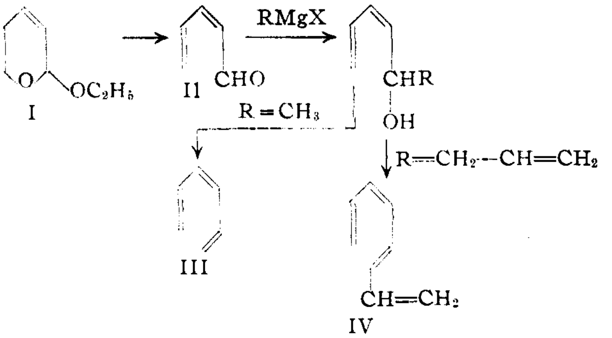
[CONTRIBUTION FROM THE LABORATORIES OF THE UNIVERSITY OF MARYLAND]

Studies in Pyran Chemistry: 3-Bromo-1,3,5-hexatriene

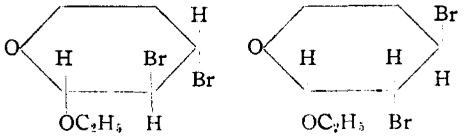
BY G. FORREST WOODS* AND SAMUEL C. TEMIN[1]

Work in this laboratory has shown that 2-ethoxy-Δ^3-dihydropyran (I) is an excellent starting material for the preparation of 1,3,5-hexatriene[2] (III) and 1,3,5,7-octatetraene[3] (IV).



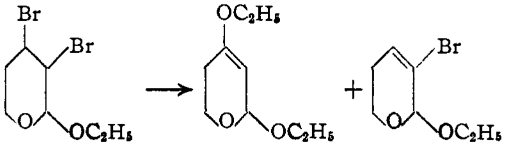
The relationship of hexatriene to benzene has been pointed out[2,4] and along this line one can consider the octatetraene as a vinylhexatriene related to styrene. We have now shown that 2-ethoxy-Δ^3-dihydropyran can also be used as the starting material in a synthesis of 3-bromo-1,3,5-hexatriene which is similarly related to bromobenzene.

The addition of bromine to the ethylenic link of 2-ethoxy-Δ^3-dihydropyran (I) was readily accomplished. As a consequence of *trans* addition to the ethylenic link, the product of the reaction consisted of two geometrical isomers of 2-ethoxy-3,4-dibromotetrahydropyran (V). These isomers are remarkably stable. For instance, the purification of the bromine addition product was accomplished by steam distillation from an aqueous solution of sodium sulfite and sodium carbonate. Under these conditions there was no evidence of reaction. Also, a mixture of the isomers was steam distilled from a dilute sulfuric acid medium and almost all of the starting material was recovered. The stability of the acetal link in the dibromide compound is thus considerably greater than that of 2-ethoxytetrahydropyran[5] or 2-ethoxy-Δ^3-dihydropyran (I).



VA VB

Several methods were explored in an effort to effect the dehydrohalogenation of 2-ethoxy-3,4-dibromotetrahydropyran. Amines were found to be ineffective. Potassium acetate in refluxing diethylene glycol caused a reaction resulting in the displacement of one bromine atom by an acetoxy group. The structure of this substance was not determined. The reaction of the dibromide with either sodium ethoxide or potassium hydroxide dissolved in ethanol was not a simple one. Both dehydrobromination and displacement of bromine occurred to give a mixture, in poor yield, as depicted below



V VI(?) VII

The structure of the diethoxydihydropyran (VI) was not elucidated. However, a 2,4-dinitrophenylhydrazone, prepared from this compound after acid cleavage, contained an ethylenic link and one ethoxyl group while hydrogenation established the presence of one ethylenic link. Since product (VII) was the desired substance, and could not be obtained either in good yield or good purity by this process, the reaction of the dibromide (V) with molten potassium hydroxide was investigated. It was found that when a mixture of 2-ethoxy-3,4-dibromotetrahydropyran (V) and toluene was dropped into molten potassium hydroxide (250°), a 50% yield of 3-bromo-2-ethoxy-Δ^3-dihydropyran (VII) was obtained. All attempts to hydrogenate the ethylenic link of (VII) without concurrent hydrogenolysis of the bromine atom were unsuccessful. This is unfortunate, for the substance 3-bromo-2-ethoxytetrahydropyran is a known compound.[5] The product of hydrogenation was shown to be 2-ethoxytetrahydropyran, a substance we have prepared by an independent method.[5] The isolation of this substance showed that dehydrohalogenation had not caused a ring contraction. The structure we have assigned to (VII) is actually based on the analogy of the behavior of α,β-dibromocarbonyl compounds in dehydrobromination reactions.

The acetal link of 2-ethoxy-3-bromo-Δ^3-dihydropyran (VII) can be opened on treatment with acid at room temperature in the presence of 2,4-dinitrophenylhydrazine to yield the 2,4-dinitrophenylhydrazone of 5-hydroxy-2-bromo-2-pentenal (VIII). Yet, treatment of (VII) with acid, but at lower temperatures, yielded (IX) which contains a glycosidic link. Further action of acid at higher temperature on (IX) also yielded (VIII) isolated as the 2,4-dinitrophenylhydrazone.

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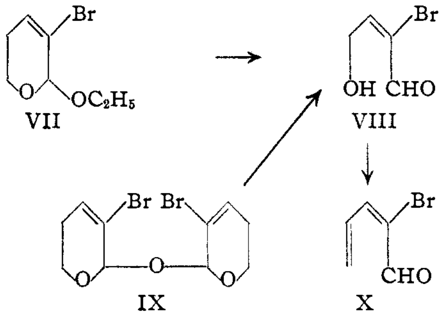
[1] National Institute of Health Predoctorate Research Fellow.

[2] Woods and Schwartzman, THIS JOURNAL, **70**, 3394 (1948).

[3] Woods and Schwartzman, *ibid.*, **71**, 1396 (1949).

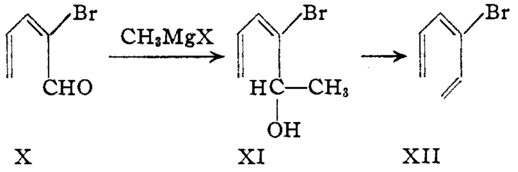
[4] Farmer, Laroia, Switz and Thorpe, *J. Chem. Soc.*, 2937 (1927).

[5] Woods and Sanders, THIS JOURNAL, **68**, 2483 (1946).



2-Bromo-2,4-pentadienal (X) could be obtained through acid dehydration of (VIII) by the addition of 2-ethoxy-3-bromo-Δ^3-dihydropyran (VII) to a strongly acidic medium under steam distillation conditions, but the product was always contaminated with the starting material (VII). Therefore, it was found best to prepare bromopentadienal by the steam distillation of a strongly acidic medium containing (IX). Since neither (IX) nor (VIII) is steam-volatile, the product (X) was obtained in a fairly pure state. This aldehyde is strongly lachrymatory and very irritating to the mucous membrane. It readily yielded a semicarbazone and a red 2,4-dinitrophenylhydrazone.

Treatment of bromopentadienal (X) with methylmagnesium bromide afforded 3-bromo-3,5-hexadien-2-ol (XI). This alcohol was identified by reduction to 2-hexanol and then oxidation of this latter alcohol to 2-hexanone, which was characterized by its semicarbazone and 2,4-dinitrophenylhydrazone derivatives.



Catalytic dehydration of 2-bromo-3,5-hexadien-2-ol over alumina at reduced pressure in a nitrogen atmosphere led to 3-bromo-1,3,5-hexatriene (XII).

Farmer[4] has previously reported the preparation of bromohexatriene. His material was prepared by the addition of bromine to 1,3,5-hexatriene with the subsequent elimination of a molecule of hydrogen bromide. It followed that more than one isomeric form could be obtained. Farmer discussed this and assigned configurations to his products. But it has been shown that Farmer's hexatriene was contaminated with cyclohexadiene[6] and the structures of the products with which he was working remain in doubt. The material prepared in this investigation, for which good analyses were obtained, was a colorless liquid of penetrating odor. Hydrogenation over Adams catalyst resulted in an absorption of hydrogen corresponding to that calculated for saturation of three ethylenic linkages and hydrogenolysis of one bromine atom. The ultraviolet and infrared spectra were determined as shown in Figs. 1 and 2. Addition of bromine to bromohexatriene yielded a white solid with the apparent empirical formula $C_6H_7Br_5$.

It should be observed that if the bromine atom in the bromoethoxydihydropyran (VII) obtained by action of molten potassium hydroxide on 2-ethoxy-3,4-dibromotetrahydropyran (V), were in the 4-position, the subsequent reactions described above would still have led to 3-bromo-1,3,5-hexatriene. Steam distillation of 4-bromo-2-ethoxydihydropyran from an acid medium would have led to 3-bromo-2,4-pentadienal which would have yielded 4-bromo-3,5-hexadien-2-al and 3-bromo-3,5-hexadien-2-al would yield the same product (XII) on dehydration. Thus, the position of the bromine atom in our bromohexatriene is definitely established.

Experimental

2-Ethoxy-3,4-dibromotetrahydropyran (V).—2-Ethoxy-Δ^3-dihydropyran was prepared by the method of Woods and Sanders.[5] To a well-cooled solution of 2-ethoxy-Δ^3-dihydropyran (430 g., 3.36 moles) in 200 ml. of carbon tetrachloride was added, with stirring, a solution of 537 g. (3.36 moles) of bromine in about 80 ml. of carbon tetrachloride at such a rate that the temperature was maintained below −30°. The reaction medium was added to 400 ml. of water containing 100 g. each of sodium sulfite and sodium carbonate and the mixture steam distilled. The water was separated from the more dense 2-ethoxy-3,4-dibromotetrahydropyran and extracted with a small amount of carbon tetrachloride. The carbon tetrachloride washings and dibromo compound were combined and dried over magnesium sulfate. After removal of drying agent the solution was distilled under reduced pressure. 2-Ethoxy-3,4-dibromotetrahydropyran[7] (670 g., 68%) boiled at 80–85° (0.3 mm.), n^{32}_D 1.5140, d^{29}_4 1.55.

Anal. Calcd. for $C_7H_{12}Br_2O_2$: Br, 55.5. Found: Br, 55.5, 55.4.

Separation of Isomers of 2-Ethoxy-3,4-dibromotetrahydropyran.—Two hundred and twenty grams of 2-ethoxy-3,4-dibromotetrahydropyran, obtained by bromination of 2-ethoxy-Δ^3-dihydropyran, was dissolved in 800 ml. of petroleum ether (20–40°) and the solution cooled in a Dry Ice–acetone bath. White crystals precipitated which were collected by suction filtration and washed with cold petroleum ether. After recrystallization the solid isomer (56 g.) of 2-ethoxy-3,4-dibromotetrahydropyran melted at 60–61°.

Anal. Calcd. for $C_7H_{12}Br_2O_2$: C, 29.20; H, 4.20. Found: C, 29.19; H, 4.25.

The petroleum ether solution remaining after removal of the solid isomer was placed in a distilling pot and the solvent removed. The residue was distilled at reduced pressure (123° (12 mm.)) and the first two-thirds of the distillate collected separately. This product (n^{25}_D 1.5158)

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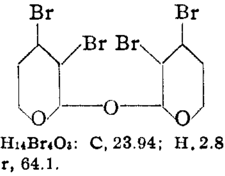
[6] Butz, This Journal, 64, 1978 (1942).

[7] On one occasion when 2-ethoxy-3,4-dibromotetrahydropyran (mixture of isomers) was added dropwise, with stirring, to cold conc. sulfuric acid, a small amount of gummy solid was obtained which recrystallized in long, white needles from aqueous acetone. This melted at 201° and was believed to have the structure shown



Anal. Calcd. for $C_{10}H_{14}Br_4O_3$: C, 23.94; H, 2.81; Br, 63.7. Found: C, 24.27; H, 3.00; Br, 64.1.

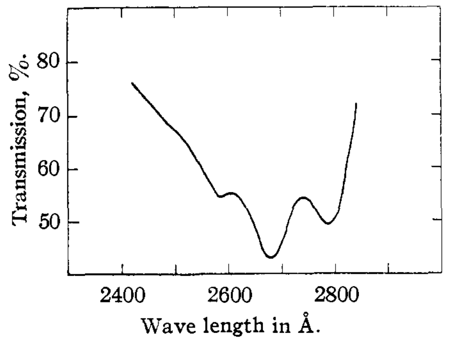


Fig. 1.—Ultraviolet spectrum of $CH_2{=}CHCBr{=}CHCH{=}CH_2$.

was believed to be mainly the liquid isomer. It did not yield crystals upon seeding at very low temperatures.

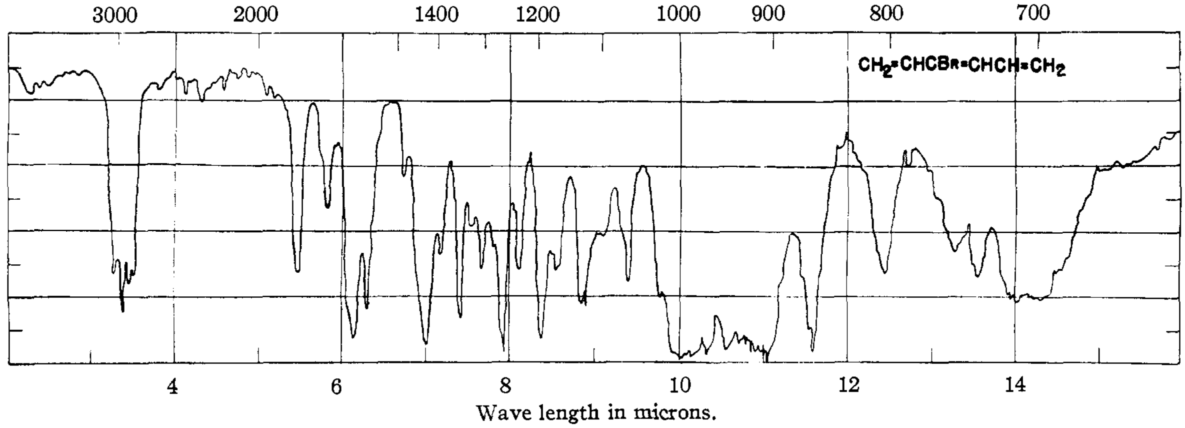


Fig. 2.—Infrared spectrum of 3-bromo-1,3,5-hexatriene.

Hydrogenation of 2-Ethoxy-3,4-dibromotetrahydropyran.—Five and one-half grams of 2-ethoxy-3,4-dibromotetrahydropyran (mostly liquid isomer), 4 g. of sodium carbonate, 0.5 g. of 5% palladium–charcoal catalyst and 75 ml. of 95% ethanol were shaken under hydrogen at atmospheric pressure. After 740 ml. of hydrogen (theoretical for hydrogenolysis of the two bromine atoms is 800 ml.) was absorbed (two hours), the reaction arrested itself. The product was not isolated but a yellow 2,4-dinitrophenylhydrazone was prepared in the usual manner from the liquid remaining after removal of solvent. This derivative was recrystallized from ethyl acetate and melted at 107–107.5°. The mixed melting point determination with an authentic sample of the 2,4-dinitrophenylhydrazone of 5-hydroxypentanal prepared from 2-ethoxytetrahydropyran was 107.5–108°.

2-Ethoxy-3(or 4)-bromo-4(or 3)-acetoxytetrahydropyran.—2-Ethoxy-3,4-dibromotetrahydropyran (50 g.) was heated with 32 g. of anhydrous potassium acetate and 75 ml. of diethylene glycol until reaction commenced. The contents of the flask were boiled for five minutes after the major violence of the reaction was spent and then cooled to room temperature. The odor of acetic acid was apparent. After neutralization of the acid, the mixture was filtered. Water was added to the filtrate which was then extracted with ether. The ether extract was dried over magnesium sulfate and filtered. After removal of solvent the residue yielded 8 g. of material boiling from 90–100° at 10 mm. and 14 g. of material boiling from 100–130° at 10 mm. The higher-boiling material was mainly unreacted 2-ethoxy-3,4-dibromotetrahydropyran. The lower-boiling fraction was 2-ethoxy-3(or 4)-bromo-4(or 3)-acetoxytetrahydropyran. A redistilled sample boiled at 90° (12 mm.), n^{25}_D 1.4754.

Anal. Calcd. for $C_9H_{15}BrO_4$: C, 40.47; H, 5.66; Br, 29.9. Found: C, 41.95; H, 6.00; Br, 29.2.

The acetal link of 2-ethoxybromoacetoxytetrahydropyran was cleaved by heating in an acidic alcoholic solution and then 2,4-dinitrophenylhydrazine was added. An orange derivative of the aldehyde, 2(or 3)-bromo-3(or 2)-acetoxy-5-hydroxypentanal, was obtained and recrystallized first from aqueous alcohol and then from benzene, m. p. 145–146° (with dec.).

Anal. Calcd. for $C_{13}H_{15}BrO_7N_4$: C, 37.25; H, 3.61. Found: C, 37.41; H, 3.31.

Diethoxydihydropyran (VI).—2-Ethoxy-3,4-dibromotetrahydropyran (V) was treated with excess alcoholic potassium hydroxide or excess alcoholic sodium ethoxide in a large number of experiments. The product obtained consisted of a mixture of diethoxydihydropyran (VI) and 3-bromo-2-ethoxy-Δ^3-dihydropyran (VII) as well as some unreacted 2-ethoxy-3,4-dibromotetrahydropyran. The bromine content of the mixture, which could not be separated by ordinary fractionation procedures, varied from 27 to 16% depending upon the time of heating (V) with the alkaline reagents. Continued treatment of this mixture with either sodium ethoxide or potassium hydroxide dissolved in alcohol led to a bromine-free product. A final distillation from metallic sodium yielded pure diethoxydihydropyran (13–16%) boiling at 98–101° (17 mm.) (205°/760 mm.), n^{27}_D 1.4445.

Anal. Calcd. for $C_9H_{16}O_3$: C, 62.77; H, 9.32. Found: C, 62.69; H, 9.73.

Diethoxydihydropyran was cleaved by acids to yield a 5-hydroxyethoxypentenal with the loss of one (the acetal) ethoxyl group. An orange 2,4-dinitrophenylhydrazone was prepared in the usual manner from the aldehydic hydrolysis product which was not otherwise isolated, m. p. 145°.

Anal. Calcd. for $C_{13}H_{16}O_6N_4$: C, 48.14; H, 4.97. Found: C, 48.08; H, 5.11.

Diethoxydihydropyran (8 g.) was hydrogenated over palladium–charcoal at atmospheric pressure. The theoretical uptake of hydrogen required one hour. The product (7.3 g.) was a diethoxytetrahydropyran, b. p. 93° (15 mm.), n^{28}_D 1.4315.

Anal. Calcd. for $C_9H_{18}O_3$: C, 61.74; H, 10.34. Found: C, 61.71; H, 10.39.

3-Bromo-2-ethoxy-Δ^3-dihydropyran (VII).—A solution of 2-ethoxy-3,4-dibromotetrahydropyran (120 g.) in 120 ml. of toluene was slowly dropped, with stirring, into molten (250°) potassium hydroxide (500 g.) contained in a steel cylinder. The gases from the cylinder were led to, and condensed in, a receiver cooled in an ice-water-bath. This distillate was washed once with water and then dried over magnesium sulfate. The solution was filtered and the solvent removed. The residue yielded crude 3-bromo-2-ethoxy-Δ^3-dihydropyran (41 g., 48%), b. p. 95–100°

(10 mm.), and unreacted 2-ethoxy-3,4-dibromotetrahydropyran (35 g., 29%), b. p. 125° (10 mm). Based on the 2-ethoxy-3,4-dibromotetrahydropyran recovered, the yield of crude material was 67%. Pure 3-bromo-2-ethoxy-Δ^3-dihydropyran boiled at 88° at 10 mm., n^{21}_{D} 1.4900, d^{21}_{4} 1.385.

Anal. Calcd. for $C_7H_{12}BrO_2$: C, 40.60; H, 5.35; Br, 38.58. Found: C, 40.68; H, 5.49; Br, 38.51.

One gram each of 3-bromo-2-ethoxy-Δ^3-dihydropyran and 2,4-dinitrophenylhydrazine were heated on the steam-cone with 50 ml. of 95% ethanol until a clear solution resulted. Then 2 ml. of concentrated hydrochloric acid was added and heating continued while 20 ml. of water was gradually added. Under these conditions the acetal link in 3-bromo-2-ethoxy-Δ^3-dihydropyran was cleaved with elimination of the acetal ethoxyl group to form the free aldehyde, 2-bromo-5-hydroxy-2-pentenal (VIII). The hot aqueous alcoholic solution was filtered and an orange solid crystallized from solution on cooling. After recrystallization from benzene–petroleum ether and then aqueous alcohol, the derivative melted at 159–160° (with dec.).

Anal. Calcd. for $C_{11}H_{11}BrO_5N_4$: C, 36.78; H, 3.09. Found: C, 36.94; H, 3.21.

Hydrogenation of 3-Bromo-2-ethoxy-Δ^3-dihydropyran.—3-Bromo-2-ethoxy-Δ^3-dihydropyran (12 g.) was hydrogenated at 1-atm. pressure over palladium–charcoal catalyst in the presence of sodium carbonate. The theoretical hydrogen uptake, calculated for saturation of one double bond and hydrogenolysis of one bromine atom, required two hours. The product, 2-ethoxytetrahydropyran (b. p. 44° (13 mm.), n^{27}_{D} 1.4260) yielded a yellow 2,4-dinitrophenylhydrazone, m. p. 107°, which gave no depression in a mixed melting point determination with an authentic sample of the derivative of 5-hydroxypentenal obtained from 2-ethoxytetrahydropyran.

Glycosidic Compound (IX) from 3-Bromo-2-ethoxy-Δ^3-dihydropyran.—3-Bromo-2-ethoxy-Δ^3-dihydropyran (138 g.) was added slowly to an efficiently stirred solution of concentrated sulfuric acid (250 ml.) in 250 ml. of water. The temperature of the acid solution was kept below 5°. Solid rapidly formed. The stirring was continued for fifteen minutes after addition was complete and ice (200 g.) then added. The solid, collected by suction filtration, was washed thoroughly with water, then alcohol and finally dried in the air. The yield was 78 g. (69%). After recrystallization from aqueous acetone the solid melted at 143°.

Anal. Calcd. for $C_{10}H_{12}Br_2O_3$: C, 35.23; H, 3.56; Br, 47.00. Found: C, 35.12; H, 3.58; Br, 47.24.

A 2,4-dinitrophenylhydrazone was prepared from the glycosidic compound (IX) after cleavage of the acetal link, which was identical with the 2,4-dinitrophenylhydrazone prepared from 3-bromo-2-ethoxy-Δ^3-dihydropyran (VII).

2-Bromo-2,4-pentadienal (X).—Compound (IX) (30 g.) was added to a solution of 185 ml. of 85% phosphoric acid in 300 ml. of water and the mixture steam distilled. Ice and salt were added to the distillate which was extracted three times with ether. After 3–4 liters of distillate had been collected, another 30 g. of the solid (IX) was added and the distillation and extraction continued as before until the odor of 2-bromo-2,4-pentadienal could no longer be detected in the distillate. The combined ether extracts were dried over magnesium sulfate in the cold and filtered. The ether was removed under a nitrogen atmosphere at reduced pressure. Hydroquinone was added to the residue which was distilled in a nitrogen atmosphere. 2-Bromo-2,4-pentadienal (27.2 g., 48%) boiled at 48–52° (2–3 mm.) (or 78° (10 mm.)), n^{25}_{D} 1.5862, and was still yellow after redistillation.

Anal. Calcd. for C_5H_5BrO: C, 37.30; H, 3.13. Found: C, 37.68; H, 3.60.

This aldehyde was unstable and difficult to analyze. On two occasions distillation of a pure sample at 10–15 mm. led to polymerization near the end of the distillation that was sufficiently rapid and violent to blow off the top of the fractionating column.

When treated in the usual manner, 2-bromo-2,4-pentadienal readily yielded a red 2,4-dinitrophenylhydrazone which darkened before melting at 155° with decomposition.

Anal. Calcd. for $C_{11}H_9BrO_4N_4$: C, 38.73; H, 2.66. Found: C, 38.76; H, 2.67.

A semicarbazone was prepared from 2-bromo-2,4-pentadienal in the usual manner and was recrystallized from aqueous acetone. It gradually darkened and decomposed without melting on heating to 250°.

Anal. Calcd. for $C_6H_8BrON_3$: C, 33.05; H, 3.70. Found: C, 33.46; H, 3.86.

3-Bromo-3,5-hexadien-2-ol (XI).—2-Bromo-2,4-pentadienal (20 g., 0.13 mole) was slowly added to an ethereal solution of methylmagnesium bromide prepared from 8 g. (0.33 mole) of magnesium and methyl bromide. The Grignard addition complex was decomposed by pouring the ether solution into a mixture of cracked ice and ammonium chloride. An emulsion was obtained from which as much of the ether layer was removed as possible. The emulsion was treated with sodium sulfate and the ether derived from the emulsion combined with the original ether layer. The combined ether extract was dried over magnesium sulfate, filtered, and the solvent removed under reduced pressure in a nitrogen atmosphere. The residue, distilled in a nitrogen atmosphere in the presence of hydroquinone, yielded 3-bromo-3,5-hexadien-2-ol (18.5 g., 83%), b. p. 56° (0.8 mm.), n^{26}_{D} 1.5335.

Anal. Calcd. for C_6H_9BrO: C, 40.70; H, 5.12. Found: C, 40.88; H, 5.37.

Hydrogenation of 3-Bromo-3,5-hexadien-2-ol.—3-Bromo-3,5-hexadien-2-ol (3 g.) was hydrogenated over Adams catalyst at one atmosphere pressure. The theoretical uptake of hydrogen, calculated for saturation of two double bonds and hydrogenolysis of one bromine atom, required twenty-seven minutes. The product, 2-hexanol, boiled at 138°.

2-Hexanol (0.6 g.) was oxidized at 50° in a solution of 6 g. of potassium dichromate, 3.3 ml. of concentrated sulfuric acid and 10 ml. of water. The mixture was steam distilled and 2-hexanone obtained in the distillate. A portion of the above distillate yielded a 2,4-dinitrophenylhydrazone, m. p. 107–109°, which gave no depression in a mixed melting point determination with an authentic sample of the 2,4-dinitrophenylhydrazone of 2-hexanone. Another portion of the distillate yielded a semicarbazone, m. p. 123–124°, which gave no depression with an authentic sample of the semicarbazone of 2-hexanone.

3-Bromo-1,3,5-hexatriene (XII).—3-Bromo-3,5-hexadien-2-ol (16 g.) was catalytically dehydrated in a nitrogen atmosphere at reduced pressure (0.1 mm.) over aluminum oxide (12 mesh) heated to 315–325°. The product was condensed in a receiver cooled by a Dry Ice–acetone bath. Anhydrous potassium carbonate was added to the product and the mixture filtered. A minimum of ether (peroxide free) was used to wash the solid. Hydroquinone was added to the filtrate which was distilled at reduced pressure. 3-Bromo-1,3,5-hexatriene (4 g. 20%) boiled at 42° (10 mm.), n^{28}_{D} 1.5683, d^{28}_{4} 1.320.

Anal. Calcd. for C_6H_7Br: C, 45.31; H, 4.44; Br, 50.25. Found: C, 45.85; H, 4.63; Br, 50.62.

It is interesting to note that pure 3-bromohexatriene decomposes very rapidly on standing. Another analysis, done immediately on a sample of 3-bromohexatriene which had just been distilled, yielded: C, 45.91; H, 4.80. Analysis of the same material, but after it had been allowed to stand for two hours, yielded: C, 46.23; H, 5.64. The distilling pot contained a residue of deep blue color which was always observed in this distillation. Bromohexatriene is quite unstable and difficult to keep free of color. However, it may be stored essentially unchanged in Dry Ice in the presence of hydroquinone for a period of weeks. Bromohexatriene slowly decomposed, as evidenced by coloration, when stored in the ice box over hydroquinone.

3-Bromohexatriene (0.312 g.) in 95% ethanol was hydrogenated over Adams catalyst at room temperature and atmospheric pressure. The theoretical amount of hydrogen, calculated for saturation of three double bonds and hydrogenolysis of one bromine atom, was absorbed in forty minutes.

3-Bromo-1,3,5-hexatriene (0.3 g.) in 5 ml. of carbon tetrachloride was treated with a solution of bromine in carbon tetrachloride until the bromine color persisted. The reaction medium was then heated on the steam-cone until all solvent had been removed. Petroleum ether (30–60°) was added to the residue and crystals appeared when the mixture was cooled to about −60°. After recrystallization from petroleum ether (30–60°) the solid melted at 87–88°.

Anal. Calcd. for $C_6H_7Br_5$: C, 15.05; H, 1.49; Br, 83.6. Found: C, 15.39; H, 1.66; Br, 84.1.

The ultraviolet absorption spectrum was measured with a Beckmann quartz spectrophotometer in carefully purified cyclohexane. Due to the instability of 3-bromo-1,3,5-hexatriene, no careful weighings were made so only the relation of per cent. transmission to wave length could be obtained. The approximate concentration was 2×10^{-5} mole/liter. Maxima of absorption were observed at 2785, 2675 and 2580 Å. The infrared absorption spectrum determination was kindly done in the laboratory of Dr. Plyler, Radiometry Section of the Bureau of Standards, Washington, D. C.

Summary

1. 3,4-Dibromo-2-ethoxytetrahydropyran has been prepared from 2-ethoxy-Δ^3-dihydropyran.

2. Dehydrohalogenation of 3,4-dibromo-2-ethoxytetrahydropyran yielded 3-bromo-2-ethoxy-Δ^3-dihydropyran.

3. 2-Bromopentadienal was prepared from 3-bromo-2-ethoxy-Δ^3-dihydropyran and treated with methylmagnesium bromide. The product was 3-bromo-3,5-hexadien-2-ol.

4. 3-Bromo-1,3,5-hexatriene was prepared by the catalytic dehydration of 3-bromo-3,5-hexadien-2-ol.

COLLEGE PARK, MD. RECEIVED JUNE 15, 1949

[CONTRIBUTION FROM THE CHANDLER LABORATORY, COLUMBIA UNIVERSITY]

Mechanism of the Decarboxylation of α-Pyridylacetic Acid[1]

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The decarboxylation of α-pyridylacetic acid,[2] α-quinolylacetic acid[3] and γ-quinolylacetic acid[4] but not β-pyridylacetic acid[5] occurs with remarkable ease at temperatures below 100°. As a contribution to the elucidation of this decarboxylation, we have synthesized and resolved methylethyl-α-pyridylacetic acid (I) and studied its decarboxylation to α-*s*-butylpyridine (II). As the significance of the study depends both on the optical stability and on a measurably large rotation of the decarboxylation product, II has been resolved and its racemization studied.

The synthesis of II,[6] effected unsatisfactorily (6%) by the reaction of *s*-butylmagnesium bromide and pyridine,[7] is accomplished smoothly (59%) by the reaction[8] of pyridine and *s*-butyllithium. The resolution of II,[9] not realizable through the amorphous *d*-10-camphorsulfonate and *l*-malate salts nor through the crystalline hydrogen *d*-tartrate, is effected by way of the nicely crystalline dibenzoyl-*d*-tartrate, albeit to a substantially complete degree only after a tedious fractional crystallization of twenty steps. The magnitude of the specific rotation ($[\alpha]^{25}{}_{D}$ −30°) of the most highly resolved II is sufficient to allow facile detection of as little as 0.1% residual optical activity in samples of racemized II.

In racemization attempts (−)-II is optically stable to prolonged refluxing with 1,2-propanediol (b. p. 189°), with concentrated hydrochloric acid, and with ethanolic sodium ethoxide, but is racemized by a solution of potassium in triethylcarbinol rapidly at 142° and more slowly at 100°.[10] The related methiodide (III) of optically active α-*s*-butylpyridine is racemized by boiling in propanediol, but is not affected by boiling in water containing a small amount of acetic acid.

Since the racemization of II is a most sensitive measure of the removal of the α-hydrogen and therefore furnishes information bearing both on condensations of the α-picoline type and on the tautomerization of suitably substituted pyridines to enamines (*e. g.*, IV),[11] it is pertinent to point out that the consistent mechanism of the racemization of II involves the resonating planar carbanion V which is formed by the bimolecular attack of a strong base on the α-hydrogen and not by spontaneous dissociation. Furthermore the

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[1] Taken from a dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Faculty of Pure Science, Columbia University.

[2] Oparina, *J. Gen. Chem.* (*U. S. S. R.*), **5**, 1699 (1935); *Chem. Zentr.*, **106**, I, 2536 (1935).

[3] Borsche and Manteuffel, *Ann.*, **526**, 22 (1936).

[4] Borsche and Bütschli, *ibid.*, **529**, 266 (1937).

[5] Miescher and Kagi, *Helv. Chim. Acta*, **24**, 1471 (1941), have reported that 2-carboxy-3-pyridineacetic acid at 180° in dimethylaniline is decarboxylated to β-pyridylacetic acid which itself decarboxylates only on heating to higher temperature.

[6] Diels and Alder, *Ann.*, **505**, 103 (1933), have synthesized II from α-acetylpyridine in 24% yield in two steps, addition of ethylmagnesium iodide and reduction with hydrogen iodide and phosphorus.

[7] For reactions of this type see Bergstrom and McAllister, THIS JOURNAL, **52**, 2845 (1930).

[8] Ziegler and Zeiser, *Ber.*, **63**, 1847 (1930).

[9] The resolution affords rigorous proof of the *s*-butyl structure of II.

[10] A preliminary kinetic study of the racemization failed to yield results consistent from one experiment to the next, although within a particular run the data may be of sufficient value to allow the inference that the reaction is first order.

[11] Chichibabin, *Ber.*, **60**, 1607 (1927); *Bull. soc. chim.*, [5] **3**, 1607 (1936); [5] **5**, 429, 436 (1938).