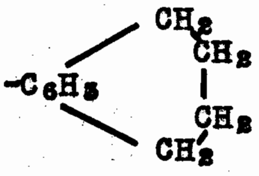
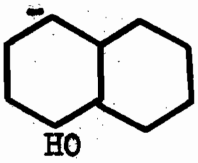
A new catalyst, copper chloride (150) or better cuprous chloride were found to cause quinaldine formation from aniline and acetylene. Condensation of 2-,3- or 4-toluidine (151) inttoluene with excess of acetylene using the same catalyst gave also a quinaldine ring compound as final product. Use of cuprous bromide (152) as well as mercuric chloride in alcohol solution (152, 153) led to compounds of identical structure, 4-nitroaniline giving a 50 per cent yield of 4-nitroquinaldine and α- and β-naphthylamines giving naphthoquinaldines.

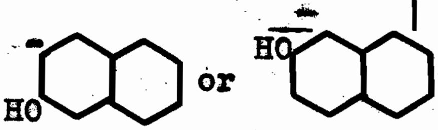
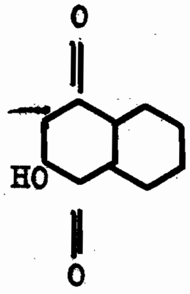
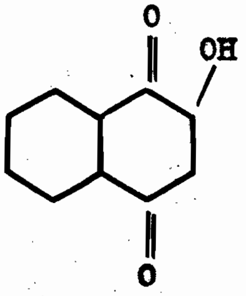
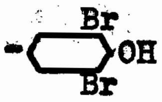
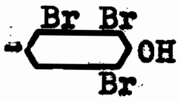
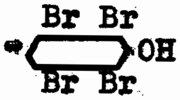
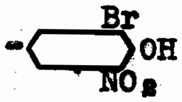
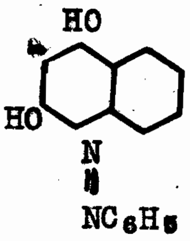
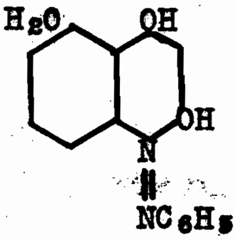
In the above historical introduction, the main methods for the synthesis of 1,1-disubstituted ethanes were described. There exists, however, a number of methods of minor importance, as well as a series of compounds synthesised through them, some of which were never obtained by the main methods. A table of all the 1,1-disubstituted ethanes so far reported follows:

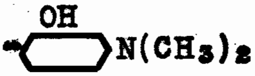
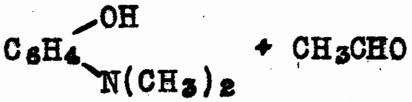
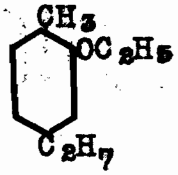
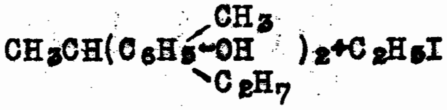
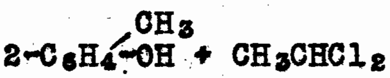
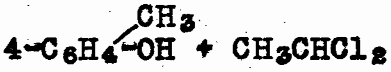
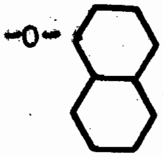
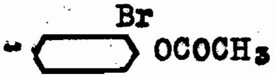
UNSYMMETRICALLY SUBSTITUTED ETHANES

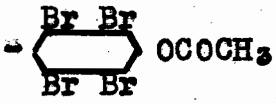
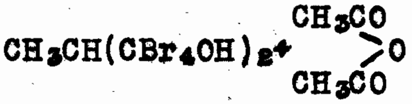
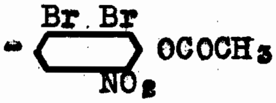
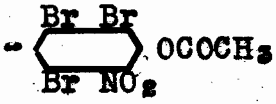
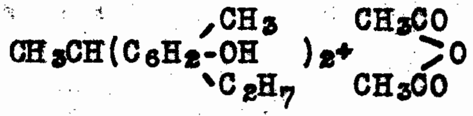
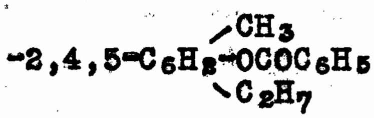
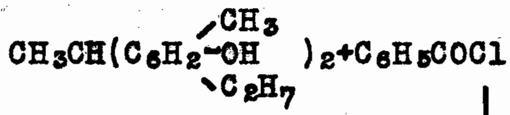
R	CH_3CHR_2 m.p. of cmpd.	 b.p. °C	Starting Materials	Ref.
Hydrocarbons				
$-C_6H_5$	-	268-70	$C_6H_6 + CH_3CHO$	1,2,3, this report
			$C_6H_6 + CH\equiv CH$	141
		136 (12 mm)	$C_6H_6 + CH_3CHCl_2$	154,155, 169
			$C_6H_6 + CH_2=CHCl$	155
		150	$C_6H_6 + CH_3CHBr_2$	156
			$C_6H_6 + CBr_2=CBr_2$	157
			$C_6H_6 + CHBrCHBr_2$	158
			$C_6H_6 + CHBrCBr_3$	159
			$C_6H_6 + CH_2=CHBr$	158
			$C_6H_6 + C_6H_5CHBrCH_3$	158,160
			$C_6H_6 + C_6H_5CH_2ClCH_3$	161
			$CCl_3CH(C)H_5)_2$	162,105
			$CH_2=C(C_6H_5)_2$	163
			 $CH_3-\overset{COOH}{C}-(C_6H_5)_2$	164
			$CH_3CH_2(C_6H_4COOH)_2$	165
			 $C_6H_6 + CH_3-\overset{C_6H_5}{CHOH}$	166
			$CH_3MgBr + (C_6H_5)_2CHBr$	167
		270-72	$(C_6H_5)_2C=CH_2$	168
			$C_6H_6 + C_6H_5CH=CH_2$	169,161
$-C_6H_4CH_3$		295-300	$C_6H_5CH_3 + CH_3CHO$	4,5,6, this report

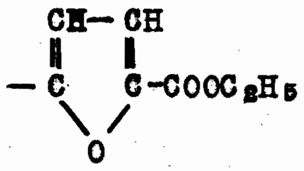
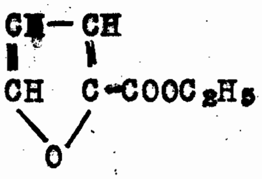
R	m.p.	b.p.	Starting Materials	Ref.
	of cmpd. °C			
Hydrocarbons(cont.)				
$-4-C_6H_4CH_3$		153-56 (11 mm)	$C_6H_5CH_3 + CH\equiv CH$	141
			$C_6H_5CH_3 + CH_3CHCl_2$	170
			(C_6H_5)	171
			$CH_3-C\overset{(C_6H_5CH_3)_2}{-}COOH$	172
			$C_6H_5CH_3 + CH_3CHO$	this report
$-C_6H_3(CH_3)_2$		322-26	$C_6H_4(CH_3)_2 + CH\equiv CH$	141
		169-72 (11 mm)	$C_6H_4(CH_3)_2 + CH_3CHCl_2$	173
$-2,4,6-C_6H_2(CH_3)_3$		344-48	$C_6H_3(CH_3)_3 + CH_3CHO$	this report
			$C_6H_3(CH_3)_3 + CH\equiv CH$	141
$-2,4,5-C_6H_2(CH_3)_3$	126-7		$C_6H_3(CH_3)_3 + CH_3CHO$	7
			$CCl_3CH\left[C_6H_2(CH_3)_3\right]_2$	174
$-4-C_6H_4C_2H_5$		328-32	$C_6H_5C_2H_5 + CH_3CHO$	this report
			$C_6H_5C_2H_5 + CH\equiv CH$	141
$-4-C_6H_4CH_2CH_2CH_3$		192-94 (12 mm)	$C_6H_5C_3H_7 + CH\equiv CH$	147
$-4-C_6H_4CH(CH_3)_2$		240-45 (37 mm)	$C_6H_5C_3H_7 + CH\equiv CH$	147
$-4-C_6H_4CH_2CH_2CH_2CH_3$		244-48 (37 mm)	$C_6H_5C_4H_9 + CH\equiv CH$	147
$-4-C_6H_4CH(CH_3)CH_2CH_3$		250-52 (12 mm)	$C_6H_5C_4H_9 + CH\equiv CH$	147
$-4-C_6H_4C(CH_3)_3$	94	212-14 (16 mm)	$C_6H_5C_4H_9 + CH\equiv CH$	147
$-4-C_6H_4CH(C_2H_5)_2$		234-36 (29 mm)	$C_6H_5C_5H_{11} + CH\equiv CH$	147
$-4-C_6H_4CH(CH_3)CH(CH_3)_2$		225-28 (13 mm)	$C_6H_5C_5H_{11} + CH\equiv CH$	147
$-2,5-C_6H_3\overset{CH_3}{-}CH(CH_3)_2$		153-54 (9 mm)	$C_6H_4\overset{C_3H_7}{-}(CH_3) + CH_3CHO$	this report

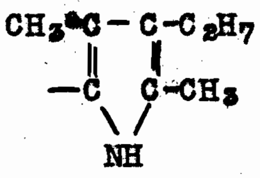
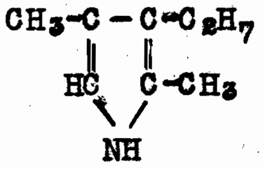
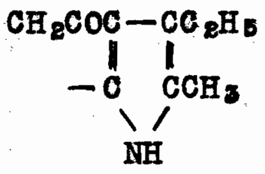
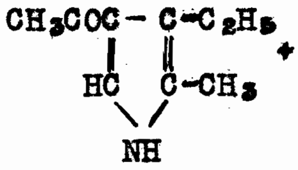
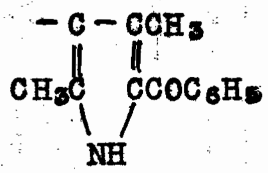
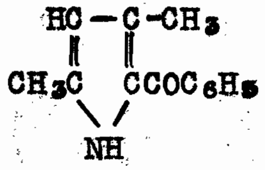
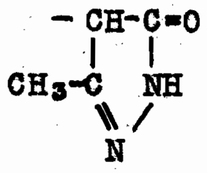
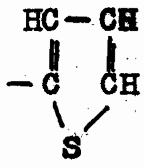
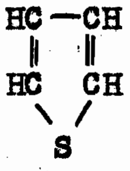
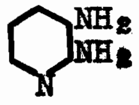
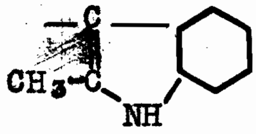
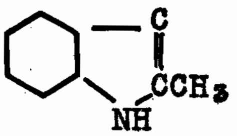
R	m.p. of cmpd.	b.p. °C	Starting Materials	Ref.
Hydrocarbons (cont.)				
		384	$C_{10}H_{12}$ + CH_3CHO	this report
		261-65 (16 mm)	$C_{10}H_{12}$ + CH CH	147
$-C_{10}H_7$	136		$CCl_3CH(1-C_{10}H_7)_2$	108
Substituted Hydrocarbons				
$-4-C_6H_4Cl$		319-21	C_6H_5Cl + $CH\equiv CH$	144
$-C_{10}H_6Br_2$	215		$CH_3CH(C_{10}H_7)_2$ + Br	108
$-C_{10}H_3(NO_2)_4$	258		$CH_3CH(C_{10}H_7)_2$ + conc. HNO_3	107
Phenols				
$-4-C_6H_4OH$	122	218 (1 mm) 245 (12 mm)	C_6H_5OH + CH_3CHO	8,14,15,16,17,18
			$CCl_3CH(C_6H_4OH)$	175
$-2,4-C_6H_3(OH)_2$			$C_6H_4(OH)_2$ + CH_3CHO	28,29
$-C_6H_2\overset{(OH)_2}{-}CH_3$			$C_6H_3\overset{(OH)_2}{}CH_3$ + CH_3CHO	31
$-2,4,5-C_6H_2\begin{matrix}CH_3\\-OH\\C_2H_7\end{matrix}$	185		$C_6H_3\begin{matrix}CH_3\\-OH\\C_2H_7\end{matrix}$ + CH_3CHO	22
			$CCl_3(C_6H_2\begin{matrix}CH_3\\-OH\\C_2H_7\end{matrix})_2$	113
			$1-C_{10}H_7OH$ + CH_3CHO	8
			$1-C_{10}H_7OH$ + $CH\equiv CH$	139

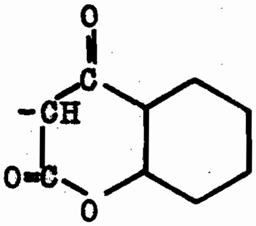
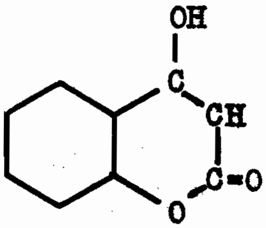
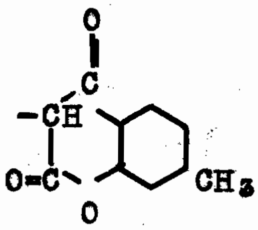
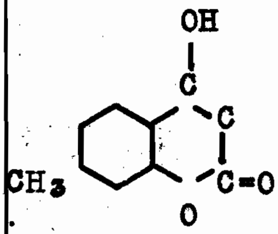
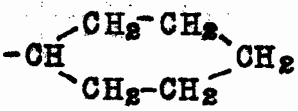
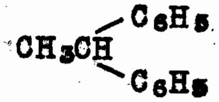
R	m.p. of cmpd.	b.p. °C.	Starting Materials	Ref.
	168.5		$2\text{-}C_{10}H_7OH + CH_3CHO$ $2\text{-}C_{10}H_7OH + CH\equiv CH$	13,20 148
	190		 $+ CH_3CHO$	35
Substituted Phenols				
	140-41		$CH_3CH(C_6H_4OH)_2$	176
			$CH_3CH(C_6H_4OH)_2$	176
	227-78		$CH_3CH(C_6H_4OH)_2$	176
	172		$CH_3CH(C_6H_2Br_2OH)_2$	176
	233		$CH_3CH(C_6Br_4OH)_2$	176
			 $+ CH_3CHO$	36

R	m.p. of cmpd.	b.p. °C.	Starting Materials	Ref.
	140		 $C_6H_4(OH)(N(CH_3)_2)$ + CH_3CHO	51
Phenolic Ethers				
$-4-C_6H_4OCH_3$	72	203-4 (10 mm)	$C_6H_5OCH_3$ + CH_3CHO	48, this report
	59.4	352-4	$CH_3CH(C_6H_4OH)_2$ + CH_3I	14
$-C_6H_3(OCH_3)_2$	77-77.5		$C_6H_4(OCH_3)_2$ + CH_3CHO	49
$-4-C_6H_4OC_2H_5$	141-2		$C_6H_5OC_2H_5$ + CH_3CHO	this report
	72		 $CH_3CH(C_6H_5(CH_3)(OH)(C_2H_7))_2$+$C_2H_5I$	52
$-OC_6H_5$	10	174-6 (27 mm)	C_6H_5OH + CH_3CHCl_2	177
$-2-OC_6H_4CH_3$	12	180-5 (27 mm)	 $2-C_6H_4(CH_3)-OH$ + CH_3CHCl_2	178
$-4-OC_6H_4CH_3$	15-17	200-4 (27 mm)	 $4-C_6H_4(CH_3)-OH$ + CH_3CHCl_2	179
	200-1		$C_{10}H_7OH$ + CH_3CHO	19,20
			$C_{10}H_7OH$ + CH_3CHCl_2	178
			$C_{10}H_7OH$ + $CH\equiv CH$	178
Phenolic Esters				
$-4-C_6H_4OCOC_6H_5$	152		$CH_3CH(C_6H_4OH)_2$ + C_6H_5COCl	17
	169-70		 $CH_3CH(C_6H_2Br_2OH)_2$+ $(CH_3CO)_2O$	176

R	m.p.	b.p.	Starting Materials	Ref.
	of cmpd. °C.			
Phenolic Esters (cont.)				
	205-6		$CH_3CH(CBr_4OH)_2+\begin{matrix}CH_3CO\\CH_3CO\end{matrix}>O$	176
	123		$CH_3CH(C_6HBr_2(NO_2)OH)_2$	176
	253-4		$CH_3CH(C_6Br_3(NO_2)OH)_2$	176
$-2,4,5-C_6H_2\begin{matrix}CH_3\\-OCOCH_3\\C_2H_7\end{matrix}$	100		$CH_3CH(C_6H_2\begin{matrix}CH_3\\-OH\\C_2H_7\end{matrix})_2+\begin{matrix}CH_3CO\\CH_3CO\end{matrix}>O$	32
$-2,4,5-C_6H_2\begin{matrix}CH_3\\-OCOC_6H_5\\C_2H_7\end{matrix}$	190		$CH_3CH(C_6H_2\begin{matrix}CH_3\\-OH\\C_2H_7\end{matrix})_2+C_6H_5COCl$	32
Aromatic Acids and Derivatives				
$-4-C_6H_4COOH$	275		$CH_3\overset{COOH}{C}(C_6H_4COOH)_2$	165
$-O-COC_6H_5$	12		$C_6H_5COOAg + CH_3CHBr_2$	179
			$C_6H_5COOH + CH\equiv CH$	180
$-4-CO-C_6H_4CH_3$	192	240-500 (20 mm)	$C_6H_5CH_3 + CH_3CH(COCl)_2$	181
Aromatic Amines				
$-NHC_6H_5$	51		$C_6H_5NH_2 + CH_3CHO$	59,60,61
$-4-NHC_6H_4Cl$	64-5		$ClC_6H_4NH_2 + CH_3CHO$	62
$-4-NHC_6H_4NO_2$	167		$NO_2C_6H_4NH_2 + CH_3CHO$	62

R	m.p. of cmpd.	b.p. °C.	Starting Materials	Ref.
Aromatic Amines(cont.)				
$-N(C_2H_5)C_6H_5$			$C_6H_5NHC_2H_5$ + CH_3CHO	73
$-4-C_6H_4N(CH_3)_2$	68-9		$C_6H_5N(CH_3)_2$ + CH_3CHO	74
			$CH_3-CH(C_6H_4N(CH_3)_2)_2$	182
$-4-C_6H_4N(C_2H_5)_2$	145		$CH_2=C\ C_6H_4N(C_2H_5)_2\ _2$	182
Amides				
$-NHCOC_6H_5$	188		$C_6H_5CONH_2$ + CH_3CHO	81
	202-204		C_6H_5CN + CH_3CHO	183,184
	188		C_6H_5COCl + CH_3CHO ammonia	185
$-NHCOCH_2C_6H_5$	227-8		$C_6H_5CH_2CONH_2$ + CH_3CHO	82
	224-5		$C_6H_5CH_2CN$ + CH_3CHO	186
Sulphur-containing Compounds				
$-SC_6H_5$			C_6H_5SNa + CH_3CHCl_2	186
$-SCH_2C_6H_5$		200-205 (5 mm)	$C_6H_5CH_2SH$ + CH_3CHO	83,84
$-SOCH_2C_6H_5$			$CH_3CH(SCH_2C_6H_5)_2$	83
$-SO_2CH_2C_6H_5$	176		$CH_3CH(SCH_2C_6H_5)_2$	83,187
	101-2		$CH_3C(SC_6H_5)_2COOH$	187
Heterocyclic and Aliphatic Ring Cmpds.				
		210 (5 mm)	 + CH_3CHO	85

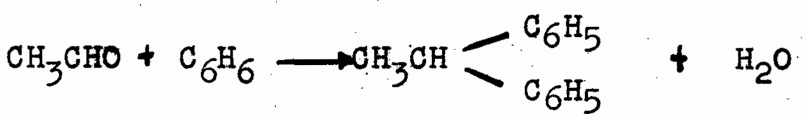
R	m.p. of cmpd.	b.p. °C.	Starting Materials	Ref.
Heterocyclic and Aliphatic Ring Cmpds.(cont)				
	150		 + CH_3CHO	87
	248		 + CH_3CHO	87
			 + CH_3CHO	88
	255		$CH_3CH(COOC_2H_5)_2$ + NH_2NH_2	188,189
		270-80	 + CH_3CHO	91
	112.5		 + CH_3CHO	92
$-N(CH_2)_5$		58-60 (3 mm)	$NH(CH_2)_5$ + CH_3CHO	93
	191		 + CH_3CHO	95,6

R	m.p. of cmpd. °C.	b.p. of cmpd. °C.	Starting Materials	Ref.
Heterocyclic and Aliphatic Ring Cmpds.(cont.)				
	115		 + CH_3CHO	98,9
	206		 + CH_3CHO	100
		118 (2 mm)	 $CH_3CH(C_6H_{11})(C_6H_5)$	168
			 $CH_3CH(C_6H_5)_2$	190

THEORETICAL DISCUSSION

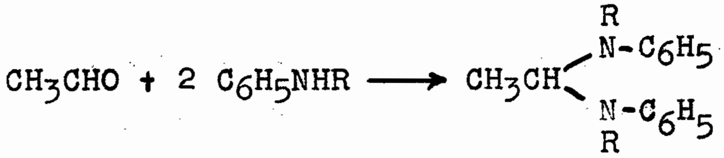
The synthesis of a series of unsymetrically substituted ethanes was attempted by condensing acetaldehyde, in the form of paraldehyde, with the corresponding hydrocarbon using concentrated sulphuric acid as catalyst, with a view of determining the limits of the reaction. The working conditions of all the reactions were identical, the optimum conditions for benzene - acetaldehyde condensation, as determined by other workers in this Department (3) being used. A few attempts with different catalysts and different temperature conditions were made in the case of the simpler aromatic hydrocarbons.

The mechanism of the condensation reaction to form an unsymetrically substituted ethane is a very straight forward one. In the simplest case, this is the benzene - acetaldehyde condensation, the product is formed through elimination of a molecule of water by interaction of the aldehydic oxygen and two hydrogens on two aromatic rings,



$$CH_3CHO + C_6H_6 \longrightarrow CH_3CH{<}\begin{matrix}C_6H_5\\C_6H_5\end{matrix} + H_2O$$

However, in substituted benzene compounds the question arises part which hydrogens are going to take place in the reaction as two cases are possible, either the side-chain or the nuclear hydrogens may be eliminated. Aniline compounds with at least one amino hydrogen free, react according to the first mechanism:



$$CH_3CHO + 2\ C_6H_5NHR \longrightarrow CH_3CH\begin{cases} N(R)-C_6H_5 \\ N(R)-C_6H_5 \end{cases}$$

In the case of the second mechanism three possibilities have to be considered. From the examination of all the syntheses up to date it is found that in mono-substituted benzenes, such as toluene and phenol, the ethylidene group is assumed by all workers to enter the 4-position in the ring, sometimes with a small amount of the 2-substituted compound as by-product (6). The only experimental proof of this hypothesis is the formation of a xanthane in condensation of resorcinol and acetaldehyde (see page 8 to 10). The formation of such a product shows clearly that no addition in the 3-position takes place. Also the improved yields, as compared to benzene, of the monosubstituted benzenes with 2,4-directing groups (with the exception of halogens) is in agreement with the above hypothesis as well as strictly in confirmity with other aromatic substitution reactions. The fact that no products form in attempted condensations of substituted benzenes with 3-directing groups is noteworthy. At this point it has to be noted that the structure of products obtained in condensation reactions of mono- and poly-substituted benzenes will always depend, just as in all other substitution reactions, not only on the directing influence of the substituent group but also on the inhibiting or activating power of this group. Therefore, the lack of products in the condensations of benzenes with 3-directing groups can also be explained by the inhibiting influence of this group and the good yields of most benzenes with 2,4-directing groups as due to their activating power. In the case of 1,4-di-substituted benzenes the ethylidene group is assumed to enter the 2-position, in 1,3-di-substituted the 4-position, in 1,2-di-substituted the position was never determined.

The method of synthesis employed by this worker was essentially that of Bayer (1,13) but changes in the working conditions, such as order and rate of addition of reagents, method of neutralization of the reaction mixture led to a marked improvement of yields, as compared with the ones obtained by earlier workers. Use of paraldehyde instead of pure acetaldehyde was not found to influence the reaction, which is understandable if we consider the fact that acetaldehyde, when heated with sulphuric acid, changes to more stable paraaldehyde.

The same procedure was used throughout the whole series of experiments, the optimum conditions for benzene-acetaldehyde condensation being used. In all the successfully completed synthesis a large amount of high boiling dark residue was present; in the unsuccessful ones the starting materials with a small amount of nonedistillable resinous product, or a large amount of the resinous product only, were obtained. The results obtained with each hydrocarbon will be discussed separately.

I. Aromatic Hydrocarbons

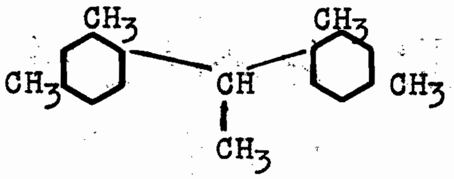
1. Benzene and Toluene

The synthesis of 1,1-diphenylethane and 1,1-ditolylethane were repeated and 40-50 per cent and 60-70 per cent yields respectively were obtained. This is a marked improvement over Fisher's and Bayer's results (14) but is comparable with the yields obtained in the aluminum chloride catalysed acetaldehyde and in the acetylene reactions. In both cases a large amount of tar was formed.

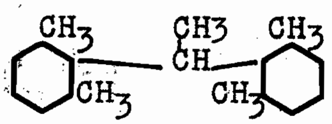
and?

2. Xylene

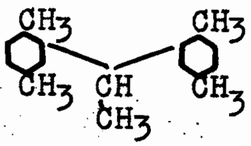
Condensation of technical xylene (a mixture of isomeric 1,2-,1,3-,1,4-xylenes) gave a product identical with the one obtained by Niewland, the yield being comparable with that obtained with toluene. The product is probably a mixture of several unsymetrical ethanes,



or



the two forms obtained from the 1,3-xylene, the second being less probable due to the steric hindrance of the two methyl groups. The 1,4-xylene will give one product,



while 1,2-xylene will probably give two ethanes again, the ethylidene group entering the 4- and 5-positions.

3. Mesitylene

Mesitylene reacted to give a poor yield of the unsymetrically substituted ethane, which can be explained by the hindering effect of the three symetrical methyl groups. The product was identical with the 1,1-dimesitylethane obtained from acetylene.

4. Ethylbenzene

Ethylbenzene gave lower yield when compared with that of toluene, which is difficult to explain considering the similarity of structure of both compounds. The above result would indicate a tendency to a decrease in yields with an increase of molecular weight. The only previous preparation of 1,1-(4'-ethylphenyl) ethane was the acetylene synthesis, but no boiling point data were given in the report (141).

5. p-Cymene (1-Methyl-4-isopropylbenzene)

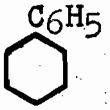
Synthesis of 1,1-dicymylethane was successfully completed. No reference in literature to the preparation of this compound was found. The small yields obtained in this condensation would indicate the tendency to a decrease of yields not only with an increase in molecular weight but also with an increase in complexity of the molecule. The ethylidene group is assumed to enter the 2-position to the methyl group.

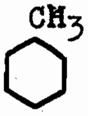
6. Naphthalene, 1-Methylnaphthalene, Anthracene, Phenanthrene

Naphthalene, 1-methylnaphthalene, anthracene, phenanthrene were found to resist condensation, starting materials and a small amount of tar were obtained, which is in agreement with the negative results obtained by Niewland (147) when condensing naphthalene. 1-Methylnaphthalene gave a small amount of dark brown brittle resin.

7. Diphenyl

Diphenyl, when dissolved in carbon tetrachloride and condensed in the usual way with paraldehyde gave a new compound, presumably 1,1-di(diphenyl) ethane, in contrast to the negative result of the diphenyl - acetylene condensation (147). Such reaction seems, however, very acceptable if we compare the two structures of diphenyl and toluene,





in which both side-chains are 1,3-directing and both are activating. The ethylidene group is assumed to enter the 4-position to the link between the two phenyl groups.

8. Indene

A product of the reaction was isolated and it's properties indicated, that the indene polymerized under the influence of sulphuric acid to paraindene (191). Paraindene corresponds to a combination of twelve to twenty-two molecules of indene.

9. Fluorene (diphenylenemethane)

Fluorene did not react and the starting material was recovered.

10. Tetralin

Condensation of paraldehyde and tetralin led to the formation, in small yields, of 1,1-di(tetrahydronaphthyl) ethane, tetrahydronaphthalene reacting like a dialkyl benzene. The ethylidene group was assumed to enter the 5- or 6-position. Some resinous and a large quantity of starting material were obtained.

12. Acenaphthene

The highly coloured material obtained from the acenaphthene reaction, of melting point around 150°C. could not be purified and no definite results were obtained.

II. Substituted Benzene Compounds

Starting materials were obtained when chlorobenzene, 1,4-dichlorobenzene, technical mixture of the isomeric trichlorobenzenes and bromobenzene were treated with paraldehyde. This fact is not surprising if we note that the chlorine group although 2,4-directing has an inhibiting influence on the incoming groups. Niewland's experimental results seem however to contradict the above argument; he obtained 1,1-di(4'-chlorophenyl) ethane when condensing acetylene and chlorobenzene.

Nitrobenzene did not give any product either, but that can be easily explained by the inhibiting property of the nitro group.

III. Phenolic Compounds

As noted in the first part of this work (see page 4) strong catalysts cause resinification in the acetaldehyde-phenol condensation. That was certainly found to be the case when concentrated sulphuric acid was used.

The phenol condensation product was a dark non-distillable oil, while o-cresol gave a viscous brown liquid, m-cresol a soft yellow resin and p-cresol a hard brown resin. Thymol gave a soft dark resin. All attempts to obtain crystalline products from these compounds failed completely.

IV. Aromatic Acids

Benzoic acid did not condense with acid aldehyde and starting material was recovered. As an explanation the inhibiting property of the carboxylic group can be noted.

V. Phenolic Ethers

This group of compounds, contrary to Niewland's statement that substitution of the phenolic hydrogen impeded the reaction, was found to give a series of crystalline products, of well defined melting point. The ease of formation of that group of compounds can be again explained by the activating influence of the 4-directing ether groups.

Anisole (methylphenylether) and veratrole (1,2-dimethoxybenzene) gave 1,1-dianisylethane and 1,1-diveratrylethane respectively. Both these compounds were synthesized by other workers before (see page 16). In the present case good yields of easily purified products were obtained, comparable to Oliverio's (49) yields in veratrole condensation. This method of synthesis seems to have an advantage over the hydrochloric acid condensation (48) as shown by the two anisole condensations.

Condensation of phenatol (ethylphenylether) with paraldehyde led to a new compound 1,1-di($4'$-etoxyphenyl) ethane. No reference to this compound was found in literature. The yield was lower than that of the first two ethanes in this group.

In the reaction of diphenylether a small yield of solid product, melting at 150 - 160°C., was obtained. All attempts to purify the product failed and a dark green viscous oil was the only final product.

VI. Aromatic Amines

The instability of 1,1-di(phenylamino) ethane at higher temperatures showed up clearly in this condensation. At the low temperature of the reaction as well as in the ice-water solution a white precipitate was observed, which changed however, into a dark heavy oil when separation of products at room temperature was attempted. Judging from the literature survey, it is suggested that the initial product of condensation, the unsymetrically substituted ethane, changed to the well-known dimeric, or even a polymeric Eckstein's base.

$$CH_3CHO + 2\ C_6H_5NH_2 \rightarrow CH_3CH(NHC_6H_5)_2 \rightarrow C_6H_5N{+}CH_2CH(CH_3)HNC_6H_5$$

When using dimethylaniline, and taking great care to keep the temperature of the reaction mixture low, a small yield of 1,1-di($4'$-dimethylaminophenyl) ethane and a large amount of highly coloured non-distillable by-product were formed.

VII. Heterocyclic and Aliphatic Ring Compounds

The experiments with simple five and six member heterocyclic as well as benzoheterocyclic compounds did not lead to any separable products, the latter fact being in agreement with Niewland's observations, that benzene derivatives with unsaturation in the side-chain do not condense with acetylene. From the, described on page experiments we could have, however, expected the formation of unsymetrically substituted ethanes in the case of monobenzoheterocyclic compounds by interaction of the hydrogens from the heterocyclic part of the molecule. ?

The aliphatic cyclic compounds, cyclohexane and decalin, did not react and the starting materials could be completely recovered.

1. Oxygen containing compounds

Furane was resinified by the strong acid, in the case of coumarone the sulphuric acid caused the formation of paracoumarone, and insoluble and infusable resin of composition $(C_8H_6O)_n$ where n is four, eight or twelve. Distillation depolymerizes somewhat the resin(192). Dibenzofurane did not react and the starting material was recovered. i

2. Nitrogen containing compounds

All nitrogen containing compounds were found to form tars even at the low temperature of the reaction. Pyrrole, indole, carbazole, pyridine, quinoline and isoquinoline gave dark solid insoluble in any solvent residues.

Attempts to condense benzene or toluene and acetaldehyde, using other than concentrated sulphuric catalysts, did not lead to any positive results. Concentrated hydrochloric acid was used at different temperatures and in different quantities, also using nigrosin black and zinc chloride as catalysts promoters. Phosphoric and benzenesulphonic acid in dilute sulphuric acid were experimented with. Also tin chloride in carbon tetrachloride solution proved unsuccessful.

The influence of change in concentration of sulphuric acid was studied but other workers of this Department and the concentrated acid, 95.96 per cent acid ?
was found to give the best results.

In general, the described method proved to be not very versatile, to be used as a standard procedure of for use
synthesis of 1,1-disubstituted ethanes. It gave positive results in case of alkyl substituted and alkoxyl benzenes only, and only in few cases satisfactory yields could be obtained. The catalyst was found to be too potent for phenolic and amino compounds, and gave unsatisfactory results in the case of heterocyclic compounds.

EXPERIMENTAL

Each condensation was carried out three times according to the following prodedures.

Standard procedure for the sulphuric acid catalysed reaction:

Concentrated, 95.96 per cent, sulphuric acid, 769.8cc., corresponding to 15.4 D.V.S., was placed in a 2l. three-neck,-round bottomed flask and cooled to 0-5°C. by means of a ice-salt bath. Acetaldehyde , 0.5 moles, in the form of paraldehyde and 5 moles of the reagent were used in a separatory funnel and added slowly with constant strong stirring of the mixture, the temperature of the reaction being maintained at 0-5°C. Stirring was continued for another half an hour after all the starting materials were added. Then the contents of the flask was poured on ice and left standing until all the ice had melted.

The sulphuric-acid layer was separated and discarded, as it was found by other workers in the case of benzene and by this worker in the case of toluene, xylene and ethylbenzene that further washing of the inorganic layer with ether or choroform does not yield any noticable amount of product.

The organic layer was washed with a 5-per cent solution of sodium hydroxide, or a 10-per cent solutioh of sodium bicarbonate , depending on the starting material, and then twice with water. The washed solution was dried with anhydrous calcium chloride, or sodium sulphate, and fractionally distilled, the first run under normal pressure, the second under reduced pressure and the third under the more favorable of the two.

If a precipate separated after the ice has melted, it was filtered, purified by washing successively with sodium bicarbonate solution and with water, with subsequent recrystallization and identification of the product. The remaining liquid was treated as described above and the precipate left after distillation of the excess of starting material was combined with the initially obtained one.

When solid reagents were used as starting material, they were dissolved in just sufficient quantity of carbon tetrachloride that the reagent would not separate at the temperature of the reaction. Acetaldehyde, 0.5 moles, in the form of paraldehyde and one mole of the dissolved reagent and 769.8 cc. of sulphuric acid were used, the procedure being identical with the one described above.

Ether was found to be an unsatisfactory solvent due to its great solubility in the acid.

The liquid reagents were all distilled before used, use the solid, if of technical quality, recrystallized; the paraldehyde used was a Merck's reagent.

In some cases half or a quarter of the above mentioned quantities were used.

The crystalline products were recrystallized to constant melting point from methyl alcohol and from ethyl alcohol.

The following table and a few additional data will give the full list of experiments conducted and the description of products. The starting materials are listed in the same order as discussed in the previous parts of this thesis.

Experimental Results

Starting mat.	Product	B.p. or m.p. in °C.	Yield %
Benzene	1,1-diphenylethane	bp.268-272	40-50
Toluene	1,1-ditolylethane	bp.295-300	60-70
Xylene	1,1-dixylylethane	bp.322-326	60-70
Mesitelene	1,1-dimesitylethane	bp.344-348	15-20
Ethyl-Benzene[1]	1,1-di(4'-ethylphenyl) ethane	bp.128-132 (9mm.)	30-40
Paracymene[2]	1,1-dicymylethane	bp.153-154 (9mm.)	15-20
Naphthalene	starting material		
Anthracene	starting material		
Phenanthrene	starting material		
1-Methyl-benzene	starting material and dark brown brittle resin		
Diphenyl[3]	1,1-di(diphenyl) ethane	mp.113-114	20-30
Indene[4]	paraindene	mp.210	
Fluorene	starting material		
Tetralin	1,1-di(tetrahydronaphthyl)ethane	bp.384-385	10-12
Acenaphthene[5]	not identified	mp. 150	
Chloro-benzene	starting material		
1,4-dichloro-benzene	starting material		
Trichloro-benzene	starting material		
Nitrobenzene	starting material		
Phenol[6]	dark non-distillable oil		
o-Cresol	viscous brown liquid		
p-Cresol	hard brown resin		

Starting mat.	Product	B.p. or m.p. in °C.	Yield %
m-Cresol	soft yellow resin		
Thymol	soft dark resin		
Benzoic acid	starting material		
Anisole[7]	1,1-dianisylethane	m.p.70-71	70-80
Veratrole	1,1-diveratrylethane	m.p.77-77.5	60-70
Phenatol[8]	1,1-diphenatylethane	m.p.141-42	60-70
Diphenylether[9]	dark coloured precipitate changing to oil on recryst.	m.p.(crude prod.)150-60	
Aniline	1,1-di(phenylamino) ethane oil		
Dimethyl-aniline	1,1-di(4^{1}-dimethylaminophenyl) ethane and large amt. of tar	m.p.68-69	3-8
Cyclohexane	starting material		
Decalin	starting material		
Furane	resin		
Coumarone[10]	paracoumarone	m.p.107-09	
Dibenzofurane	starting material		
Pyrrole	tar, insoluble in any solvent		
Indole	tar, insoluble in any solvent		
Carbazole	tar, insoluble in any solvent		
Pyridine	tar, insoluble in any solvent		
Quinoline	tar, insoluble in any solvent		
Iso-quinoline	tar, insoluble in any solvent		

Footnotes

1. 1,1-di(ethylphenyl) ethane, b.p. 196-200 (19mm.pressure)

n_D^{20} 1.5533

Anal. Calcd. for $C_{18}H_{22}$: C,90.76; H,9.24;
Found: C,90.46; H,8.98;

heavy colourless liquid.

2. 1,1-di(1',-methyl-4'-isopropyl) ethane, b.p. 153-54°C. (9mm.pr.)

Anal. Calcd. for $C_{12}H_{30}$: C,89.05; H,10.95;
Found: C,88.87; H,10.54;

3 heavy yellow oil, distills with decomposition under normal pressure.

3. 1,1-di(diphenyl) ethane, m.p. 113-114°C.

was recrystallized from (a) ethyl alcohol, (b) benzene.

Anal. Calcd. for $C_{26}H_{22}$: C,93.41; H,6.59;
Found: C,93.30; H,6.08;

very fine, colourless crystals.

4. paraindene

When the product, after pouring on ice, was left to stand a pink resinous solid separated. After thorough washing with alkali and water some white precipitate, insoluble in ether, separated, with physical constants corresponding to paraindene.

5. acenaphthene

The condensation product, obtained in the form of a black precipitate, when washed with alkali and water, gave a fine brown powder which dissolved with difficulty in alcohol, benzene, carbon tetrachloride and did not crystallize from it, but gave on partial evaporation of the solvent the initial impure product of melting point around 150°C.

Could be better expressed →

6. phenolic compounds

The products could not be washed with sodium hydroxide as the hydrocarbons, as sodium salts of the compounds would be formed, sodium bicarbonate was therefore used instead.

7. 1,1-dianisylethane

crystallized from ethyl and methyl alcohol.

Anal. Calcd. for $C_{16}H_{18}O_2$: C,79.34; H,7.44;
Found : C,79.46; H,7.40;

% OCH_3 for $C_{14}H_{12}(OCH_3)_2$: 25.62
Found : 25.15

well shaped colourless crystals .

8. 1,1-diphenatylethane

crystallized from ethyl- and methyl alcohol.

Anal. Calcd. for $C_{18}H_{22}O_2$: C,80.01; H,8.14;
Found : C,79.85; H,7.99;

flake-like colourless crystals.

9. diphenylether product

When the product was poured on ice some precipitate separated, but recrystallization from benzene, ethylether, ethyl alcohol, methyl alcohol was attempted, only a dark green oil was obtained. When the solvent, carbon tetrachloride, was distilled off from the liquid portion of the product an oil was also obtained.

10. paracoumarone

A large amount of heat was generated during the reaction. The resin formed, when washed and dried, was insoluble in usual organic solvents, when powdered a m.p. 107-9°C. was obtained. These specifications correspond to the infusible and insoluble type of paracoumarone, formed in the presence of excess sulphuric acid.

The following condensations were also attempted, all giving a small amount of tar and starting materials.

Each condensation was attempted with benzene and toluene, using one mole of the reagent and 0.5 mole of acetaldehyde in the form of paraldehyde. The only change from the sulphuric acid condensation procedure lies in the catalyst and the temperature of the reaction.

Catalyst	Temperature in °C.
Trace of concentrated HCl	0
30 cc. of conc. HCl	0, 20, 30
100cc. of conc. HCl	30
100cc. of conc. HCl and 5g. $ZnCl_2$	30
100cc. of conc. HCl and trace of nigrosin	30
100cc. of conc. H_3PO_4	0
200cc. of conc. H_3PO_4	0, 20
20g. of $SnCl_4$ in CCl_4	0, 10, 20.

SUMMARY

1. 1,1-Disubstituted ethanes can be formed by condensation of the aromatic hydrocarbons or heterocyclic compounds with acetaldehyde in the presence or absence of different catalysts, depending on the compounds used.
2. The only substituted benzenes which give the ethane compounds are those in which the substituent group is of an activating nature, i.e., the 4,2-directing ones, with the exception of the halogens.
3. The 1,1-disubstituted ethanes form through interaction of the aldehydic oxygen with the hydrogens of two aromatic groups, with the exception of the aromatic amine condensations, in which the amino-hydrogen is involved, and the benzo-heterocycle compounds in which the hydrogen of the heterocyclic ring takes part in the reaction.
4. Benzene and alkyl benzenes form 1,1-disubstituted ethanes when condensed in the presence of concentrated sulphuric acid or aluminium chloride.
5. Phenolic compounds form 1,1-disubstituted ethanes in the presence of dilute hydrochloric acid or tin chloride; stronger catalysts cause resinification. Polyhydroxy compounds have the tendency to form internal ethers through the interaction of the hydroxy groups.
6. Phenolic ethers condense to give 1,1-disubstituted ethanes in the presence of concentrated sulphuric acid.
7. 1,1-Di(phenylamino)ethane, stable at low temperature only,

can be condensed at such temperature and in slightly acid solution. Substituted anilines give 1,1-disubstituted ethanes, when condensed in acid media.

8. Only substituted heterocyclic and benzoheterocyclic compounds condense to give 1,1-disubstituted ethanes. The reactions are, in most cases, non-catalytic.
9. Paraldehyde can be used in all condensations. Acetylene in the presence of concentrated sulphuric acid and mercuric salts gives parallel results to acetaldehyde and paraldehyde.
10. Chloral, benzaldehyde and cyclohexanone react similarly to acetaldehyde.

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