ing point with a known sample of 3,5-dichloroaniline showed no deviation.

In another run, diethanolamine was employed without added alkali. No attempt was made here to identify other products than azo which was present in about 40% yield.

Preparation of 3,3′,4,4′-Tetrachloroazobenzene.—The 3,4-dichloronitrobenzene was, in most cases, refluxed with either di- or triethanolamine. The experimental procedure was the same as described above. The amount of 3,4-dichloroaniline recovered was small, usually under 10%. The azo product was recrystallized from a petroleum ether–benzene mixture giving a light orange product melting at 195.5° (cor.). Analyses indicated a persistent impurity, difficult to remove through successive recrystallizations: calculated % N for 3,3′,4,4′-tetrachloroazobenzene, 8.76; N found, 9.15, 9.07. Further identification was furnished by reducing the product with tin and hydrochloric acid. A white product giving a primary amine test and melting at 71° was obtained. A mixed melting point with a known sample of 3,4-dichloroaniline was unchanged.

Discussion

That reduction of the dichloronitrobenzenes occurs in definite stages is clearly borne out by some of the experiments. The one involving the action of diethanolamine on 3,4-dichloronitrobenzene is representative. When the two are refluxed together for a period of two hours, the only reduction product isolated is the azo compound; if heating is continued for four hours, no tetrachloroazobenzene can be identified, but reduction to the amino state is found to have taken place.

In previous work,[1] it was established that the 2,4-, 3,4- and 2,5-dichloronitrobenzenes were the most reactive of the isomers insofar as condensation reactions were concerned, while the 2,3- and 2,6- were much less reactive. When we examine the reducing tendency of the ethanolamines upon the various isomers, this general division still holds. The latter two compounds were much given to tar formation, from which tars little of interest could be extracted. For this reason most of the reported work dealt with the reactions of the 2,5-, 3,4- and 3,5-isomers, the 2,5- especially having been studied at length.

Hydrolysis of one of the chloro groups of 2,5- and 3,4-dichloronitrobenzenes was found to occur in certain of the reactions. That the chloro groups of these compounds are more active than the corresponding chloro groups of the other isomers already has been amply demonstrated.

Summary

1. Reduction to the amino and azo condition is found to occur when the isomeric dichloronitrobenzenes are reacted upon by the ethanolamines in the absence of a neutral solvent.

2. Condensation, hydrolysis and addition reactions are also found to occur.

3. Two new azo compounds, 3,3′,4,4′- and 3,3′,5,5′-tetrachloroazobenzene, are reported.

NEW YORK, N. Y. RECEIVED MARCH 16, 1940

[CONTRIBUTION FROM THE LABORATORY OF ORGANIC CHEMISTRY OF THE UNIVERSITY OF WISCONSIN]

Ketene Acetals. V. The Reaction of Ketene Diethylacetal with Various Compounds Containing an Active Hydrogen[1]

BY HARRY M. BARNES,[2] D. KUNDIGER AND S. M. MCELVAIN

In the fourth paper[3] of this series the unusual hetero-enoid system that is present in ketene diethylacetal was discussed, particularly as it affected the polymerization of the compound. It was to be expected that the reaction of a compound having such a strong nucleophilic center as does ketene acetal with other substances containing an active hydrogen would be of considerable interest. The present paper is a report of the results obtained from a study of the reactions of a variety of compounds, in which hydrogen is found attached to halogen, oxygen, carbon and nitrogen, with ketene acetal.

At the time that the preparation of ketene acetal was first reported,[4] the vigorous reaction of both water and ethyl alcohol with it was noted. These reactions produce ethyl acetate and ethyl orthoacetate, respectively. The formation of the former compound probably, and the latter obviously, involves addition across the carbon to carbon double bond of ketene acetal, thus

$$CH_2{=}C(OEt)_2 + HOEt \longrightarrow CH_3C(OEt)_3$$

Secondary alcohols (*i*-propyl and *s*-butyl) react similarly, but *t*-butyl alcohol does not appear to

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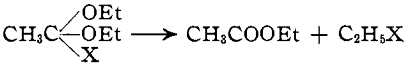
[1] This work was supported in part by grants from the Wisconsin Alumni Research Foundation.

[2] Wisconsin Alumni Research Foundation Scholar, 1935–1936.

[3] Johnson, Barnes and McElvain, THIS JOURNAL, **62**, 964 (1940).

[4] Beyerstedt and McElvain, *ibid.*, **58**, 529 (1936).

react even after several hours of refluxing with the acetal. In a similar manner the halogen acids. carboxylic acids and phenol appear to add to ketene acetal. The reaction takes place at room temperature with the liberation of considerable heat. The addition product (I), however, is

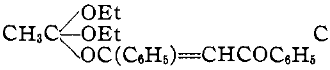


$$CH_3C\begin{cases}OEt\\OEt\\X\end{cases} \longrightarrow CH_3COOEt + C_2H_5X$$

I

unstable and decomposes into ethyl acetate and C_2H_5X(X is —Br, RCOO—, or C_6H_5O—). In the case of the phenol reaction a small amount of I decomposes into phenyl acetate and ether.

In contrast to the behavior of phenol, the highly enolic dibenzoylmethane gives a stable addition product, (O-(α,α-diethoxyethyl)-dibenzoylmethane, (II) with ketene acetal. Reaction occurs at



$$CH_3C\begin{cases}OEt\\OEt\\OC(C_6H_5){=}CHCOC_6H_5\end{cases}$$

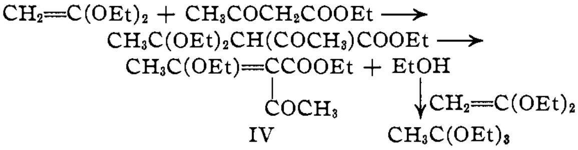
II

$CH_3C(OEt)_2CH(COC_6H_5)_2$

III

25° and is practically quantitative. The reaction product melts at 87° (m. p. of dibenzoylmethane, 78°) and was shown to have the structure II by the fact that it reacted to only a small extent (16%) with a standard ethereal solution of sodium triphenylmethyl. The enolizable alternative addition product III, which would result from the addition of the dibenzoylmethane as H and CH-$(COC_6H_5)_2$ to ketene acetal, would be expected to react quantitatively with this reagent as does dibenzoylmethane. When the product II is heated at 140° it decomposes into its components, dibenzoylmethane and ketene acetal. This is the same type of decomposition of an ortho-ester into a ketene acetal as that reported by Staudinger and Rathsam.[5] Indeed, II slowly decomposes at room temperature; a sample after standing in a vacuum desiccator over calcium chloride for three months was found to have reverted entirely into dibenzoylmethane.

Acetoacetic ester, which contains a relatively small amount (7%) of the enolic form, shows an entirely different behavior with ketene acetal. While each of the reactants described above reacts with the acetal in the molecular ratio of 1:1, each mole of acetoacetic ester that reacts consumes two moles of the acetal. No apparent reaction occurs at 25° but after nine hours at 85° a 12% yield of ethyl (α-ethoxyethylidene)-acetoacetate (IV) and an equivalent amount of ethyl orthoacetate may be isolated. The product IV is probably formed by the addition of the keto-ester as H and $CH(COCH_3)COOEt$ to ketene acetal followed by the loss of alcohol from the addition product. This liberated alcohol then reacts with another equivalent of ketene acetal to produce the ortho-ester. These reactions are



$$CH_2{=}C(OEt)_2 + CH_3COCH_2COOEt \longrightarrow CH_3C(OEt)_2CH(COCH_3)COOEt \longrightarrow \underset{\text{IV}}{CH_3C(OEt){=}\underset{\textstyle COCH_3}{\underset{|}{C}}COOEt} + EtOH \xrightarrow{CH_2=C(OEt)_2} CH_3C(OEt)_3$$

The yield of IV from the above reaction may be increased to 55–60% of the theoretical by the addition of 1 mole per cent. of sodium ethoxide to the reaction mixture. A corresponding increase in the yield of ethyl orthoacetate also is obtained.

The structure of the ester IV was established by (a) carbon, hydrogen and ethoxyl analyses, (b) partial hydrolysis to ethyl diacetoacetate and (c) partial hydrolysis into alcohol, acetoacetic ester and acetic acid.

In the absence of sodium ethoxide malonic ester does not react with ketene acetal even after several hours of heating at temperatures as high as 200°. With 1 mole per cent. of this catalyst, however, a 55% yield of diethyl (α-ethoxyethylidene)-malonate (V) and the corresponding amount of ethyl orthoacetate may be obtained after sixteen hours at 125°. The structure of V was established by (a) analyses, (b) partial hydrolysis to diethyl acetomalonate and (c) catalytic reduction to diethyl (α-ethoxyethyl)-malonate (VI).

$CH_3C(OEt){=}C(COOEt)_2$ V

$CH_3CH(OEt)CH(COOEt)_2$ VI

$CH_2{=}C(OEt)CH(COOEt)_2$ VII

Differentiation between structure V and the alternative structure VII was made by ozonolysis.[6]

Methyl malonic ester could not be caused to react with ketene acetal under conditions that were effective for the reaction of malonic ester. The use of sodium ethoxide, in quantities of 1–50 mole per cent., or sodium triphenylmethyl as condensing agents together with temperatures

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[5] Staudinger and Rathsam, *Helv. Chim. Acta*, **5**, 646 (1922).

[6] This ozonolysis was carried out by Mr. Howard Burkett of this Laboratory. He has found that a considerable amount of VII generally accompanies V as a product of this reaction. The combined yields of the two amount to about 80% of the theoretical. Their structures have been established by (a) ozonolysis and (b) alkylation of each to the same malonic esters, $CH_2{=}C(OEt)C(R)(COOEt)_2$, a series of which is being prepared and converted into the corresponding barbituric acids. This work will be reported in a future paper.

as high as 200° gave no appreciable reaction and in each case most of the starting materials could be recovered.

bis-(Phenylsulfonyl)-methane contains an acidic hydrogen, as shown by its solubility in alkali, but, presumably, is incapable of enolization. This disulfone gives no indication of reaction when treated with two equivalents of ketene acetal at 25°. When these reactants were heated together at 100° in dioxane solution for twelve hours and the solvent then removed by distillation, a glass-like residue remained. From this residue a considerable amount (42%) of the starting disulfone was separated, but no ketene acetal was recovered from the distilled solvent. The reaction product could be neither crystallized nor distilled. These facts indicate that this reaction was complicated by the polymerization of the ketene acetal. Similar results were obtained with these reactants when sodium ethoxide was used.

The nitrogen compounds used in this study were ammonia, aniline, ethylaniline and piperidine. In contrast to the vigorous reaction of water, ammonia shows no reaction with ketene acetal at 25°. At 100°, however, reaction between acetal and an excess of ammonia appears to be complete in three hours. For each mole of ketene acetal used, 1.68 moles of alcohol, 0.55 mole of acetonitrile (XI), 0.22 mole of acetamidine (X) and 0.02 mole of ethyl orthoacetate were isolated as reaction products. These products indicate that the following reactions occur

$$\begin{tikzcd} CH_2{=}C(OEt)_2 + NH_3 \arrow[r] & \underset{\text{VIII}}{[CH_3C(OEt)_2NH_2]} \arrow[r] & EtOH + \underset{\text{IX}}{CH_3C(OEt){=}NH} \arrow[d, "-EtOH"] \\ CH_3C(OEt){=}NH + NH_3 \arrow[r] & EtOH + \underset{\text{X}}{CH_3C(NH_2){=}NH} \arrow[r, "-NH_3"'] & \underset{\text{XI}}{CH_3CN} \end{tikzcd}$$

The low yield of the ortho-ester suggests that the addition product VIII is sufficiently stable not to decompose into alcohol, which would convert the ketene acetal into the ortho-ester, until the ammonia has reacted with most of the acetal. The other alternative, *viz.*, that the imino-ether (IX) is formed from the ortho-ester and ammonia seems unlikely since some ortho-ester does remain in the reaction mixture in the presence of a large excess of ammonia.

Aniline reacts quite readily with ketene acetal at 25°. The main reaction product is ethyl N-phenyl iminoacetate (XIII) which is obtained in an 81% yield. An amount of alcohol equivalent to that required in the reactions below and a 7% yield of N,N′-diphenylacetamidine (XIV) is also obtained. No ethyl orthoacetate was isolated. The reactions that take place are

$$CH_2{=}C(OEt)_2 + H_2NC_6H_5 \longrightarrow \underset{\text{XII}}{[CH_3C(OEt)_2NHC_6H_5]} \longrightarrow \underset{\text{XIII}}{CH_3C(OEt){=}NC_6H_5} + EtOH$$

$$CH_3C(OEt){=}NC_6H_5 + H_2NC_6H_5 \longrightarrow \underset{\text{XIV}}{CH_3C(NHC_6H_5){=}NC_6H_5} + EtOH$$

Ethylaniline reacts with ketene acetal, slowly at 25°, but quite readily at 100° to give N-ethyl-N-(α-ethoxyvinyl)-aniline (XV) and ethyl orthoacetate. When the reactants are used in equivalent molecular quantities, one-half of the ethylaniline is recovered, indicating the following reaction course

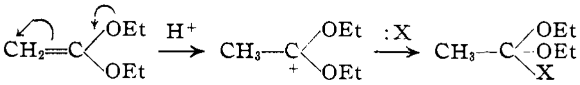
$$2CH_2{=}C(OEt)_2 + C_2H_5NHC_6H_5 \longrightarrow \underset{\text{XV}}{CH_2{=}C(OEt)N(C_2H_5)C_6H_5} + CH_3C(OEt)_3$$

Whether or not an intermediate addition product of the type of VIII and XII is a precursor of XV is not known. The product XV was characterized by (a) analyses and (b) hydrolysis to ethylaniline, alcohol and acetic acid. It was not possible to partially hydrolyze XV to N-ethylacetanilide.

Piperidine shows no reaction with ketene acetal at 25°. When a mixture of a five-fold excess of the base with the acetal is refluxed for two hours, reaction takes place and 0.43 mole each of 1,1,1-tripiperidinoethane XVI and ethyl orthoacetate for each mole of ketene acetal used in the reaction may be isolated. The formation of these compounds is illustrated as follows

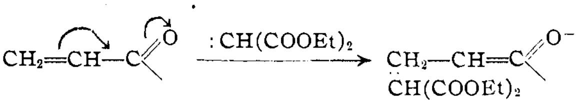
$$2CH_2{=}C(OEt)_2 + 3HNC_5H_{10} \longrightarrow \underset{\text{XVI}}{CH_3C(NC_5H_{10})_3} + CH_3C(OEt)_3 + EtOH$$

From the foregoing reactions it is seen that acids and, in general, compounds containing a replaceable hydrogen attached to oxygen (water, primary and secondary alcohols, enols, etc.) react readily with ketene acetal at ordinary temperatures. The reactivity appears to be related to the acidity of the compound. The same seems to be true for ammonia and its derivatives; the relatively strong bases (*i. e.*, weak acids), ammonia and piperidine, are decidedly less reactive than the very much weaker bases, aniline and ethylaniline. All of these reactions follow the course that would be expected, *viz.*, the attack of a proton on the nucleophilic center of a polarized molecule of ketene acetal, followed by the attachment of the negative portion of the addendum, :X, to the other carbon with an open sextet



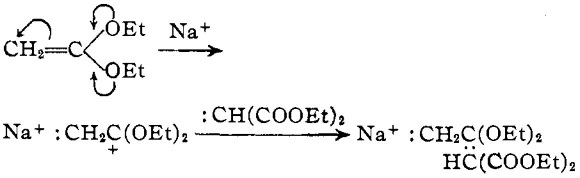
$$CH_2{=}C(OEt)_2 \xrightarrow{H^+} CH_3{-}\overset{+}{C}(OEt)_2 \xrightarrow{:X} CH_3{-}C(OEt)_2X$$

The reactivities of the active methylene compounds, acetoacetic ester, malonic ester and methylmalonic ester, also decrease with the acidity of the ester but in these cases the reaction, when it occurs, is decidedly different in that it is catalyzed by sodium ethoxide and a new carbon to carbon bond is formed. It seems likely that the addenda in a case such as malonic ester are Na^+ and $:CH(COOEt)_2$, but whether the sodium cation or the anion is the attacking portion of the addendum is a matter of speculation. This reaction has some resemblance to a Michael reaction. The latter also involves the addition of an active methylene compound to a carbon to carbon double bond through the catalytic influence of sodium ethoxide. In this reaction it seems likely that the polarization of the carbonyl group of the unsaturated compound creates a center of low electron density at the carbon to which the addendum anion becomes attached



$$CH_2{=}CH{-}C{=}O \xrightarrow{:CH(COOEt)_2} \underset{CH(COOEt)_2}{CH_2}{-}CH{=}C{-}O^-$$

The hetero-enoid polarization of ketene acetal, however, is such that neither of the carbons acquires an electron deficit. It seems necessary to suppose, therefore, that the alkaline catalyst functions through the ability of the sodium cation to hold the electron increment that is built up on the methylene carbon until the anion portion of the addendum becomes attached to the other carbon which, after depolarization, would have the requisite electron deficit, thus



$$CH_2{=}C(OEt)_2 \xrightarrow{Na^+} Na^+\ :CH_2\underset{+}{C}(OEt)_2 \xrightarrow{:CH(COOEt)_2} Na^+\ :CH_2\underset{H\ddot{C}(COOEt)_2}{C}(OEt)_2$$

Another molecule of malonic ester could substitute a proton for the sodium cation, or a molecule of sodium ethoxide could be eliminated from the addition product, and the reaction continue through repetition of the steps above indicated. This formulation is similar to that used to explain the catalysis of cadmium chloride for the polymerization of ketene acetal.[3]

Since it has been shown[7] that active methylene groups in sulfones undergo the Michael reaction it was thought that *bis*-(phenylsulfonyl)-methane would behave similarly to malonic ester with ketene acetal. However, this was not the case. Even though it was not possible to isolate any product (except considerable of the starting disulfone) from this reaction it was quite obvious that it had taken a different course than that of the other active methylene compounds that were studied.

Experimental

The Reaction of Ketene Acetal with Acids and Enols

Hydrobromic Acid.—A solution of 18.6 g. (0.23 mole) of hydrogen bromide (from the bromination of xylene) in 200 g. of di-*n*-butyl ether was cooled to about 0° and treated dropwise, with vigorous stirring, with 26.7 g. (0.23 mole) of ketene acetal.[3] A yellow precipitate, which redissolved, was formed when each drop of the acetal entered the solution. A considerable amount of heat was evolved. After about one-fifth of the acetal had been added a red oil separated to the bottom of the reaction flask. This did not seem to increase in quantity during the reaction. After all of the acetal had been added, titration of the solution showed that 17% of the starting hydrogen bromide still was present. Distillation of the ether solution yielded 24 g. (85%) of the ethyl bromide and 12.7 g. (72%) of ethyl acetate.

3,5-Dinitrobenzoic Acid.—To 2.17 g. (0.01 mole) of 3,5-dinitrobenzoic acid, suspended in 30 ml. of ether, was added 1.7 g. (0.015 mole) of ketene acetal. The solution was evaporated on the steam-bath and recrystallized from alcohol. A yield of 1.8 g. (74%) of ethyl 3,5-dinitrobenzoate, m. p. 94–95°, was obtained.

Phenol.—To 47.0 g. (0.5 mole) of phenol in a flask attached to a condenser carrying a drierite tube, 58.0 g. (0.5 mole) of ketene acetal was slowly added with shaking. The temperature quickly rose to 80°. After standing for an hour, the reaction mixture was fractionated: 20.9 g. (59%) of ethyl acetate, b. p. 72–79°; 38.2 g. (78%) of phenetole, b. p. 162–169°, and 11.6 g. (17%) of phenyl acetate, b. p. 189–194°, were obtained.

Dibenzoylmethane.—To 14.0 g. (0.06 mole) of dibenzoylmethane, m. p. 77–78°, contained in a flask attached to a condenser carrying a drierite tube was added, with shaking, 14.5 g. (0.12 mole) of ketene acetal. In about thirty minutes the temperature of the solution had risen to 40°. After standing five to six hours the solution changed to a crystalline mass. The flask was then placed in an oil-bath at 60° and the excess of ketene acetal (6–7 g.) removed under 0.5 mm. pressure and collected in a cold trap.

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(7) Connor, *et al.*, THIS JOURNAL, **58**, 1386 (1936).

The remaining 22 g. of residue was triturated in a mortar with 45 ml. of cold petroleum ether (60–68°) for ten minutes and then filtered by suction. The crystalline product so obtained was similarly washed with three other 18-ml. portions of petroleum ether and dried *in vacuo* to constant weight. The yield of product (II), melting at 86–87°, was 20.3 g. (95%). Its melting point remained unchanged after recrystallization from petroleum ether (60–68°); mol. wt. (cryoscopic in benzene), 335; calcd., 340.

Anal. Calcd. for $C_{21}H_{24}O_4$: C, 74.08; H, 7.11; OC_2H_5, 26.47. Found: C, 73.95; H, 7.06; OC_2H_5, 26.50.

The O-(α,α-diethoxyethyl)-dibenzoylmethane was characterized by the following reactions, (a) hydrolysis with 5% sulfuric acid converted it into ethyl alcohol, acetic acid and dibenzoylmethane; (b) pyrolysis of 20 g. of this product at 140° (38 mm.) under nitrogen produced 2.1 g. (31%) of ketene acetal as a distillate and left a rather tarry residue which, after washing with petroleum ether, and two recrystallizations from methanol yielded 8.3 g. (61%) of dibenzoylmethane, m. p. 77–78°; (c) simultaneous titration under nitrogen of a 1.2014 g. sample of the reaction product and a 0.4994 g. sample of dibenzoylmethane with a 0.0982 *N* solution of sodium triphenylmethyl[8] showed that the product used only 16% of a molecular equivalent while dibenzoylmethane used 100% of a molecular equivalent of the sodium triphenylmethyl before the red color of the solution of the latter compound persisted.

Ethyl (α-Ethoxyethylidene)-acetoacetate (IV).—To 22.8 g. (0.18 mole) of acetoacetic ester containing 1 mole per cent. of sodium ethoxide in a flask attached to a reflux condenser carrying a drierite tube was added 40 g. (0.36 mole) of ketene acetal. After heating for nine hours in an oil-bath at 85° the reaction mixture was fractionated. The following fractions were obtained, (a) 5.1 g. of a mixture of ethyl acetate and ethyl alcohol, (b) 21.8 g. (78% based on one-half of the ketene acetal used) of ethyl orthoacetate, b. p. 100–102° (200 mm.), (c) 1.5 g. of an intermediate fraction, and (d) 23.9 g. of a fraction boiling at 96–103° (1 mm.). Refractionation of fraction (d) gave 22.8 g. (68%) of IV, b. p. 96–98° (1 mm.); mol. wt. (cryoscopic in benzene), 208; calcd., 200.

Anal. Calcd. for $C_{10}H_{16}O_4$: C, 59.97; H, 8.06; OC_2H_5, 45.0. Found: C, 59.62; H, 8.02; OC_2H_5, 44.7.

When the above experiment was carried out in the absence of sodium ethoxide, a yield of only 12% of the theoretical amount of IV was obtained, even after twenty-four hours of heating at 85°.

Hydrolysis of 10 g. (0.05 mole) of IV with 1.8 g. (0.1 mole) of water in dioxane gave, after five hours of refluxing, 92% of the theoretical quantity of acetic acid (titration) and 2.0 g. of acetoacetic ester, b. p. 175–178°. Hydrolysis of 11.2 g. of IV with only one equivalent (0.95 g.) of water in 20 g. of dioxane gave, after thirty minutes of refluxing followed by fractionation, 3.7 g. of diacetoacetic ester,[9] b. p. 102–104° (15 mm.), the copper salt of which melted at 149–150°.[10]

Diethyl (α-Ethoxyethylidene)-malonate (V).—A mixture of 23.2 g. (0.2 mole) of ketene acetal, 16 g. (0.1 mole) of diethyl malonate and 0.1 g. of sodium ethoxide was heated in an oil-bath at 125° for sixteen hours, after which time the reaction mixture was fractionated. A yield of 13.2 g. (81%) of ethyl orthoacetate and 19 g. of a fraction boiling at 100–102° (1 mm.) were obtained. This fraction was cooled to −15° and rapidly filtered through a cold filter. The crystals so obtained amounted to about 70% of the weight of the fraction boiling at 100–102° (1 mm.). The crystalline product (V) weighed 12.7 g. (55%) and melted at 26–27°.[11] Mol. wt. (cryoscopic in benzene), 219; calcd., 230.

Anal. Calcd. for $C_{11}H_{18}O_5$: C, 57.37; H, 7.88; OC_2H_5, 58.7. Found: C, 57.62; H, 7.86; OC_2H_5, 58.6.

A mixture of 11 g. of V and 10 ml. of 2 *N* hydrochloric acid was heated, with intermittent shaking, for ten minutes on a steam-bath. The mixture was cooled and extracted with ether. The ethereal solution, after washing with sodium carbonate solution, was dried and distilled. A yield of 6.8 g. of diethyl acetomalonate, b. p. 65–70° (0.55 mm.); $n^{25}D$ 1.4435; d^{25}_{25} 1.0906, was obtained. Its copper derivative melted at 124–125° and showed no depression in melting point when mixed with the copper derivative of a known sample of diethyl acetomalonate prepared by the procedure of Nef.[12]

Diethyl (α-Ethoxyethyl)-malonate (VI).—A solution of 9.4 g. (0.04 mole) of diethyl (α-ethoxyethylidene)-malonate (V) in 15 ml. of absolute alcohol was hydrogenated at 100° under an initial hydrogen pressure of 2800 pounds in the presence of 1 g. of Raney nickel. Hydrogen absorption ceased in forty-five minutes after about 0.05 mole had been absorbed. Careful fractionation of the alcoholic solution, after filtering off the nickel catalyst, yielded 5 g. of VI, b. p. 66–67° (0.4 mm.); $n^{25}D$ 1.4198; d^{25}_4 1.0120; M_D calcd., 57.95; found, 58.0; saponification equivalent, calcd., 116; found, 118.

Anal. Calcd. for $C_{11}H_{20}O_5$: C, 56.68; H, 8.68; OC_2H_5, 58.2. Found: C, 56.84; H, 8.97; OC_2H_5, 56.1.

Attempted Reaction of Diethyl Methylmalonate with Ketene Acetal.—A mixture of 19 g. (0.11 mole) of diethyl methylmalonate, 12.8 g. (0.11 mole) of ketene acetal and 0.1 g. of sodium ethoxide was heated in an oil-bath under a reflux condenser at 125° for sixteen hours. Upon fractionation of the reaction mixture, 10.7 g. of ketene acetal, b. p. 80–85° (200 mm.), and 18.2 g. of diethyl methylmalonate, b. p. 86–87° (13 mm.), were recovered.

Reaction of *bis*-(Phenylsulfonyl)-methane with Ketene Acetal.—To 6.4 g. (0.025 mole) of the disulfone dissolved in 45 g. of dioxane was added 5.8 g. (0.05 mole) of ketene acetal and the resulting solution refluxed for twelve hours. The solvent was then allowed to evaporate spontaneously from a crystallizing dish in a vacuum desiccator, with the last traces of the dioxane being removed at 80° under 1 mm. pressure. The liquid removed by this evaporation was collected in an acetone–carbon dioxide snow cold trap.

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[8] Hauser, *et al.*, THIS JOURNAL, **59**, 1823 (1937); **60**, 1960 (1938).

[9] Claisen, *Ann.*, **277**, 172 (1893).

[10] James, *ibid.*, **226**, 212 (1884).

[11] Diethyl (α-ethoxyethylidene)-malonate has been reported by Sah, THIS JOURNAL, **53**, 1836 (1931), as a product (yield 4%) of the reaction of ethyl orthoacetate and diethyl malonate in the presence of acetic anhydride at 140°. He describes it as a red, glycol-thick liquid, the color of which could not be removed by redistillation.

[12] Nef, *Ann.*, **266**, 105 (1891).

Upon distillation it was found to be dioxane with small amounts of materials boiling above ketene acetal but lower than the disulfone. No ketene acetal was found. The glassy residue remaining after the evaporation was extracted with three 20-cc. portions of ether. These extractions left a quantity of the original disulfone as a white powder, which after recrystallization from dilute alcohol weighed 2.7 g. (42%) and melted at 118–119°. Evaporation of the ether used to extract the reaction product left a thick oil which changed to a dark non-volatile tar on attempted distillation under 0.01 mm. pressure.

The use of 5 mole per cent. of sodium ethoxide in a reaction similar to that described above gave practically the same results.

Reaction of Ketene Acetal with Ammonia and Amines. Ammonia.—Into 28.4 g. of ketene acetal contained in a bomb tube, prepared for sealing and cooled in an acetone–carbon dioxide snow bath, 14 g. of dry ammonia was distilled and the tube sealed off. The two liquids are immiscible. The bomb tube then was heated for three hours at 110°, after which time it was cooled and opened. The ammonia was allowed to distil off at room temperature and collected in a cold trap; 9 g. was recovered. Fractionation of the remaining liquid through a Widmer column yielded the following fractions: (a) 23.5 g. of a mixture of ethyl alcohol, ammonia and acetonitrile, b. p. 71–76°; (b) 6.2 g. in receiver and cold trap boiling below 40° (8 mm.); (c) 2 g. of a residue of acetamidine. The residue (c) could be sublimed but was best purified by dissolving in a mixture of anhydrous alcohol and ether and precipitating as the hydrochloride with hydrogen chloride. After filtration and recrystallization this hydrochloride melted at 177–178°.

Anal. Calcd. for $C_2H_7N_2Cl$: N, 29.65; Cl, 37.6. Found: N, 30.2; Cl, 36.3.

This amidine hydrochloride was further characterized as follows. A 0.6667-g. sample was treated with a solution of 5 g. of sodium hydroxide in 200 cc. of water and the ammonia distilled into a standard solution of sulfuric acid. The solution remaining in the boiling flask was treated with 2 g. of silver oxide and 30 cc. of 6 *N* sulfuric acid. The acetic acid was distilled out and titrated. Yields of 0.234 g. (97.5%) of ammonia and 0.415 g. (97.8%) of acetic acid were obtained.

Redistillation of fraction (b) gave 2.1 g. of material boiling at 73–76°, which was added to fraction (a), and 1.0 g. of ethyl orthoacetate boiling at 130–145°. A 3.60-g. sample of fraction (a) was titrated with 0.5 *N* sulfuric acid to neutrality with a methyl red–methylene blue indicator; this titration showed 0.031 g. of ammonia to be present. The acetonitrile was hydrolyzed by boiling with a sodium hydroxide solution as described above and the total ammonia collected in standard sulfuric acid. The acetic acid was determined in the remaining solution, from which the ammonia had been distilled, by acidification with sulfuric acid followed by distillation. Yields of 0.365 g. of ammonia and 1.19 g. of acetic acid were obtained from the 3.60-g. sample of fraction (a). After deduction of the free ammonia that was present in this sample, the molecular ratio of the ammonia to the acetic acid from the hydrolysis was 1:1.010. These values indicate that 5.6 g. (56%) of acetonitrile was formed in the reaction.

Aniline.—The addition of 5 g. of ketene acetal to 4 g. of aniline caused a considerable evolution of heat. After heating the mixture on a steam-bath for two hours in order to assure a more complete reaction, it was distilled. The following fractions were collected, (a) 1.7 g. (86% of the theoretical) of ethyl alcohol, b. p. 75–80°, (b) 5.7 g. of ethyl N-phenyliminoacetate, b. p. 93–94° (9 mm.), and (c) 0.6 g. of residue. Fraction (c), which was N,N'-diphenylacetamidine, solidified on cooling and after recrystallization from 70% alcohol, melted at 132–133°.[13] Fraction (b) was characterized by conversion into N,N'-diphenylacetamidine according to the procedure of Lander.[14]

Ethylaniline.—A mixture of 7.3 g. (0.06 mole) of ethylaniline and 7.0 g. (0.06 mole) of ketene acetal was heated on a steam-bath for five hours. After this time the reaction mixture was fractionated and the following fractions collected, (a) 1.25 g. (0.01 mole) of ethyl orthoacetate, b. p. 30–50° (22 mm.), (b) 3.7 g. (0.03 mole of ethylaniline, b. p. 100–105° (22 mm.), (c) 0.53 g. of an intermediate fraction boiling at 105–125° (22 mm.), (d) 5.47 g. (0.029 mole) of N-ethyl-N-(α-ethoxyvinyl)-aniline (XV), b. p. 128–130° (22 mm.). Redistillation of fraction (d) gave a product that boiled at 129–130° (22 mm.); $n^{25}D$ 1.5232; d^{25}_{25} 0.9750.

Anal. Calcd. for $C_{12}H_{17}ON$: N, 7.32; OC_2H_5, 23.6. Found: N, 7.28; OC_2H_5, 23.0.

The N-ethyl-N-(α-ethoxyvinyl)-aniline on treatment with 0.2 *N* sulfuric acid evolves considerable heat, but careful attempts to isolate N-ethylacetanilide from a partial hydrolysis of it were unsuccessful. All attempts at hydrolysis resulted in complete cleavage into alcohol, acetic acid and ethylaniline.

Piperidine.—Addition of 5 g. (0.043 mole) of ketene acetal to 19.5 g. (0.230 mole) of carefully dried piperidine produced no indication of reaction. The mixture, therefore, was refluxed for two hours. After this time it was fractionated into (a) 13.4 g. of a mixture of alcohol and piperidine, b. p. 45–55° (200 mm.), (b) 3.0 g. (43%) of ethyl orthoacetate, b. p. 45–50° (19 mm.) and (c) 5.2 g. (43% based on the acetal used) of 1,1,1-tripiperidinoethane, b. p. 113–115° (1 mm.); $n^{25}D$ 1.5042; d^{25}_{25} 0.9520.

Anal. Calcd. for $C_{17}H_{33}N_3$: N, 15.0. Found: N, 15.2.

Hydrolysis of a 1.77-g. sample of the tripiperidinoethane was carried out by refluxing it for twenty-four hours in 10 cc. of 6 *N* sulfuric acid solution. On making this hydrolysis solution alkaline, 83% of the theoretical quantity of piperidine could be distilled out. Acidification of the remaining alkaline solution with sulfuric acid followed by distillation gave 110% of the calculated quantity of acetic acid.

Summary

The reactions that take place between ketene acetal and a variety of compounds, in which an active hydrogen is attached to halogen, oxygen, carbon and nitrogen, are reported. In most of these cases the primary reaction involves the addition of the hydrogen to the methylene

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[13] *Cf.* Biederman, *Ber.*, **7**, 540 (1874).

[14] Lander, *J. Chem. Soc.*, **77**, 737 (1900).

carbon of the acetal followed by the attachment of the remainder of the addendum to the carbon carrying the ethoxyl groups. This primary reaction may be followed by one or more subsequent reactions.

In the cases of acetoacetic ester and malonic ester the reaction takes a different course. These compounds do not add as H and O—C(R)=CHCOR, as does dibenzoylmethane, but rather as H and $CH(COR)_2$ and the addition is strongly catalyzed by small amounts of sodium ethoxide. The function of the catalyst in this reaction is discussed.

MADISON, WISCONSIN RECEIVED MARCH 15, 1940

[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF HARVARD UNIVERSITY]

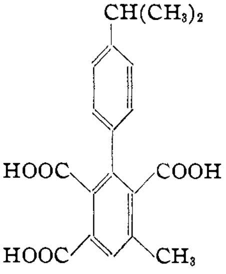
Acetylretene and 6-Retenol

BY WILLIAM P. CAMPBELL AND DAVID TODD

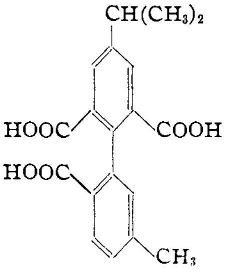
Acetylretene was first prepared by Bogert and Hasselstrom[1] and was shown[2] to have the acetyl group in the same position as the hydroxyl group of the β-retenol of Komppa and Wahlforss[3] by conversion into that substance. Evidence based on the coupling reaction, reduction potential data, and the Dimroth test, indicating that the β-retenol is either the 3- or the 6-derivative had been presented by Fieser and Young[4] and their view that the substituent probably is in the 6-position has been accepted in subsequent literature even though conclusive evidence was lacking. More recently there appeared a paper by Nyman[5] on acetylretene presenting evidence resulting mainly from oxidation experiments which he interprets as indicating that the acetyl group (and, therefore, the hydroxyl group of the β-retenol) occupies the 4- instead of the 6-position.

In the present research the possibility that these groups occupy the 6-position is definitely eliminated[6] by the preparation of 6-retenol (VII) of proven structure, which is different from the β-retenol. A careful study and reinterpretation of the results of Nyman[5] and of Fieser and Young[4] led us to the conclusion that the acetyl and hydroxyl groups must be in the 3-position in these compounds, and this view has been proven to be correct.

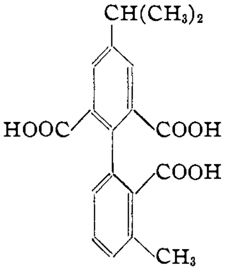
All of the arguments by which Nyman eliminated the various possible positions for the acetyl group in acetylretene seem valid with the exception of those regarding the 3-position. The point in question involves a distinction between I which would result from 3-acetylretene and IIa or b which would result from the 4-isomer. The evidence presented in favor of II was that the substance melts at a high temperature (277°) without apparent loss of water, and fails to form an anhydride on heating with acetyl chloride, although heating with acetic anhydride does produce the anhydride. There is ample contradictory evidence in the literature which can lead only to the conclusion that it is not possible to decide between these compounds on the basis of such evidence. For example, trimellitic acid, which is analogous to I, melts at 238° without apparent loss of water



I



IIa



IIb

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[1] Bogert and Hasselstrom, THIS JOURNAL, **53**, 3462 (1931).

[2] Adelson and Bogert, *ibid.*, **58**, 653 (1936).

[3] Komppa and Wahlforss, *ibid.*, **52**, 5009 (1930).

[4] Fieser and Young, *ibid.*, **53**, 4120 (1931).

[5] Nyman, *Ann. Acad. Sci. Fennicae*, **A48**, No. 6 (1937); *Chem. Abst.*, **33**, 8192 (1939).

[6] In a publication which reached us after this paper was written, Ruzicka and St. Kaufmann (*Helv. Chim. Acta*, **23**, 288 (1940)) arrived at this same conclusion by a comparison of the melting points of 6-ethylretene (prepared by way of 6-acetyldehydroabietic ester) and two of its derivatives with those reported by Bogert and Hasselstrom[1] for their ethylretene obtained from acetylretene. In the present paper, a direct comparison of the corresponding retenols by mixed melting point has been made.