under vacuum to yield white crystals of **2-amino-1,7-heptanedioic acid** (0.51 g., 29.2%); m.p. 220–222°, lit.[29] 225°. The product gave a characteristic red color with ferric chloride solution and liberated ammonia when heated with soda lime.

d,l-**Lysine Dihydrochloride.**—A mixture of 2-cyanocyclohexanone (12.3 g., 0.1 mole) and hydrazoic acid (4.95 g., 0.115 mole) in chloroform (110 ml.) was added dropwise, in two hours, to a stirred mixture of concentrated sulfuric acid (20 ml.) and chloroform (60 ml.) at 3–7°. After addition was complete, the solution was stirred for two hours at room temperature, then slowly poured on cracked ice. The layers were separated and the chloroform layer was washed twice with 50 ml. of water. The aqueous solutions were combined, refluxed for three hours, then evaporated to a thick sirup under vacuum on a steam-bath. Hydrazoic acid (4.95 g., 0.115 mole) in chloroform (110 ml.) was added. Sulfur trioxide (*ca.* 25 g.) was distilled into the stirred solution at 40–45° until gas was evolved steadily. After evolution of gas had ceased, the mixture was stirred overnight at room temperature.

The layers were separated and the aqueous layer was almost neutralized with hot, saturated barium hydroxide solution. The mixture was centrifuged and the decantate was decolorized with activated charcoal. After adding concentrated hydrochloric acid (100 ml.) to the solution, it was evaporated to a thick sirup under vacuum on a steam-bath. The sirup was dissolved in a minimum amount of hot absolute alcohol and then cooled; ether was added in small amounts with stirring and cooling until the total volume was approximately five times that of the alcohol added. *d,l*-Lysine dihydrochloride precipitated as white crystals; the product was filtered and dried in vacuum; yield 13.0 g. (59.5%); m.p. 195–197°, lit.,[8] 187–189°. A second experiment gave a yield of 58.5%.

d,l-Lysine dipicrate (90%) was prepared from aqueous *d,l*-lysine dihydrochloride and picric acid, m.p. 183–185°, lit.,[8] m.p. 184–187°.

Anal. Calcd. for $C_{18}H_{20}N_8O_{16}$: C, 35.73; H, 3.33; N, 18.52. Found: C, 35.67; H, 3.51; N, 18.61.

Reaction of 2-Chlorocyclohexanone and Hydrazoic Acid.—A mixture of 2-chlorocyclohexanone (13.2 g., 0.1 mole) and hydrazoic acid (4.95 g., 0.115 mole) in chloroform (120 ml.) was added dropwise with stirring to a mixture of concentrated sulfuric acid (35 ml.) and absolute ethanol (100 ml.) at 40–45°. The mixture was stirred for one hour after addition of reactants, then cooled in an ice–salt mixture and neutralized with 40% sodium hydroxide at temperatures below 10°. Sodium sulfate that precipitated was filtered and washed with chloroform. The aqueous product was separated and extracted with chloroform. The chloroform extracts were combined, washed with 10% sodium carbonate solution, dried over sodium sulfate, and distilled under vacuum to yield, after removal of chloroform: Fraction 1, 2-chlorocyclohexanone, 4.66 g., b.p. 90–95° (15 mm.); Fraction 2, 0.29 g., b.p. 95–180° (15 mm.); Fraction 3, 3.05 g., b.p. 180–185° (15 mm.); residue, 1.8 g. Fraction 3 solidified to a white solid upon cooling and was identified as **3-chloro-2-ketohexamethylenimine** (31.4%); m.p. 97–98° (from 30–60° petroleum ether). Evaporation of the aqueous extract under vacuum yielded an elastic polymer.

Anal. Calcd. for $C_6H_{10}OClN$: C, 48.82; H, 6.83; N, 9.49. Found: C, 48.68; H, 6.82; N, 9.52.

6-Benzoylamino-2-chlorohexanoic Acid.—3-Chloro-2-ketohexamethylenimine (0.9 g., 0.0065 mole) was refluxed for 12 hours with concentrated hydrochloric acid (10 ml.). The solution was made basic with sodium hydroxide and cooled; benzoyl chloride (1 g.) was added with stirring and cooling. The mixture was stirred for 15 minutes at 0°, then acidified with dilute hydrochloric acid. The oil which separated was crystallized from water to give **6-benzoylamino-2-chlorohexanoic acid** (1.10 g., 66%); m.p. 137.5–138.5°, no depression by an authentic sample, m.p. 137.8–138.8.[30]

Anal. Calcd. for $C_{13}H_{16}O_3NCl$: C, 57.89; H, 5.98; N, 5.19. Found: C, 58.23; H, 5.76; N, 5.34.

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[29] W. Dieckmann, *Ber.*, **38**, 1654 (1905).

[30] Reference 11 reports that 6-benzoylamino-2-chlorohexanoic acid melts at 145–147°; an authentic sample obtained from Dr. Galat melted at 137.8–138.8° and is identical with the product obtained in this research.

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[CONTRIBUTION FROM THE CHEMISTRY DEPARTMENT, UNIVERSITY OF MISSOURI]

The Alkylation of Phenol with Ethyl 6-Bromosorbate[1]

BY HERBERT E. UNGNADE[2] AND THOMAS R. HOPKINS

Ethyl 6-bromosorbate reacts with phenol to give ethyl 4-phenoxysorbate or ethyl 4-(*o*-hydroxyphenyl)-sorbate, depending on the conditions. Evidence for the assigned structures has been presented.

Only one previous attempt has been reported to prepare an allyl phenyl ether in which the allylic double bond is part of a conjugated system, namely, the reaction of phenol with sorbyl chloride. The usual method of preparation failed in this case and the product of a modified procedure proved to be *o*-sorbylphenol rather than the expected ether.[3]

In view of the difficulties involved in the preparation of sorbyl halides, the present investigation was undertaken with the more accessible ethyl 6-bromosorbate.

Bromination of ethyl sorbate with N-bromosuccinimide in benzene has given ethyl 6-bromosorbate (I) in 40–50% yield. Its structure is based on the ultraviolet absorption spectrum, the addition of maleic anhydride and the isolation of glyoxal from the ozonization products. The ester (I) reacts with phenol and potassium carbonate in methyl ethyl ketone to give a liquid phenoxy ester (II) which is unchanged by heating at 230–250°. It yields an adduct with maleic anhydride, absorbs at 255 mμ (log ϵ 4.2)[4] and gives acetaldehyde as the only volatile product from ozonization and reductive hydrolysis. It is therefore regarded as a substituted sorbic ester. The corresponding acid (III) is smoothly decarboxylated. The structure of the decarboxylation product (IV) has been established as 3-phenoxy-1,3-pentadiene by isolation of approximately equal amounts of acetaldehyde and formaldehyde from its ozonization products. The structure of the phenyl ether (II) is assigned on the basis of the reaction sequence (II) → (IV) and the formation of acetaldehyde in the ozonization of (II), but the possibility remains that the ester (II) actually has the phenoxy group on the beta carbon.[5]

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[1] From the Master's thesis of T. R. Hopkins.

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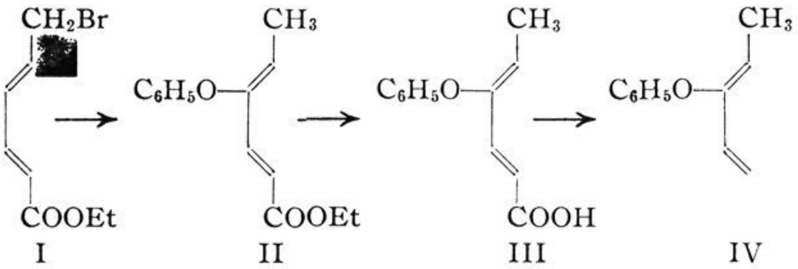
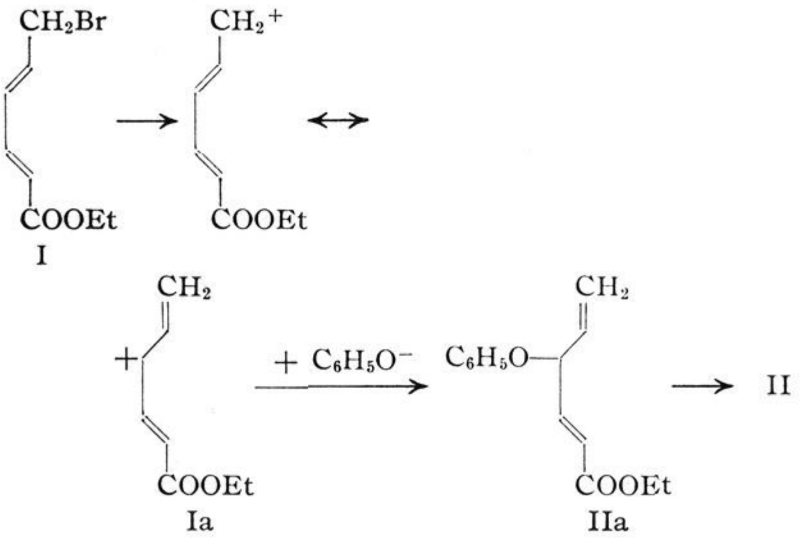
[3] Reichstein and Trivelli, *Helv. Chim. Acta*, **16**, 969 (1933).

[4] The phenoxy group evidently does not exert a measurable bathochromic effect in this case.

[5] As long as the point of attachment of the phenoxy group is not definitely established.



The proposed structure of (II) requires that the bromide (I) undergoes an allylic rearrangement. If the resultant ion (Ia) reacts with phenoxide ion, a bond isomer (IIa) results, which should isomerize with ease.



Various attempts have been made to synthesize the reduction product of III in order to establish the point of attachment of the phenoxyl group. These have failed because the intermediates are cleaved by acid even at low temperatures. Other attempts to establish the structure by dehydrogenation of the Diels–Alder adduct were similarly unsuccessful.

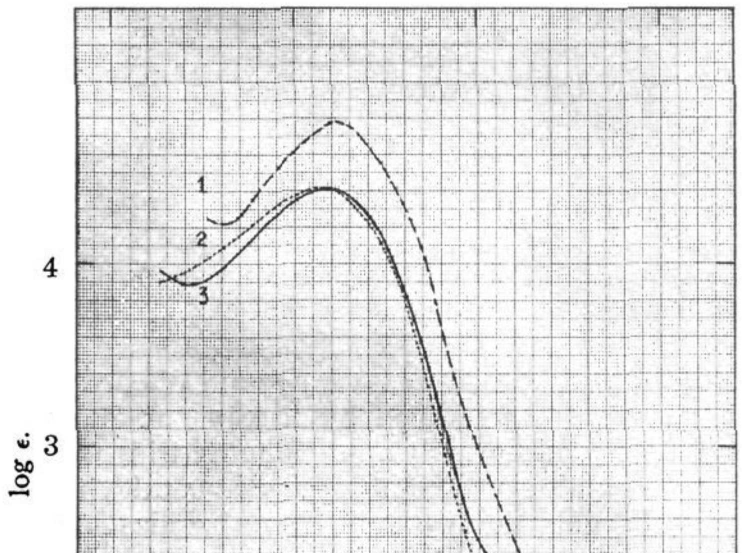
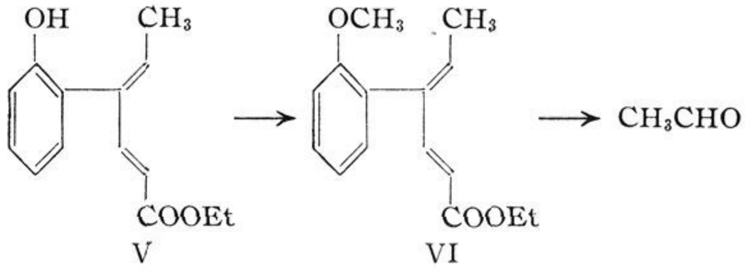


Fig. 1.—Ultraviolet absorption curves: 1, ethyl 4-(*o*-hydroxyphenyl)-sorbate (V); 2, ethyl 4-phenoxysorbate (II); 3, ethyl sorbate.

The direct nuclear alkylation of phenol with ethyl 6-bromosorbate presumably also takes place with inversion and a similar mechanism is proposed for its formation. The product has been converted to the methyl ether which gives only acetaldehyde on ozonolysis. Structures (V) and (VI) for these compounds are compatible with the evidence and are regarded as the most likely possibilities.



The ultraviolet absorption spectrum of the nuclear alkylation product shows an increase in absorption and a shift of the maximum to higher wave lengths as compared to ethyl sorbate, which would be expected on the basis of the proposed structure (Fig. 1).

Considerable difficulties have been encountered due to the ease with which the doubly unsaturated compounds polymerize.

Experimental[6]

Ethyl 6-Bromosorbate (I).—Ethyl sorbate (24 g.), prepared from sorbic acid by the esterification method of Thielepape[7] in 72–80% yield, was brominated by refluxing for ten hours with 30.0 g. of N-bromosuccinimide, 0.36 g. of benzoyl peroxide and 80 cc. of dry, thiophene-free benzene. The mixture was cooled and filtered. The filtrate was washed with water, dried and distilled. The pure bromo ester boiled at 102–103° (2 mm.), yield 40–45%. Its spectrum ($\lambda_{\text{max.}}$ 260 mμ, log $\epsilon_{\text{max.}}$ 3.94) was similar to that of ethyl sorbate. The low extinction was probably due to polymerization.[8,9]

Anal. Calcd. for $C_8H_{11}BrO_2$: C, 43.83; H, 5.22. Found: C, 43.78; H, 5.14.

Ozonization of the ester (110 mg.) in ethyl bromide (60 cc.) at 0°, followed by reductive hydrolysis of the ozonide and treatment with methone gave 0.12 g. of dimethone. Recrystallization from aqueous methanol gave a single pure compound, melting point and mixed melting point with authentic glyoxaldimethone 184–186°.

3-Carbethoxy-6-bromomethyl-1,2,3,6-tetrahydrophthalic Anhydride.—A mixture of ethyl 6-bromosorbate (2.0 g.) and maleic anhydride (0.75 g.) was heated to 160° for one minute. The mixture was cooled and filtered. The precipitate was crystallized twice from acetone and ether. The white crystalline solid (0.43 g.) gave a positive test for halogen with alcoholic silver nitrate. It melted at 265–268° and sublimed at 272°.

Anal. Calcd. for $C_{12}H_{13}BrO_5$: C, 45.42; H, 4.10. Found: C, 45.24; H, 3.90.

The hydrolysis of 3-carbethoxy-6-bromomethyl-1,2,3,6-tetrahydrophthalic anhydride (0.32 g.) was brought about by adding 5% aqueous sodium carbonate. The anhydride went into solution immediately. The solution was acidified with hydrochloric acid and extracted three times with ether. The ether layer was evaporated to dryness and yielded 0.11 g. of a white solid residue. This solid gave a positive test with silver nitrate. Its melting range was indefinite (230–271°).

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(6) All temperatures uncorrected.

(7) Thielepape, *Ber.*, **66**, 1454 (1933).

(8) Heilbron, Jones and O'Sullivan (*J. Chem. Soc.*, 866 (1946)) report $\lambda_{\text{max.}}$ 265 mμ and log $\epsilon_{\text{max.}}$ 4.278 for methyl 6-bromosorbate.

(9) Ultraviolet absorption spectra by Dr. E. E. Pickett, University of Missouri.

Anal. Calcd. for $C_{12}H_{15}BrO_6$: C, 42.99; H, 4.43. Found: C, 42.79; H, 4.35.

Sublimation of this substance gave back the original anhydride, m.p. 265–268°.

3-Carbethoxy-6-methyl-1,2,3,6-tetrahydrophthalic Anhydride.—The adduct from ethyl sorbate (6.0 g.) and maleic anhydride (3.5 g.), prepared in the same manner, weighed 4.6 g., m.p. 118–119° (from ether–ligroin).

Anal. Calcd. for $C_{12}H_{14}O_5$: C, 60.50; H, 5.88. Found: C, 60.78; H, 6.14.

Hydrolysis of the anhydride with boiling water gave an 80% yield of the corresponding acid melting at 143–146° (from ether–ligroin).

Anal. Calcd. for $C_{12}H_{16}O_6$: C, 55.85; H, 6.25. Found: C, 55.92; H, 6.51.

Ethyl 4-Phenoxysorbate (II).—Ethyl 6-bromosorbate (8.0 g.) was refluxed for 20 hours with 6.8 g. of phenol, 6.5 g. of potassium carbonate and 80 cc. of methyl ethyl ketone. The mixture was cooled, filtered and distilled to remove the excess solvent. The residue was diluted with cold benzene and was washed three times with 10% aqueous sodium hydroxide and then six times with Claisen alkali. The organic layer was washed with water, dried by distilling the benzene and distilled at 100–125° (2 mm.) from a molecular pot still. The colorless liquid distillate (2.5 g.) had the following constants: $n^{21}\text{D}$ 1.5512, d^{21}_{21} 1.103, $M\text{D}$ (found) 67.37, (calcd.) 66.47.

Anal. Calcd. for $C_{14}H_{16}O_3$: C, 72.39; H, 6.90. Found: C, 72.18; H, 6.92.

The Claisen alkali layer contained 0.9 g. of phenol and polymerized material which was non-volatile at 200° (2 mm.).

Ozonization of the pure phenoxy compound (110 mg.) at 0° in ethyl bromide (60 cc.) followed by reductive hydrolysis, steam distillation and treatment with methone yielded 110 mg. of acetaldimethone, melting point and mixed melting point with an authentic specimen 138–139° (from aqueous methanol).

3-Carbethoxy-5-phenoxy-6-methyl-1,2,3,6-tetrahydrophthalic Acid.—A mixture of ethyl 4-phenoxysorbate (2.0 g.) and maleic anhydride (0.8 g.) was heated to 150° for one minute. Upon cooling a viscous mass was obtained which crystallized after standing for two days. The material was refluxed with water for five minutes, filtered, washed several times with cold benzene and then with acetone. The remaining colorless solid melted at 273–276°, yield 0.25 g.

Anal. Calcd. for $C_{18}H_{28}O_7$: C, 62.07; H, 5.74. Found: C, 62.06; H, 5.57.

4-Phenoxysorbic Acid (III).—The hydrolysis of ethyl 4-phenoxysorbate (1.5 g.) was brought about by refluxing for two hours with 20% potassium hydroxide in 20% aqueous methanol. The alcohol was removed by distillation from a water-bath, the residue was acidified with hydrochloric acid and extracted with benzene. The extract was dried by distilling the benzene and the dry residue was sublimed from a molecular still at 165–175° (2 mm.). The liquid distillate (0.62 g.) failed to crystallize over a period of several months but did polymerize. The ultraviolet absorption spectrum of a fresh sample showed a maximum at 255 mμ (log ε 4.54).

Anal. Calcd. for $C_{12}H_{12}O_3$: C, 70.58; H, 5.88. Found: C, 70.63; H, 6.03.

3-Phenoxy-1,3-pentadiene (IV).—4-Phenoxysorbic acid (1.0 g.) was slowly heated with copper sulfate (2.2 g.) and quinoline (20 cc.) to 240°. The heating was continued for one hour. The mixture was cooled and filtered. The inorganic precipitate was extracted with ether. The filtrate was diluted with 50 cc. of benzene and the solution was washed several times with 6 *N* hydrochloric acid. The benzene solution was combined with the ether extract and distilled to remove the solvents. The residue was sublimed from a Washburn molecular still at 75–110° (2 mm.). The distillate (0.2 g.) was a pale yellow liquid.

Anal. Calcd. for $C_{11}H_{12}O$: C, 82.50; H, 7.50. Found: C, 82.21; H, 7.28.

Ozonolysis of 120 mg. of this substance in 60 cc. of ethyl bromide at 0°, followed by reductive hydrolysis, steam distillation and treatment of the distillate with methone, yielded 180 mg. of dimethone which was separated by fractional crystallization from ligroin, melting point and mixed melting point of acetaldimethone (90 mg.) 137–139° and melting point and mixed melting point of formaldimethone (75 mg.) 183–185°.

Ethyl 4-(*o*-Hydroxyphenyl)-sorbate (V).—Ethyl 6-bromosorbate (16.0 g.) was slowly added with stirring to a mixture of dry potassium phenolate (10.0 g.) and dry benzene (50 cc.). The mixture was refluxed for eight hours, cooled, filtered and extracted several times with Claisen alkali. The aqueous layer was acidified with hydrochloric acid and extracted with benzene. The extract was washed with water and was distilled to remove water and benzene. The residue was distilled at 120–150° (2 mm.) from a molecular pot still. Redistillation of the volatile substance (4.0 g.) yielded 3.2 g. of a pale yellow viscous liquid.

Anal. Calcd. for $C_{14}H_{16}O_3$: C, 72.38; H, 6.94. Found: C, 72.12; H, 6.90.

Ethyl 4-(*o*-Methoxyphenyl)-sorbate (VI).—The above phenol (2.0 g.), dissolved in 20 cc. of methanolic sodium methoxide containing 0.3 g. of sodium was treated with 4.0 g. of dimethyl sulfate. Most of the methanol was distilled off and residue was refluxed with 15 cc. of 10% aqueous potassium hydroxide for 15 minutes. The mixture was cooled and extracted with benzene. The organic layer was washed with Claisen alkali and water and distilled from a water-bath. The residue was sublimed from a molecular still at 100–120° (2 mm.). The colorless distillate weighed 0.9 g.

Anal. Calcd. for $C_{15}H_{18}O_3$: C, 73.17; H, 7.32. Found: C, 73.41; H, 7.21.

Ozonization of 110 mg. of this ester, reductive hydrolysis, steam distillation and reaction of the distillate with methone, gave 0.1 g. of acetaldimethone which melted at 138–139° (from aqueous methanol) and did not depress the melting point of an authentic specimen.

Ultraviolet absorption spectra of the compounds were determined in 95% ethyl alcohol in 0.001 molar solutions with a Beckman spectrophotometer.[9]

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