Summary

1. O,N-dialkylhydroxyurethans have been prepared by the action of alkyl sulfates on hydroxyurethan.
2. O,N-dialkylhydroxylamines have been obtained by hydrolysis of O,N-dialkylhydroxyurethans with alcoholic potassium hydroxide.
3. The addition of water has been shown to lower the boiling point of O,N-diethylhydroxylamine but not that of O,N-dimethylhydroxylamine.

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[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF BARNARD COLLEGE]

5-BROMO-2,4-DIMETHOXYBENZOYLACRYLIC ACID AND ITS ESTERS. II

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In a study[1] of bromodimethoxybenzoylacrylic acid it has been found that the esters of this unsaturated γ-ketonic acid readily form addition products with alcohols in the presence of a trace of potassium hydroxide. This reaction suggested an investigation of the behavior of the dibromo addition products of the acid and its esters on treatment with alkaline reagents under conditions which would favor the formation of acetylenic compounds as intermediate products.

On treatment with bromine, bromodimethoxybenzoylacrylic acid gives one dibromo acid, but under the same conditions the methyl and ethyl esters give mixtures of racemic compounds which were separated only after tedious fractional crystallization; the pairs of isomers have practically the same solubilities in the common organic solvents and the two racemic methyl esters have melting points within one degree of each other.[2] The mixture of racemic dibromomethyl esters was shown to give the same products with sodium methylate as the higher melting one of the isomers; in subsequent work therefore the mixtures of both dibromo esters were used.

The products obtained are alkoxy and hydroxy compounds which can be explained as addition products of bromodimethoxybenzoylpropiolic ester, formed by loss of two molecules of hydrogen bromide from the dibromo esters. No attempt has been made to isolate the acetylenic compounds, which would be expected to show the same ease of addition as the corresponding ethylenic esters.[1] Pairs of ethylenic bromo isomers, however, have been prepared from the dibromo methyl and ethyl esters and one of these ethylenic bromo methyl esters has been shown to give the same products as the saturated dibromo ester on treatment with a methyl alcohol solution of potash. That a second molecule of hydrogen bromide

[1] Rice, THIS JOURNAL, **50**, 229 (1928).

[2] Lutz, *ibid.*, **48**, 2905 (1926).

is eliminated from the ethylenic bromo ester and that addition takes place to the resulting acetylenic compound seems beyond doubt from the recent work of Lutz[2] on 1,4-diketones. He has shown that dibenzoylacetylene is an intermediate product in the reaction of sodium acetate on dibenzoyldibromo-ethane and that it gives the same products of reaction as the dibromo compound.

The dibromo methyl ester of bromodimethoxybenzoylpropionic acid, on treatment with a concentrated solution of potassium hydroxide in methyl alcohol, gives as the chief product of reaction an unsaturated methoxy ester, I; there are also formed small quantities of the corresponding unsaturated methoxy acid, IV, an unsaturated hydroxy acid, V, and a considerable amount of material which was not identified.

With sodium methylate, however, the reaction is rapid and can be controlled so that any one of three substances, I, II, III, may be the chief product; a small quantity of the hydroxy acid, V, is formed in every reaction.

$$(CH_3O)_2C_6H_2BrCOCHBrCHBrCO_2CH_3 \xrightarrow[CH_3OH]{KOH} \underset{I}{(CH_3O)_2C_6H_2BrCOCH{=}COCH_3CO_2CH_3}$$

$$\downarrow CH_3ONa \qquad \underset{IV}{(CH_3O)_2C_6H_2BrCOCH{=}COCH_3CO_2H}$$

$$\underset{V}{(CH_3O)_2C_6H_2BrCOCH{=}COHCO_2H}$$

$$\underset{I}{(CH_3O)_2C_6H_2BrCOCH{=}COCH_3CO_2CH_3}$$

$$\underset{II}{(CH_3O)_2C_6H_2BrCOCH_2C(OCH_3)_2CO_2CH_3}$$

$$\underset{III}{(CH_3O)_2C_6H_2BrCOCH_2C(OCH_3)_2CO_2H}$$

That the substituents in these substances are in the alpha position is indicated by the fact that the esters of bromodimethoxybenzoylacrylic acid form addition products when treated with alcohols, in the presence of potassium hydroxide, in which the alkoxyl groups have been proved to be in the alpha position.[1]

All of these substances are colorless except the acid, V, which is brilliant yellow. The methoxy ester, I, and the hydroxy acid, V, decolorize a cold solution of potassium permanganate and add bromine quantitatively in ice-cold solution. The methoxy ester, I, forms a dibromo addition product which loses hydrogen bromide on recrystallization, giving an unsaturated bromomethoxy ester; this same ester results from the bromination of the saturated dimethoxy ester, II. The bromine atom in the unsaturated substance is therefore in the beta position.

$$\underset{I}{(CH_3O)_2C_6H_2BrCOCH{=}COCH_3CO_2CH_3} \xrightarrow{Br_2} \underset{VI}{(CH_3O)_2C_6H_2BrCOCHBrCBrOCH_3CO_2CH_3}$$

$$\downarrow -HBr$$

$$\underset{II}{(CH_3O)_2C_6H_2BrCOCH_2C(OCH_3)_2CO_2CH_3} \xrightarrow[-CH_3OH]{Br_2} \underset{VII}{(CH_3O)_2C_6H_2BrCOCBr{=}COCH_3CO_2CH_3}$$

The unsaturated hydroxy acid, V, adds the calculated amount of bromine at 0° but hydrogen bromide is eliminated slowly and the product which separates in quantitative yield is probably the diketone, $(CH_3O)_2C_6H_2BrCOCHBrCOCO_2H$. That the acid, V, has not the keto form $(CH_3O)_2C_6H_2BrCOCH_2COCO_2H$ but the enol form as written or enolizes with extreme rapidity at 0° was established by the Kurt Meyer titration method. It reacts in absolute ether solution with one molecular equivalent of diazomethane to give a brilliant yellow ester; this forms a copper derivative and is an enol as shown by the Kurt Meyer titration method. The enolic ester reacts with a second molecular equivalent of diazomethane to give a colorless methoxy ester (113°) which is the geometrical isomer of the methoxy ester, I, since it gives the same dibromo compound as this substance on treatment with bromine.

The quantitative transformation of the acid, III, into the ester, II, indicates the relationship between these substances. That their two methoxyl groups are attached to the same carbon atom[3] is indicated by the behavior of the substances with acids. The dimethoxy ester, II, is transformed by cold, concd. hydrochloric acid into a bright yellow ester identical with that formed from the hydroxy acid, V, on treatment with diazomethane. This same yellow ester is obtained on treatment of the unsaturated methoxy ester, I, with concd. hydrochloric acid. The dimethoxy acid, III, loses its methoxyl groups much more readily than its ester, for it is changed completely into the unsaturated hydroxy acid, V, even on recrystallization from glacial acetic acid.

The unsaturated methoxy acid, IV, is the only one of the five products from the reactions with the dibromo ester which cannot be obtained in any quantity desired; only traces of it were separated in the reactions with the dibromo ester but a small amount of it was formed when the dibromo acid was treated with a concd. solution of potassium hydroxide in methyl alcohol. Treatment of the dibromo acid with a concd. solution of potassium hydroxide in ethyl alcohol gave the corresponding unsaturated ethoxy acid; this reaction proves the structure of the substance, IV.

The relationships of the substances are shown in the following scheme.

The dibromo ethyl ester gives with the alkaline reagents used products analogous to all those obtained from the dibromo methyl ester with one interesting exception; the diethoxy acid corresponding to the acid, III, is not formed. The dibromo acid, on the other hand, is remarkably unreactive compared with its esters; with sodium methylate only one molecule of hydrogen bromide is eliminated and the products of reaction are unsaturated bromo acids.

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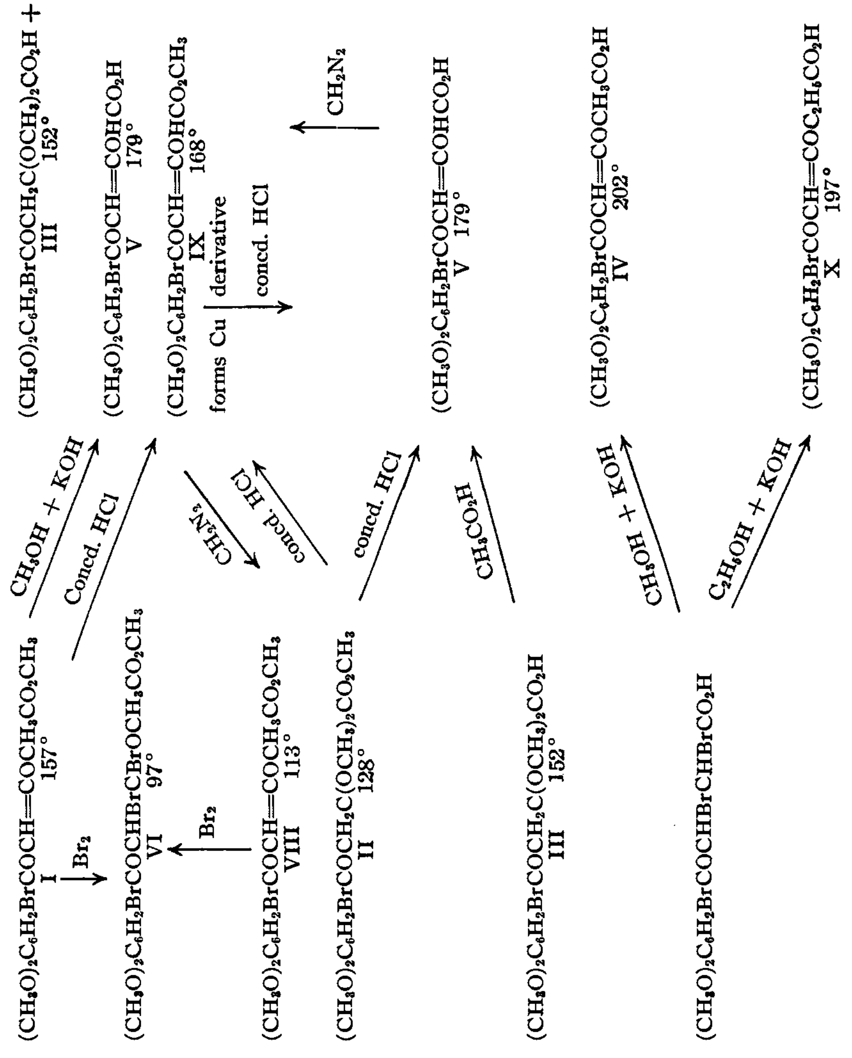
[3] Michael and Bucher, *Ber.*, 29, 1792 (1896); Moureu, *Compt. rend.*, **137**, 259 (1903).



Experimental Part

Methyl α,β-Dibromo-5-bromo-2,4-dimethoxybenzoylpropionate, $(CH_3O)_2C_6H_2Br\text{-}COCHBrCHBrCO_2CH_3$.—The reaction between methyl 5-bromo-2,4-dimethoxybenzoylacrylate and bromine was carried out in the usual way with chloroform as a solvent; the crude product was obtained in quantitative yield. It is a mixture of isomers from which the higher melting one can be separated by warming the mixture with methyl alcohol and recrystallizing the undissolved portion from the same solvent; a 70–80% yield of ester melting at 150.5° was thus obtained. The filtrates contain a mixture from which a small quantity of a second isomer (149–150°) was isolated by tedious picking apart of two kinds of crystals and fractional recrystallization from methyl alcohol. It was not found possible to separate the rest of the product, which invariably crystallized from all the solvents used in mixed crystals which began to melt at about 127°; the mixture of the two pure isomers had this same melting point.

Anal. Calcd. for $C_{13}H_{13}O_5Br_3$: C, 31.91; H, 2.65. Found: I (150.5°) C, 32.12; H, 2.72. II (149–150°) C, 32.39; H, 2.66.

After it was found that the mixture of isomers gave the same products as the isomer (150.5°) with alkaline reagents, the crude product was washed with boiling methyl alcohol and used in subsequent reactions.

Methyl Bromo-5-bromo-2,4-dimethoxybenzoylacrylate, $(CH_3O)_2C_6H_2BrCOCH{=}CBrCO_2CH_3$ or $(CH_3O)_2C_6H_2BrCOCBr{=}CHCO_2CH_3$.—Two unsaturated bromo esters were formed when the mixture of dibromo esters was heated for thirty minutes in methyl alcohol solution with potassium acetate. The solid which was precipitated by adding ice to the solution was dried—yield 80%—and dissolved in methyl alcohol; a solid crystallized in fine, lemon-colored needles melting at 139° and after partial evaporation of the filtrate a colorless solid separated in heavy, transparent crystals melting at 164°; after one such treatment about 30% of the crude product was left as a mixture of the two substances. The yellow needles are very sensitive to light and are transformed slowly in diffused daylight and very rapidly in the sunlight into the colorless solid. The mixture of isomers was exposed to the sunlight until it had lost its yellow color; the colorless solid then melted at 164°. This isomerization in the light proves that the two substances are geometrical and not structural isomers.

Anal. Calcd. for $C_{13}H_{12}O_5Br_2$: C, 38.23; H, 2.94. Found: I (139°) C, 38.38; H, 2.79. II (164°) C, 38.56; H, 2.87.

It has not been found possible up to this time to determine whether the bromine atom in the side chain of these esters and related compounds is in the alpha or beta position; work with this aim in view is now in progress.

Reaction between the Dibromo Methyl Ester and Sodium Methylate

Methyl α-Methoxy-5-bromo-2,4-dimethoxybenzoylacrylate, $(CH_3O)_2C_6H_2BrCOCH{=}COCH_3CO_2CH_3$, I.—This ester is obtained in 60% yield when the dibromo ester (4 g. in 70 cc. of methyl alcohol) is heated for thirty minutes on a boiling water-bath with the sodium methylate made by treating 10 cc. of methyl alcohol with 0.4 g. of sodium. The fine, white needles which separate as the solution cools are recrystallized from methyl alcohol; they melt at 157° and are not readily soluble in the common organic solvents.

Anal. Calcd. for $C_{14}H_{15}O_6Br$: C, 46.79; H, 4.17. Found: C, 46.81; H, 4.20.

The filtrate contains a mixture of substances which were not separated since further heating with sodium methylate transforms it into an acid, the same substance which is formed by heating the dibromo ester for an hour with two molecular equivalents of sodium methylate. The ester decolorizes a cold acetone solution of potassium permanganate but it is not reduced by sodium hydrosulfite. The lack of reactivity with this reducing agent was unexpected in view of the ease with which bromodimethoxybenzoylacrylic acid and its esters are reduced with sodium hydrosulfite. If its behavior on reduction had been like that of the ester of the unsaturated acid the product would have been α-methoxy-5-bromo-2,4-dimethoxybenzoylpropionate[1] and the position of the methoxyl group would have been established experimentally.

The ester reacts with bromine in chloroform solution at 0° to give a dibromo ester; the crude product solidified in contact with methyl alcohol and was purified by washing thrice with the ice-cold solvent. The yield of white powder was 90%.

Anal. Calcd. for $C_{14}H_{15}O_6Br_3$: C, 32.37; H, 2.89. Found: C, 32.45; H, 2.80.

The substance is not stable but changes on standing into a high melting solid which was not investigated; on recrystallization from methyl alcohol it loses hydrogen bromide and forms an unsaturated bromomethoxy ester which separates in clusters of fine needles melting at 123°. The bromine atom in this substance is in the alpha position, its formula, $(CH_3O)_2C_6H_2BrCOCBr=COCH_3CO_2CH_3$, being established by a second method of preparation. (See p. 1487.)

Anal. Calcd. for $C_{14}H_{14}O_6Br_2$: C, 38.35; H, 3.19. Found: C, 38.72; H, 3.68.

This unsaturated bromo ester is also formed if the chloroform solution is allowed to grow warm during the bromination of the unsaturated ester.

Methyl α-Hydroxy-5-bromo-2,4-dimethoxybenzoylacrylate, $(CH_3O)_2C_6H_2BrCOCH=COHCO_2CH_3$.—The unsaturated methoxy ester is not changed by boiling for two hours in glacial acetic acid solution but it is hydrolyzed by stirring for ten minutes with concd. hydrochloric acid. Ice was added to the solution, the precipitated solid filtered off and recrystallized from methyl alcohol; it separates in brilliant yellow needles melting at 168°. The ester forms an olive green copper compound when treated in ether solution with copper acetate and gives a brownish-green color with ferric chloride.

Anal. Calcd. for $C_{13}H_{13}O_6Br$: C, 45.21; H, 3.76. Found: C, 45.21; H, 3.97.

The Kurt Meyer titration methods were used to determine whether the substance is an enol or a keto form. The yellow solid was dissolved in a mixture of chloroform and absolute alcohol and titrated at $-5°$ with a standard alcoholic bromine solution. The value of this freshly prepared solution was found immediately before and after the titration and its mean value used; the time required for the whole determination was less than three minutes. Two determinations gave 103 and 91% enol, the lack of agreement being due to the difficulty of being sure of the end-point of the reaction. The indirect titration method was also used; excess of bromine was added to the dissolved substance at $-5°$, the excess decolorized with β-naphthol and the iodine set free from potassium iodide titrated with standard sodium thiosulfate solution. The end-point was difficult to obtain with the accuracy usually possible in this method because instead of obtaining a colorless solution on disappearance of free iodine, a faintly yellow colored solution was left due to the brilliant yellow color of the ester. It was for this reason that the direct method was tried but it was found that after several trials the end-point in the indirect method could be judged so that the error was not more than 5%. This method indicated that the ester is 100% enol.

Methyl α,α-Dimethoxy-5-bromo-2,4-dimethoxybenzoylpropionate, $(CH_3O)_2C_6H_2BrCOCH_2C(OCH_3)_2CO_2CH_3$, II.—Four g. of the dibromo ester suspended in 30 cc. of methyl alcohol was treated with two molecular equivalents of sodium methylate (0.4 g. of sodium in 10 cc. of methyl alcohol) and the solution heated for five minutes on a steam-bath. No crystals formed as the solution cooled so ice was added and the precipitated solid was filtered off, washed and dried; it separated in heavy needles which melted at 128° after two recrystallizations from methyl alcohol.

Anal. Calcd. for $C_{15}H_{19}O_7Br$: C, 46.03; H, 4.85. Found: C, 46.11; H, 4.81.

This dimethoxy ester was the only product of reaction except for 0.3 g. of acid obtained by acidifying the aqueous filtrate and later identified as a mixture of the acid corresponding to this ester and a trace of a yellow acid. The ester does not decolorize a potassium permanganate solution nor does it react with bromine at 0°; it reacts, however, with bromine at room temperature with elimination of hydrogen bromide and gives the same unsaturated bromo ester (123°) that was obtained by recrystallizing the dibromomethoxy ester (96°). The dimethoxy ester is not hydrolyzed by boiling glacial acetic acid; when finely powdered and left in contact with concd. hydrochloric acid for one hour, half of it was recovered unchanged and the other half was hydrolyzed to give the enol ester (168°) obtained from the unsaturated methoxy ester.

α,α-Dimethoxy-5-bromo-2,4-dimethoxybenzoylpropionic Acid, $(CH_3O)_2C_6H_2BrCOCH_2C(OCH_3)_2CO_2H$, III, and α-Hydroxy-5-bromo-2,4-dimethoxybenzoylacrylic Acid, $(CH_3O)_2C_6H_2BrCOCH{=}COHCO_2H$, V.—The dimethoxy acid is obtained mixed with a small quantity of a yellow acid when the dibromo ester is heated for one hour with a large excess of sodium methylate; 4 g. of dibromo ester, in 60 cc. of boiling methyl alcohol, was heated with sodium methylate (0.6 g. of sodium in 20 cc. of methyl alcohol) on a steam-bath for one hour. Solid did not separate when the solution was cooled nor when ice was added but hydrochloric acid precipitated a white powder which was filtered off, washed and dried; 2.7 g. of product melting at 144° was obtained. It was purified by recrystallization from chloroform, from which it separates in transparent cubes melting at 152°. A second acid was isolated in small quantity from the chloroform filtrates; it crystallizes from chloroform, methyl alcohol and benzene in fine yellow needles melting at 179° with rapid decomposition.

Anal. (152°) Calcd. for $C_{14}H_{17}O_7Br$: C, 44.56; H, 4.50; CH_3O, 32.89. Found: C, 44.63, 44.70; H, 4.42, 4.24; CH_3O, 32.39.

Anal. (179°) Calcd. for $C_{12}H_{10}O_6Br$: C, 43.50; H, 3.32; CH_3O, 18.73. Found: C, 43.24; H, 3.30; CH_3O, 18.76, 18.25.

The acid (152°) was suspended in ether solution and treated with an ether solution of diazomethane; evaporation of the solvent left the calculated quantity of the dimethoxy ester (128°). This proves that the latter is the ester of the acid (152°).

The dimethoxy acid is changed quickly and completely into the hydroxy acid (179°) by dissolving it in boiling glacial acetic acid; its behavior is, therefore, different from that of both the unsaturated methoxy ester (157°) and the dimethoxy ester (128°) which are not changed by boiling for several hours with glacial acetic acid. Boiling the dimethoxy acid with acetic acid must be avoided because the hydroxy acid which is formed reacts with glacial acetic acid.

In all the reactions with the dibromo ester and sodium methylate a small quantity of the hydroxy acid (179°) was always obtained after acidifying the aqueous solution, even when the methyl alcohol used was dried with extreme care. It is difficult to separate this acid completely from the dimethoxy acid which is precipitated with it but it can be obtained in any quantity desired by hydrolysis of the dimethoxy acid which is readily prepared.

The yellow acid (179°), suspended in chloroform, reacts quickly at 0° with the calculated quantity of bromine; elimination of hydrogen bromide begins at once and a colorless solid separates from the chloroform. It was washed with 50% acetic acid and then with ether, which left a chalk-white powder melting at 170°; yield, 90–95%.

Anal. Calcd. for $C_{12}H_{10}O_6Br_2$: C, 35.12; H, 2.43. Found: C, 35.27; H, 2.51.

Methyl α-Methoxy-5-bromo-2,4-dimethoxybenzoylacrylate, $(CH_3O)_2C_6H_2BrCOCH{=}COCH_3CO_2CH_3$, VIII.—The acid (179°) was suspended in absolute ether and treated with an absolute ether solution of diazomethane; a rapid reaction took place and a new bright yellow solid was formed. A mixed melting point proved that it was the same substance (168°) which was obtained by treatment of both the unsaturated methoxy ester (157°) and the dimethoxy ester (128°) with hydrochloric acid; it is the ester of the hydroxy acid $(CH_3O)_2C_6H_2BrCOCH{=}COHCO_2CH_3$, IX. This yellow ester, left in absolute ether with excess of diazomethane, gradually disappeared and evaporation of the ether left a colorless product, extremely soluble in organic solvents. It was recrystallized twice from methyl alcohol, from which it separated in feathery white needles melting at 113°.

Anal. Calcd. for $C_{14}H_{15}O_6Br$: C, 46.79; H, 4.17. Found: C, 47.01; H, 4.13.

This ester is formed quickly and in quantitative yield if the hydroxy acid is dissolved in a mixture of chloroform and methyl alcohol and treated with diazomethane. It reacts with bromine at 0° to give the same dibromo ester (96°) as the unsaturated methoxy ester (157°) and this dibromo ester gives the unsaturated bromomethoxy ester (123°) on recrystallization. The ester (113°) is therefore the geometrical isomer of the ester (157°).

The Kurt Meyer direct and indirect titration methods were applied, as described in the work with the yellow ester (168°), to a study of the yellow acid (179°); the following results were obtained: direct titration, 95, 97% of enol; indirect titration, 95, 94, 95, 102% of enol. The substance is therefore an enol or it enolizes rapidly at −5 to 0°.

Reaction of the Dibromo Methyl Ester in Methyl Alcohol Solution Containing Aqueous Potassium Hydroxide

A solution of 6 g. of the dibromo ester in 90 cc. of boiling methyl alcohol was heated with 3.6 cc. of potassium hydroxide solution (11 g. in 25 cc. of H_2O) for thirty minutes on a steam-bath, cooled in ice and the precipitated solid filtered off; yield 3.1 g. melting at 120–135°. Ice was added to the filtrate and the solution was extracted with ether; evaporation of the ether left 1 g. of the same mixture (120–138°). Treatment of the aqueous solution with hydrochloric acid precipitated a yellow solid, 0.2 g., which was separated into two acids by taking advantage of the lack of solubility of one of them in hot methyl alcohol. The acid left was an almost colorless powder melting at 202° and the acid which crystallized from the solution in brilliant yellow needles melted at 179° when pure. It is the acid V. From the 4.1 g. of mixture (120–138°) 1.4 g. of the ester I melting at 157° was separated by warming the mixture with carbon disulfide and crystallizing the residue from methyl alcohol; the rest was a mixture which contained some dibromo ester but it was not found possible to make a complete separation of it even after accumulating a large quantity of material. Not a trace of the ester (113°) could be found. The acid 202° is the only one of the products which is not formed in the reaction of the dibromo ester and sodium methylate; it is α-methoxy-5-bromo-2,4-dimethoxybenzoylacrylic acid, IV, which was later obtained from the reaction between dibromobromodimethoxybenzoylpropionic acid and methyl alcoholic potassium hydroxide. (See p. 1490.)

The unsaturated bromo ester (139°) was heated for a few minutes with a methyl alcohol solution of potash; the dimethoxy acid (152°) and the hydroxy acid (179°) were the only products formed. These same substances were obtained by treating the unsaturated methoxy ester (157°) in the same way. This may indicate that the methoxy ester is an intermediate product in the reactions in which these two acids are formed.

Reactions with the Dibromo Ethyl Ester

Ethyl α,β-Dibromo-5-bromo-2,4-dimethoxybenzoylpropionate, $(CH_3O)_2C_6H_2Br\text{-}COCHBrCHBrCO_2C_2H_5$.—A mixture of racemic isomers was obtained on bromination of the unsaturated ethyl ester; the lower melting one (141°) which is about 80% of the crude product was separated after several recrystallizations from alcohol. The residue in both alcohol and dilute acetic acid solutions deposits two kinds of crystals, opaque rosets and transparent stars, which can be picked apart. Mechanical separation followed by recrystallization from alcohol gave a small quantity of the isomer (160–161°).

Anal. Calcd. for $C_{14}H_{15}O_5Br_3$: C, 33.39; H, 2.98. Found: I (141°) C, 33.31; H, 2.94. II (160–161°): C, 33.71; H, 3.20.

Two isomeric unsaturated esters are formed when the dibromo esters are heated with potassium acetate; the higher melting one (144°) is yellow and is transformed in the sunlight into the lower melting, colorless isomer (114°); yield of pure substances, 77%.

Anal. Calcd. for $C_{14}H_{14}O_5Br_2$: C, 39.81; H, 3.31. Found: I (144°) C, 39.99; H, 3.05. II (114°): C, 40.06; H, 3.46.

Ethyl α-Ethoxy-5-bromo-2,4-dimethoxybenzoylacrylate, $(CH_3O)_2C_6H_2BrCOCH=COC_2H_5CO_2C_2H_5$, **and Ethyl α,α-Diethoxy-5-bromo-2,4-dimethoxybenzoylpropionate,** $(CH_3O)_2C_6H_2BrCOCH_2C(OC_2H_5)_2CO_2C_2H_5$.—A solution of 3 g. of dibromo ethyl ester in 25 cc. of absolute alcohol was boiled for fifteen minutes with sodium ethylate (0.3 g. of sodium in 10 cc. of absolute alcohol), the solution cooled and the crystalline solid filtered off, washed and dried; one g. of pure ester was separated after two recrystallizations from alcohol and chloroform. It separates in asbestos-like crystals which melt at 162°. Ice was added to the filtrate and the precipitated solid was purified with alcohol as a solvent; one g. of thick needles melting at 132° was obtained.

Anal. (162°) Calcd. for $C_{16}H_{19}O_6Br$: C, 49.61; H, 4.90. Found: C, 49.81; H, 4.91.

Anal. (132°) Calcd. for $C_{18}H_{25}O_7Br$: C, 49.88; H, 5.77. Found: C, 49.64; H, 5.68.

Treatment of the aqueous filtrate with hydrochloric acid precipitated 0.1 g. of the unsaturated hydroxy acid (179°).

The diethoxy ester can be prepared free from the unsaturated ethoxy ester if the reaction is carried out with an excess of sodium ethylate. From 3 g. of dibromo ester treated with 0.9 g. of sodium, 1 g. of diethoxy ester was obtained and 1.2 g. of unsaturated hydroxy acid (179°). When the reaction was carried out in absolutely dry apparatus with alcohol that had been distilled twice over calcium only a trace of this acid was formed.

The reaction with the dibromo ethyl ester and sodium ethylate was repeated under a variety of conditions in an attempt to prepare the diethoxy acid, but it is not formed. This was unexpected in view of the ease with which the corresponding dimethoxy acid is formed. Hydrolysis of the diethoxy ester with alkalies gives only the unsaturated hydroxy acid.

When the unsaturated ethoxy acid was treated in absolute alcohol solution with sodium ethylate, the products formed were the diethoxy ester and the hydroxy acid; with alcoholic potassium hydroxide the hydroxy acid is the only product. These reactions indicate a possible mechanism for the formation of the three products obtained from the dibromo ethyl ester.

Ethyl α-Hydroxy-5-bromo-2,4-dimethoxybenzoylacrylate, $(CH_3O)_2C_6H_2BrCOCH=COHCO_2C_2H_5$.—The unsaturated ethoxy ester and the diethoxy ester are hydrolyzed by concd. hydrochloric acid but much less readily than the corresponding methoxy esters. The hydroxy ester can be separated from the hydroxy acid, which is formed in small quantity by boiling the mixture of solids with water which dissolves the acid and leaves the ester undissolved; the ester was recrystallized from alcohol from which it separates in feathery yellow needles melting at 143°.

Anal. Calcd. for $C_{14}H_{15}O_6Br$: C, 46.78; H, 4.17. Found: C, 46.49; H, 4.11.

The substance gives a brownish-green color with ferric chloride and an olive green compound on treatment in ether solution with copper acetate.

Anal. Calcd. for $C_{14}H_{14}O_6Br\frac{1}{2}Cu$: Cu, 8.13. Found: Cu, 8.53.

Reactions with the Dibromo Acid

α,β-Dibromo-5-bromo-2,4-dimethoxybenzoylpropionic Acid, $(CH_3O)_2C_6H_2Br$-$COCHBrCHBrCO_2H$.—The unsaturated acid gave a quantitative yield of dibromo acid when brominated in chloroform solution; the substance separates from chloroform with solvent of crystallization (m. p. 177.5°) which it loses gradually, leaving a powder melting at 184.5°. It can also be recrystallized from methyl and ethyl alcohol.

Anal. Calcd. for $C_{12}H_{11}O_5Br_3$: C, 30.31; H, 2.31. Found: C, 30.65; 30.59; H, 2.20, 2.30.

α or β-Bromo-5-bromo-2,4-dimethoxybenzoylacrylic Acid, $(CH_3O)_2C_6H_2BrCOCH{=}CBrCO_2H$ or $(CH_3O)_2C_6H_2BrCOCBr{=}CHCO_2H$.—A solution of 9 g. of dibromo acid in 40 cc. of glacial acetic acid was heated with 13.5 g. of potassium acetate for fifteen minutes, the solution cooled and the precipitate washed with 50% acetic acid until colorless; m. p. 178–180°. After removal of a small quantity of the same substance from the aqueous solution, it was treated with hydrochloric acid, which precipitated a yellow solid. This separates from methyl alcohol in fine yellow needles melting at 200°; it is transformed by the sunlight into a colorless solid which melts at 182° and is the isomeric acid which separated first from the acetic acid solution. The colorless isomer can be recrystallized from chloroform or 50% acetic acid.

Anal. Calcd. for $C_{12}H_{10}O_5Br_2$: C, 36.54; H, 2.53. Found: I (200°) C, 36.66; H, 2.65. II (182°): C, 36.50; H, 2.50.

These geometrical isomers are also obtained from the reaction between the dibromo acid and sodium methylate and they are the only products formed; in one reaction the yellow acid (200°) was separated in small quantity when the dibromo acid was heated in methyl alcohol solution with aqueous potassium hydroxide.

α-Methoxy-5-bromo-2,4-dimethoxybenzoylacrylic Acid and **α-Ethoxy-5-bromo-2,4-dimethoxybenzoylacrylic** Acid, $(CH_3O)_2C_6H_2BrCOCH{=}COCH_3CO_2H$ and $(CH_3O)_2$-$C_6H_2BrCOCH{=}COC_2H_5CO_2H$.—The reaction between the dibromo acid in methyl and ethyl alcohol solution with potassium hydroxide gives intractable oils unless it is controlled carefully, and even then the yield of unsaturated alkoxyl acids is very small. The acids are decomposed by recrystallization from chloroform or benzene, so that the usual method of purification was not applied. The dibromo acid was dissolved in methyl or ethyl alcohol, a few drops of aqueous potassium hydroxide (14.5 g. in 35 cc. of water) added and the mixture allowed to stand at room temperature for five minutes. Ice was added and the solution made acid with acetic acid; a solid was precipitated which can be purified by washing with methyl or ethyl alcohol or by solution in sodium carbonate and reprecipitation with acetic acid. Both acids are faintly yellow powders; the methoxy acid melts at 202° and the ethoxy acid at 197°.

Anal. (202°) Calcd. for $C_{13}H_{13}O_6Br$: C, 45.21; H, 3.76. Found: C, 46.61; H, 3.86.

Anal. (197°) Calcd. for $C_{14}H_{15}O_6Br$: C, 46.78; H, 4.17. Found: C, 47.03; H, 4.10.

The filtrates left after removal of the alkoxy acids gave on acidification with hydrochloric acid small quantities of the unsaturated hydroxy acid (179°).

Summary

The reaction of the dibromo methyl ester of 5-bromo-2,4-dimethoxybenzoylacrylic acid with sodium methylate can be controlled so that any one of three methoxy compounds is the chief product, mixed with a small quantity of a yellow hydroxy acid. These methoxy and hydroxy com-

pounds are probably a result of addition to the bromodimethoxybenzoylpropiolic ester formed by loss of two molecules of hydrogen bromide from the dibromo ester. This acetylenic ester has not been isolated but two intermediate ethylenic bromo esters have been prepared and shown to give two of the products obtained from the dibromo ester. The reaction of this dibromo methyl ester with methyl alcoholic potash has also been studied.

The dibromo ethyl ester gives with sodium ethylate products corresponding to all those obtained from the methyl ester with one exception but the dibromo acid is unreactive compared with its esters and loses only one molecule of hydrogen bromide on treatment with sodium methylate, forming isomeric ethylenic bromo acids. With potash the dibromo acid gives products which are a result of addition to bromodimethoxybenzoylpropiolic acid.

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THE REACTION OF THE GRIGNARD REAGENT WITH γ-CHLOROPROPYL PARA-TOLUENESULFONATE. A METHOD OF LENGTHENING CARBON CHAINS BY THREE CARBON ATOMS

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In synthetic organic work it is often necessary to build up the higher homologs of any series of compounds from the lower ones. Recently the practice of increasing carbon chains by one or two methylene groups by use of the Grignard reagent and formaldehyde or ethylene oxide, respectively, has become fairly common and laboratory details for these methods are available.[1] Gilman and Beaber[2] have published a preliminary paper on the reaction of the Grignard reagent with halogenated alkyl esters of aryl sulfonic acids in which they mention the possibility of the practical use of this reaction for the lengthening of the carbon chain in alkyl halides according to the following equation: $CH_3C_6H_4SO_2O(CH_2)_xCl + RMgX \longrightarrow R(CH_2)_xCl + CH_3C_6H_4SO_2OMgX$. Most of the work reported in this paper dealt with β-chloro-ethyl *p*-toluenesulfonate, but one reaction using γ-chloropropyl *p*-toluenesulfonate was recorded. While the yields reported in this preliminary work were not exceptionally good, the reaction seemed worthy of further study.[3]

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[1] "Organic Syntheses," **6**, 22, 54 (1926).

[2] Gilman and Beaber, THIS JOURNAL, **45**, 839 (1923).

[3] Before beginning this study, we were informed by Dr. Gilman that he did not expect to extend his researches on this particular reaction and that he did not object to our undertaking a further study of it.