(b) **With Ethanol.**—A solution of 5.00 g. (0.0431 mole) of II in 19.80 g. (0.431 mole) of ethanol containing three drops of 10% solution of ferric chloride[14] in ethanol was refluxed 8 hours and allowed to stand overnight. A pellet of sodium hydroxide was added to the solution followed by refluxing for 15 minutes. After removal of the excess ethanol, distillation yielded 3.88 g. (55.5%) of the ethoxyacetal (I), b.p. 161–166°, $n^{25}\text{D}$ 1.3993. A somewhat lower yield of I was obtained when hydrogen chloride was substituted for the ferric chloride in this experiment.

(c) **With Bromine.**—(i) A solution of 0.094 g. (0.81 millimole) of II in 10 ml. of carbon tetrachloride at 0° was found to decolorize 18.22 ml. (0.638 millimole, 78.8%) of an 0.035 *M* bromine in carbon tetrachloride solution added dropwise from a buret. If the order of addition were reversed, and a 0.025 *M* solution of II in carbon tetrachloride added to 10 ml. of the standard bromine solution at 0°, 122% of the theoretical amount of II was required to completely decolorize the bromine.

(ii) In an attempt to isolate the bromo derivative of II, a solution of 4.728 g. (40.7 millimoles) of II in 5 ml. of carbon tetrachloride at 25° was treated dropwise with an 0.8 *M* bromine in carbon tetrachloride solution; only 22.7 millimoles (55%) of bromine was absorbed. When an attempt was made to distill the solvent from the solution, a black liquid separated and large quantities of hydrogen bromide were evolved. Attempts to distil this separated liquid gave more hydrogen bromide and left a black tar.

(iii) To 1.0 g. of II, in a small glass sample tube surrounded by an ice-bath, bromine was added dropwise from a micro buret. Considerable heat was evolved and the solution darkened gradually as the addition proceeded. The bromine absorption stopped after 1.0 g. (73%) of bromine was added. The reaction product was treated with 2 ml. of water and the mixture stirred vigorously for 2 to 3 minutes until the lower organic layer had dissolved. A red precipitate was formed immediately when this dark solution was added to a boiling solution of 2.64 g. of *p*-nitrophenylhydrazine and 3 ml. of concentrated hydrochloric acid in 25 ml. of 95% ethanol. When filtered off and dried, the glyoxal bis-*p*-nitrophenylhydrazone weighed 2.37 g. (84%), m.p. 290–293°. After two recrystallizations from pyridine it melted 309–310° (lit.[15] 309–310°). A mixed melting point with an authentic sample showed no depression.

(d) **With 2,4-Dinitrophenylhydrazine.**—Using the procedure described for the reaction of ethoxyacetal (I) with 2,4-dinitrophenylhydrazine, 1.00 g. of II was allowed to react with 1.88 g. of 2,4-dinitrophenylhydrazine. Yields of 1.72 g. (75%) of the ethoxyacetaldehyde 2,4-dinitrophenylhydrazone and of 0.44 g. (12%) of the glyoxal bis-2,4-dinitrophenylhydrazone were obtained.

(e) **With Phthalic Anhydride.**—In a 25-ml. distilling flask were placed 8.0 g. (0.068 mole) of II and 10.0 g. (0.068 mole) of pulverized phthalic anhydride. After heating in an oil-bath at 110–120° for 1 hour, distillation of the mixture yielded 3.86 g. of distillate, b.p. 80–129°, and 14.12 g. of a black tarry residue, from which no phthalic anhydride was obtained when heated under diminished pressure. Redistillation of the distillate gave the following fractions: (a) 1.66 g., b.p. 69–79°, $n^{25}\text{D}$ 1.3641; (b) 1.17 g., b.p. 79–150°, $n^{25}\text{D}$ 1.4062. When 0.25 g. of fraction (a) was treated with 0.65 g. of phenyl isocyanate, heat was evolved and 0.5 g. (55.5%) of ethyl N-phenylcarbamate, m.p. 45–48°, was extracted from the mixture with boiling petroleum ether (b.p. 90–100°). After recrystallization from 50% ethanol it melted 50–51°; a mixed melting point with an authentic sample showed no depression. Three drops of fraction (b) absorbed about one-third as much bromine as did a similar amount of II, indicating that this fraction was a mixture of ethanol and II.

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[14] Solid ferric chloride when added to II causes it to polymerize exothermically to a viscous, red oil.

[15] W. L. Ruigh and R. T. Major, THIS JOURNAL, **53**, 3131 (1931).

MADISON, WISCONSIN RECEIVED OCTOBER 16, 1950

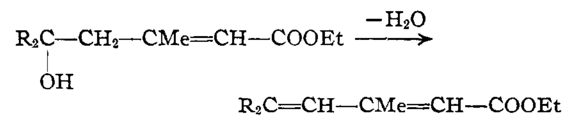
[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF NORTHWESTERN UNIVERSITY]

New Approaches to the Synthesis of Compounds Containing Conjugate Unsaturation

BY CHARLES D. HURD AND H. E. WINBERG

The synthesis of β-methyl-γ-halocrotonic esters from the epoxide of methallyl chloride is described, followed by use of the halo ester in the Reformatsky reaction with aldehydes or ketones. Some reactions of γ-ethynyl-γ-valerolactone are presented.

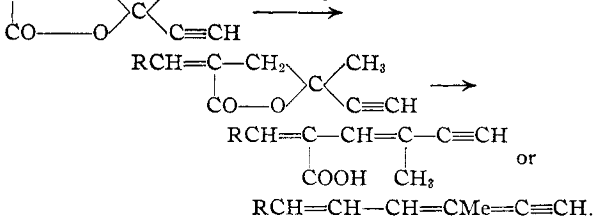
The objective of the present study was to develop new methods of preparation of unsaturated esters which might be adapted to the introduction of isoprene units in organic molecules. Two approaches were considered. First was condensation of γ-halo-β-methylcrotonic ester with aldehydes or ketones, followed by dehydration if necessary



$$\mathrm{CH_2X{-}CMe{=}CH{-}COOEt} \xrightarrow{\mathrm{R_2CO}} \underset{\displaystyle\mathrm{OH}}{\mathrm{R_2C}}\mathrm{{-}CH_2{-}CMe{=}CH{-}COOEt} \xrightarrow{-\mathrm{H_2O}} \mathrm{R_2C{=}CH{-}CMe{=}CH{-}COOEt}$$

Obviously, unsaturation could exist also in the carbonyl compound (R_2CO), for crotonaldehyde, citral or β-ionylideneacetaldehyde would be representative. If the last of these condensed as shown, the compound formed[1] would be closely related to vitamin A.

The second approach was the condensation of aldehydes with γ-ethynyl-γ-valerolactone, made from levulinic acid



As before, unsaturation may exist also in the R group.

Regarding the first of these processes, it is known[2] that the halogen of γ-halocrotonic ester is sufficiently activated through the vinylogous system to undergo this type of reaction. As a matter of fact, the Reformatzsky reaction with ethyl γ-bromo-β-methylcrotonate and β-ionylideneacetaldehyde has been announced recently.[3] In the present work the halo esters selected were

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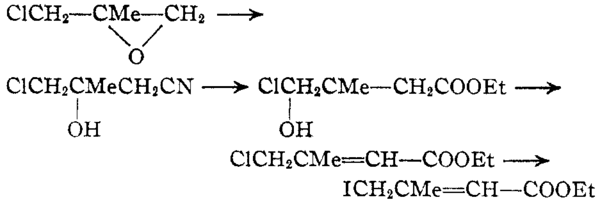
[1] This compound has been made previously by another method: Heilbron, Jones, Lowe and Wright, *J. Chem. Soc.*, 561 (1936).

[2] Fuson, Arnold and Cooke, THIS JOURNAL, **60**, 2272 (1938).

[3] Huisman, *Rec. trav. chim.*, **69**, 851 (1950).

the chloro and iodo esters rather than the bromo ester. The esters were prepared from 3-chloro-2-methyl-1,2-epoxypropane by the sequence of steps



$$\mathrm{ClCH_2{-}CMe{-}CH_2}\ (\mathrm{O}) \longrightarrow \mathrm{ClCH_2\underset{OH}{C}MeCH_2CN} \longrightarrow \mathrm{ClCH_2\underset{OH}{C}Me{-}CH_2COOEt} \longrightarrow \mathrm{ClCH_2CMe{=}CH{-}COOEt} \longrightarrow \mathrm{ICH_2CMe{=}CH{-}COOEt}$$

To gain experience in the first step of this sequence, the synthesis of γ-chloro-β-hydroxybutyronitrile was studied, starting with epichlorohydrin and hydrogen cyanide.

The Reformatzsky condensation was performed with simple model compounds, namely, benzaldehyde and cyclohexanone. The diene, ethyl 5-phenyl-3-methyl-2,4-pentadienoate, was formed from the reaction with benzaldehyde, whereas tertiary alcohol, ethyl 4-(1-hydroxycyclohexyl)-3-methylcrotonate, seemed to be formed from cyclohexanone, although it was not completely separated from an iodine-containing impurity.

The second approach was developed to the first stage. It was shown that benzaldehyde could be condensed with γ-ethynyl-γ-valerolactone to produce α-benzylidene-γ-ethynyl-γ-valerolactone. Also, it was shown that the ethynyl group could be hydrated to an acetyl group.

Experimental

1-Chloro-3-bromo-2-methyl-2-propanol was prepared according to a published procedure.[4] Several procedures were tried for its conversion into 3-chloro-2-methyl-1,2-epoxypropane, the best being to keep 200 g. of it with a mixture of 150 g. of sodium hydroxide and 150 g. of water at 45° for 6 hours. Processing involved adding another 150 g. of water, ether extraction and distillation. There was 95.5 g. of recovered starting material and 44 g. of desired epoxide, b.p. 123–124°. Powdered sodium or potassium hydroxides in ether[5] or benzene, or use of calcium hydroxide suspensions[6] have been recommended but we found them less satisfactory.

γ-Chloro-β-hydroxybutyronitrile.—This compound was previously made[7] in 65% yields by heating the reactants without a catalyst in a sealed tube at 75–85° for 90 hours. The present process avoids the sealed tube.

Epichlorohydrin and dry hydrogen cyanide (0.27 mole each) were mixed at 0°, and three drops of concentrated aqueous potassium cyanide was added as catalyst. After 12 hours at 0–5°, the mixture was left at room temperature for 24 hours, then was distilled. Fourteen grams of γ-chloro-β-hydroxybutyronitrile was collected, b.p. 138–141° (18 mm.). This is a 61% yield, based on the recovery of 7.2 g. of epichlorohydrin.

γ-Chloro-β-hydroxyisovaleronitrile.—Two solutions were prepared, both containing 54 g. of 3-chloro-2-methyl-1,2-epoxypropane, 33 ml. of anhydrous hydrogen cyanide, and two drops of concentrated aqueous potassium cyanide.

One was heated in a sealed tube for 90 hours at 75°, then was distilled; yield 33 g. of the nitrile, b.p. 97–99° (4 mm.).

The other was refluxed for 90 hours, then was distilled; yield 37 g. (55%) of nitrile, b.p. 127–129° (17 mm.); $n^{20}\mathrm{D}$ 1.4680; d^{20}_{20} 1.1911.

Anal. Calcd. for C_5H_8ClNO: Cl, 26.54. Found: Cl, 26.69, 26.54, 26.25.

Ethyl γ-Chloro-β-hydroxyisovalerate.—To a cold solution of 83 g. of concentrated sulfuric acid in 78 g. of absolute alcohol was slowly added 37.6 g. of γ-chloro-β-hydroxyisovaleronitrile. The solution was refluxed for 14 hours, the excess alcohol removed under reduced pressure, and 60 ml. of water added to the residue. The resulting mixture was extracted thrice with 50-ml. portions of ether. After drying the extract over anhydrous sodium sulfate, the solvent was removed. Distillation gave 30 g. (59%) of the colorless hydroxy ester boiling at 93–95° (11 mm.); $n^{20}\mathrm{D}$ 1.4491; d^{20}_{20} 1.1477.

Anal. Calcd. for $C_7H_{13}ClO_3$: Cl, 19.64. Found: Cl, 19.89, 20.11.

Another method for obtaining the ester was by treatment with dry hydrogen chloride instead of sulfuric acid. The results were about the same; dehydration did not occur in either experiment.

Ethyl γ-Chloro-β-methylcrotonate.—To a suspension of 34 g. of phosphorus pentoxide in 120 ml. of anhydrous benzene was added 34.5 g. of ethyl γ-chloro-β-hydroxyisovalerate. After gently refluxing the mixture for 3 hours, the cooled benzene layer was decanted and the residue washed several times with the dry solvent. Removal of the benzene and distillation of the residue gave 23 g. of desired unsaturated ester boiling at 86–91° (19 mm.). This is a 74% yield. The ester does not react with 5% bromine in carbon tetrachloride but reduces 5% potassium permanganate and reacts with alcoholic silver nitrate in the cold.

Anal. Calcd. for $C_7H_{11}ClO_2$: Cl, 21.82. Found: Cl, 22.22, 22.34.

About 45% yields were obtained when either phosphorus oxychloride or a mixture of thionyl chloride and pyridine was used in place of phosphorus pentoxide. No dehydration or reaction was noticed by heating the ester at 100° in the presence of a stream of hydrogen chloride or by heating the ester at 190° in the presence of iodine.

Ethyl γ-Iodo-β-methylcrotonate.—To a solution of 30.0 g. of sodium iodide in 100 ml. of acetone was added 28.7 g. of ethyl γ-chloro-β-methylcrotonate. Precipitation of sodium chloride began immediately. After standing for 20 hours at room temperature, the mixture was filtered and the precipitate washed with acetone. Six grams (58%) of sodium chloride was obtained. The acetone was removed and the residue was taken up in 40 ml. of ether and 10 ml. of water. Iodine color in the ether layer was discharged by use of aqueous sodium thiosulfate. The orange colored layer was dried (Na_2SO_4) and distilled. There was recovered 12.5 g. of the chloro ester, then a 17.4-g. fraction of the iodo ester was collected between 105–115° (15 mm.), most at 112–115°. The product was strongly lachrymatory. It distilled with an orange color and developed an iodine coloration, removable with thiosulfate, within a few hours. The product was pure enough for the reactions given later but analysis for iodine deviated from the calculated value by about 4%.

β,γ-Dibromoisovaleronitrile.—A solution of 49.3 g. of bromine in 100 ml. of dry chloroform was slowly added dropwise with stirring to 25 g. of β-methylallyl cyanide, b.p. 133–136°, dissolved in 100 ml. of chloroform. The reaction vessel was cooled in an ice–salt-bath and the addition was adjusted to maintain the temperature of the reaction mixture at −3 to −5°. After completion of the reaction, the slightly bromine-colored solution was decolorized by shaking with a small amount of aqueous sodium sulfite. The chloroform solution was dried with calcium chloride, the solvent removed and the residue distilled at 12 mm. Only 0.2 g. was collected up to 114°, then 62.5 g. of product distilled at 114–115°; yield 84%. Other constants were these: b.p. 78° (2 mm.), 122° (16 mm.); $n^{20}\mathrm{D}$ 1.5314; d^{20}_{20} 1.8406.

Anal. Calcd. for $C_5H_7Br_2N$: Br, 66.35. Found: Br, 66.37, 66.52.

Ethyl 5-Phenyl-3-methyl-2,4-pentadienoate.—Freshly distilled benzaldehyde (7.3 g.) was mixed with 12 ml. each of dry toluene and dry benzene, and was placed in a dry 3-necked flask fitted with a mercury-sealed stirrer and condenser. To the solution was added 4.5 g. of zinc dust cleaned by treatment for a few seconds with dilute hydrochloric acid and subsequent washing with water, acetone and benzene. The mixture was gently refluxed and with stirring a solution of 17.4 g. (0.0685 mole) of γ-iodo-β-methylcrotonate in 31 ml. of benzene–toluene was added gradually. The reaction mixture was stirred and heated at 100° for 12 hours, cooled in ice, and decomposed with dilute ice-

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[4] Hurd and Abernethy, THIS JOURNAL, **63**, 976 (1941).

[5] Columbic and Cottle, *ibid.*, **61**, 998 (1939).

[6] Hearne and deJong, *Ind. Eng. Chem.*, **33**, 940 (1941).

[7] Braun, THIS JOURNAL, **52**, 3167 (1930).

cold hydrochloric acid. The organic layer was removed and the water was extracted with ether. The ether was combined with the benzene–toluene layer and the whole was dried with anhydrous sodium sulfate, then distilled; yield 5.0 g. of viscid, light yellow oil of b.p. 162–164° (3 mm.). That this was the desired ester was proved: (a) by oxidation to benzoic acid with permanganate; (b) by non-reaction with phenyl isocyanate; (c) by saponification to an acid of m.p. 156–157.5°. The melting point of 5-phenyl-3-methyl-2,4-pentadienoic acid (various geometric isomers) is given[8] as 153, 156–157, 124, 160°.

Ethyl 4-(1-Hydroxycyclohexyl)-3-methylcrotonate.—Comparable details were used as in the last experiment, starting with 9.3 g. of cyclohexanone and 12 g. of the iodo ester. Distillation of the products yielded a 4.7-g. fraction boiling from 95–127° (3 mm.). On standing overnight, it became purple in color. It was then dissolved in ether and the solution decolorized with an aqueous solution of sodium thiosulfate and dried with anhydrous sodium sulfate. Redistillation gave 0.6 g. boiling at 100–110° (2 mm.) and 3.1 g. boiling at 112–116° (2 mm.). Analysis of the ester indicated that it was still slightly contaminated with the iodo ester.

Anal. Calcd. for $C_{13}H_{22}O_3$: C, 68.99; H, 9.80. Found: C, 67.60; H, 8.56.

α-Benzylidene-γ-ethynyl-γ-valerolactone.—γ-Ethynyl-γ-valerolactone was prepared by Kreimeier's method[9] from levulinic acid, acetylene and sodamide in liquid ammonia. It was collected at 108–109° (21 mm.).

A fine suspension of 2.3 g. (0.1 mole) of sodium shot was prepared in dry toluene in a flask protected from atmospheric moisture. After cooling, 5.8 ml. of absolute alcohol was added. Before the sodium had completely dissolved, 12.4 g. of γ-ethynyl-γ-valerolactone was added to the cold mixture. After stirring for 10 minutes, 10.6 g. (0.1 mole) of freshly distilled benzaldehyde was slowly dropped into the mixture, which was cooled in an ice-bath and stirred during the addition and for a subsequent 3 hours, then allowed to stand overnight.

The mixture was then poured into dilute acetic acid, shaken for 15 minutes, and the toluene layer was dried and cooled. The resulting precipitate was collected, washed in ether with aqueous sodium carbonate, then was recrystallized from aqueous alcohol. This yielded 2.1 g. of white needles, m.p. 85–86°. By concentrating the mother liquor, a further 1.4-g. quantity of crystals was obtained.

When treated with alcoholic silver nitrate and with potassium mercuriiodide, the compound gave positive tests for acetylenic hydrogen.

Anal. (By T. S. Ma) Calcd. for $C_{14}H_{12}O_2$: C, 79.21; H, 5.66. Found: C, 79.64; H, 5.89.

γ-Acetyl-γ-valerolactone.—To a solution of 1.5 g. of mercuric oxide dissolved in a mixture of 8.3 g. of concentrated sulfuric acid and 49.7 ml. of water was slowly added 16.3 g. of γ-ethynyl-γ-valerolactone. The resulting reaction was exothermic, and a white precipitate of the mercury salt formed. After all was added, the mixture was refluxed for 3 hours. An additional 5 cc. of sulfuric acid was added, and refluxing was continued 5 hours more. At this point, solution had been effected, leaving only a small residue of reduced mercury salts. The mixture was filtered and neutralized with concentrated aqueous potassium hydroxide added dropwise until the solution was nearly neutral. The precipitated inorganic salts were removed and the solution was repeatedly extracted with ether. After drying the ether extract with anhydrous sodium sulfate, the solvent was removed and the residue distilled at 23 mm. A 2.5-g. fraction was collected up to 126°, then 9.3 g. from 126–132° most of it coming over at 130–132°.

Redistillation of the higher boiling fraction gave the keto lactone as a colorless, water-soluble liquid boiling at 115–116° (10 mm.).

Anal. (By T. S. Ma) Calcd. for $C_7H_{10}O_3$: C, 59.12; H, 7.04. Found: C, 59.90; H, 7.13.

Semicarbazone.—A mixture of 0.5 g. of the lactone, 0.5 g. of anhydrous sodium acetate and 0.5 g. of semicarbazide hydrochloride in 5 ml. of water was allowed to stand overnight. The resulting precipitate weighed 0.6 g. and, after recrystallization from water, melted at 182–183°.

Anal. Calcd. for $C_7H_{10}O_3$: N, 21.11. Found: N, 21.49, 21.68.

2,4-Dinitrophenylhydrazone.—About 0.6 g. of the ketone, 0.4 g. of 2,4-dinitrophenylhydrazine and 25 ml. of ethanol were brought to boiling and 0.5 ml. of concentrated hydrochloric acid was added. After the solution had cooled, 0.5 g. of precipitate was collected. This derivative melted at 147–148° after two crystallizations from ethanol.

Anal. (By Mr. Krzywicki) Calcd. for $C_{13}H_{14}N_4O_6$: N, 17.38. Found: N, 18.37, 18.17.

EVANSTON, ILLINOIS RECEIVED JULY 28, 1950

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(8) Kohler and Heritage, *Am. Chem. J.*, **43**, 485 (1910): Auwers, *J. prakt. Chem.*, **105**, 380 (1922); Kuhn and Hoffer, *Ber.*, **65**, 651 (1932).

(9) Kreimeier, U. S. Patent 2,122,719, July, 1938.

[COMMUNICATION NO. 1362 FROM THE KODAK RESEARCH LABORATORIES]

Azomethine Dyes. I. Color and Constitution of Pyrazolone Azomethine Dyes

BY G. H. BROWN, B. GRAHAM, P. W. VITTUM AND A. WEISSBERGER

Azomethine dyes have been prepared from 2-amino-5-diethylaminotoluene and twenty-six pyrazolones, and their absorptions have been determined in three solvents covering a range of dielectric constant. Explanation of the absorption data is based on the assumption that the two absorption bands occurring in the visible region of the spectrum are x- and y-bands, and the effects of structural changes in the pyrazolone nucleus on these bands are explained qualitatively in terms of the resonance systems involved. The x-band (λ_{max} *ca.* 530–550 mμ) appears to be associated with excitation involving large contributions from structures in which the pyrazolone 2-nitrogen atom is negatively charged, while the y-band (λ_{max} *ca.* 440–450 mμ) is associated with excitation involving structures in which the negative charge is carried largely by the carbonyl-oxygen atom. Polarization of the 1,5-lactam group of the pyrazolone ring, and the steric arrangement of the dye molecule are shown to be important factors in determining the absorption.

The pyrazolone azomethine dyes (III) have received considerable attention since Seymour described[1] their use as the magenta dyes in certain color photographic processes. In these color processes the dyes are formed during color development[2,3] by oxidative condensation of a pyrazolone (I) with an N,N-disubstituted *p*-phenylenediamine (II), and numerous investigations[4] and patents[5] have been concerned with the effect of structural changes in the pyrazolone upon the ability to undergo the azomethine coupling reaction and upon the properties of the resulting dyes.

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(1) M. W. Seymour, U. S. Patent 1,969,479 (1934).

(2) R. Fischer, U. S. Patent 1,102,028 (1914).

(3) C. E. K. Mees, "The Theory of the Photographic Process," The Macmillan Co., New York, N. Y., 1942, p. 393.

(4) A. Weissberger and H. D. Porter, THIS JOURNAL, **64**, 2133 (1942); **65**, 52, 732, 1495, 2180 (1943); **66**, 1849 (1944).

(5) For example, U. S. Patents 2,200,924 and 2,213,986 (1940); 2,311,081, 2,311,082 and 2,334,495 (1943); 2,343,702, 2,343,703, 2,348,463, 2,353,205 and 2,354,552 (1944); 2,367,523 and 2,369,489 (1945); 2,403,329 (1946); 2,435,550, 2,437,063 and 2,439,098 (1948).