the lead tetraacetate, and the mixture was heated at 90° on a water-bath for 30 minutes. Carbon dioxide from the oxidation was swept out of the system with a slow stream of nitrogen gas and trapped in carbon dioxide-free sodium hydroxide. The residue in the reaction flask was cooled and neutralized with sodium hydroxide, and the formaldehyde, derived from the carbinol carbon, was distilled into an ice-cooled receiver. The formaldehyde was then oxidized to formic acid with sodium hypoiodite according to the procedure of Sakami[10] and the resulting formic acid steam distilled from the reaction mixture. This was then oxidized to carbon dioxide by mercuric chloride in glacial acetic acid as described by Pirie.[11]

The lactic acid was oxidized with acid permanganate according to the method of Wood, Lifson and Lorber.[12] The acetaldehyde was trapped in bisulfite solution and the carbon dioxide from the carboxyl carbon trapped in CO_2-free sodium hydroxide. A portion of the acetaldehyde–bisulfite complex was taken for formation of acetaldehyde 2,4-dinitrophenylhydrazone and the remainder was treated with sodium hypoiodite to give iodoform and formic acid. The formic acid was oxidized to carbon dioxide as described previously.[11]

Radioactivity Measurements.—The specific activities of the sugar and acid fractions were determined as negligible thickness plates by direct plating. All other compounds were determined by appropriate wet or dry combustion to carbon dioxide and counted as barium carbonate with correction for background and self-absorption in the conventional manner.

Results and Discussion

The identification of fructose and mannose, as well as glucose, in the interconversion products by means of chromatography and radioautography strongly suggested that the interaction of quaternary ammonium base type resin with glucose is similar to the base-catalyzed Lobry du Bruyn transformation and can be explained readily by the well established ene-diol mechanism.

The isotopic distribution patterns of glycolic and lactic acids isolated from the glucose degradation mixture are given in Table I.

TABLE I

DISTRIBUTION OF C^{14} IN GLYCOLIC AND LACTIC ACIDS FROM GLUCOSE-2-C^{14}

Compound	Specific activity, c.p.m. $\times 10^4$ per mM.	Total, %
Original glucose-2-C^{14}	2.71	100
Glycolic acid whole molecule	2.78	100
(1) COOH	1.45	52
(2) CH_2–OH	1.20	42
	1.33[a]	
Lactic acid whole molecule	1.22	100
(1) COOH	0.01	1
(2) CHOH	1.25	103
(3) CH_3	0	0

[a] By difference.

Since the specific activity of lactic acid is approximately one-half that of glucose, it is evident that glucose probably has undergone a C_3–C_3 split followed by the conversion of both C_3 units to lactic acid. This is further supported by the degradation studies which reveal that the labeling of lactic acid occurs exclusively in carbon atom 2. The finding is in line with the mechanism originally proposed by Evans[13] and subsequently modified by Gibbs[14] concerning the degradation of glucose by strong alkalies.

Although a relatively small amount of glycolic acid was formed in the glucose degradation process, the labeling pattern of this acid has revealed a rather interesting situation. The specific activity of this acid is practically the same as that of glucose, indicating the following possibilities: (1) that a C_2–C_4 cleavage of glucose has taken place with the C_2-unit, corresponding to glucose carbon atoms 1 and 2, in turn converted to glycolic acid; or (2) that a C_3–C_3 split of glucose has given rise to two unequivalent units with only one of these units degraded to the C_2-acid. Yet it seems probable that the latter mechanism is not involved, as suggested by the lactic acid data which demonstrate the practically complete equivalent of the C_3 units in the glucose degradation. Consequently, it appears that a C_2–C_4 cleavage of glucose was the initial step in the glycolic acid formation. The finding that both the carbon atoms were approximately equally labeled defined the nature of the C_2 compounds as symmetrical in structure and suggested that glycolic aldehyde may have been the intermediate compound which was randomized by way of the ene-diol mechanism and oxidized to glycolic acid by means of autoöxidation.

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[11] N. W. Pirie, *Biochem. J.*, **40**, 100 (1946).

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Two-stage Polymerizations. III. Infrared Evidence for the Course of Polymerization of Vinyl Ethers of Unsaturated Phenols[1]

BY GEORGE B. BUTLER

RECEIVED JULY 8, 1954

Previous work[2,3] has shown that compounds containing two or more double carbon-to-carbon linkages which vary considerably in their relative tendencies to form induced ions or free radicals can be made to undergo two-stage polymerizations. Allyl ethers of phenols containing unsaturated side chains were found to undergo polymerization through a cationic mechanism in which only the double bond of the allyl ether group was involved. The unsaturated side chains of these linear polymers could be made to enter into polymerization reactions only by thermal means. Vinyl ethers of unsaturated alcohols were found to produce linear polymers through the catalytic influence of boron trifluoride at relatively low temperatures. These linear polymers were subject to cross-linking through the catalytic effect of peroxide catalysts, as well as to copolymerization with other monomers to produce cross-linked materials. Due to the known reactivity of vinyl ethers toward polymerization by a cationic mechanism[4] it was assumed that

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[1] This material was presented in part before the Symposium on Second-Stage Cross Linking, High Polymer Division, American Chemical Society, Atlantic City, N. J., September, 1952.

[2] G. B. Butler and F. L. Ingley, THIS JOURNAL, **73**, 1512 (1951).

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[4] I. G. Farbenindustrie, A. G., German Patent 634,408 (August 26, 1936).

TABLE I

Ether of $CH_2{=}CHOCH_2CH_2O$–	n^{25}_D	d^{25}_4	MR_D Calcd.	MR_D Found	B.p., °C.	B.p., Mm.	Yield, %	Carbon, % Calcd.	Carbon, % Found	Hydrogen, % Calcd.	Hydrogen, % Found
Phenyl	1.5123	1.0353	47.60	47.56	91–92	4	21.0	73.20	73.10	7.32	7.43
2-Allylphenyl	1.5187	0.9878	61.00	62.65	102–104	2	38.0	76.47	76.98	7.84	8.11
2-Methallylphenyl	1.5335	0.9980	65.60	67.85	112	1	27.5	77.08	77.02	8.26	8.50
2-Allyl-4-chlorophenyl	1.5338	1.1010	65.95	67.40	121–122	1.5	23.5	65.46	65.17	6.29	6.61
2-Crotylphenyl	1.5207	0.9910	65.60	67.20	114–118	1.2	23.0	77.08	76.76	8.26	8.20

linear polymer formation through the cationic mechanism involved only the vinyloxy group, and that the isolated double bond remained intact, but was involved in the cross-linking reaction through the free radical mechanism.

This paper includes a study of vinyl ethers of phenols containing unsaturated side chains. These compounds were found to undergo polymerization at low temperature in presence of boron trifluoride to produce linear polymers subject to cross-linking with peroxide catalysts. It is reasonable to assume on the basis of previous work that linear polymer formation resulted from an ionic chain reaction of the vinyloxy double bond initiated by boron trifluoride, and that the unsaturated side chain remained intact and was involved only in the cross-linking step. However, additional evidence was obtained to support this assumption. The compounds prepared and characterized in this investigation showed an infrared absorption band[5] at 8.32 μ which has been attributed to the vinyloxy double bond. The characteristic bands at 6.08 and 6.18 μ for the carbon–carbon double bond also were present in the monomers. The linear polymers obtained through the cationic polymerization failed to show the absorption band at 8.32 μ, although the bands at 6.08 and 6.18 μ remained, however, somewhat less intense. These data show conclusively that the vinyloxy group is involved in the initial linear polymerization.

Experimental

Preparation of Intermediate Phenols.—2-Allylphenol, 2-methallylphenol, 2-allyl-4-chlorophenol and 2-crotylphenol were prepared by the Claisen rearrangement of allyl phenyl ether, methallyl phenyl ether, allyl 4-chlorophenyl ether and 3-phenoxybutene-1, respectively.

Preparation of Vinyloxyethyl Ethers of Phenols.—The following preparation of 1-vinyloxy-2-(2-allylphenoxy)-ethane will serve to illustrate the general procedure followed in preparation of these compounds: To 120 g. (0.9 mole) of 2-allylphenol was added 150 ml. of water in which approximately 1 g. of Santomerse D[6] had been dissolved. With stirring, a solution of 38 g. of sodium hydroxide in 200 ml. of water was added. Ninety-six grams (0.9 mole) of vinyl β-chloroethyl ether was added dropwise to the stirred solution at such a rate that gentle reflux was maintained. After the addition was complete, the solution was heated on a steam-bath for 18 hours. After cooling, the upper organic layer was separated, dried and fractionated. The yields and physical properties of these compounds are recorded in Table I.

Infrared spectra of these compounds gave characteristic absorption bands at 6.08, 6.18 and 8.32 μ indicative of the presence of carbon–carbon double bonds and the vinyloxy group.

Linear Polymerization of Vinyloxyethyl Phenyl Ethers.—Forty ml. of dry toluene and 4 ml. of $BF_3 \cdot O(C_2H_5)_2$ were placed in a three-necked, 200-ml. flask, equipped with a stirrer, drying tube filled with anhydrous potassium carbonate, addition funnel and low temperature thermometer. The flask was immersed in a Dry Ice–acetone bath until the temperature had dropped to −70°. Fifteen grams of 1-vinyloxy-2-(2-allylphenoxy)-ethane was added dropwise over a period of one hour. The temperature was maintained below −60° during the addition. The solution became very viscous. After addition was complete, stirring was continued at this temperature for two hours, after which it was allowed to warm up to −30° by removing the bath. When this temperature was reached, 10 ml. of 50% aqueous methanol was added to prevent the catalyst having any effect on the allyl side chain. When the solution had warmed to room temperature it was washed thoroughly with water, and the toluene evaporated under vacuum, leaving 14 g. of a viscous, pale yellow polymer, soluble in ketone and hydrocarbon solvents.

The other manomers were polymerized in a similar manner. Copolymers were prepared from various ratios of 1-vinyloxy-2-phenoxyethane and the other ethers listed in Table I, resulting in unsaturated polymers possessing different degrees of unsaturation.

Infrared spectra of these linear polymers gave the characteristic absorption bands at 6.08 and 6.18 μ showing the presence of the residual allyl double bond; however, the characteristic absorption band at 8.32 μ for the vinyloxy group was missing, showing conclusively that the double bond of the vinyloxy group was eliminated in the polymerization. Attempts to homopolymerize these compounds with peroxide catalysts were unsuccessful.

Copolymerization of Monomers with Maleic Anhydride.—The monomers were copolymerized with maleic anhydride in equivalent quantities, using approximately 0.5% benzoyl peroxide as catalyst, by heating in a steam-bath. The polymerizations were exothermic yielding cross-linked, insoluble copolymers from the derivatives of unsaturated phenols, and a linear, acetone-soluble copolymer from the derivative of phenol.

The acetone-soluble copolymer was found to be soluble in dilute aqueous sodium hydroxide. On making the solution acidic, the copolymer precipitated. The sodium salt, which was insoluble in 20% aqueous sodium hydroxide, was insoluble in acetone. This salt after being stirred with dilute hydrochloric acid to produce the free acid form of the copolymer was found to be soluble in acetone. *Anal.* Calcd. for $C_{14}H_{14}O_6Na_2$: Na, 14.19. Found: Na, 11.80.

A sample of the copolymer was dissolved in acetone, and the copolymer precipitated by pouring this solution into isopropyl ether. Both monomers are soluble in both solvents. After repeating this process, a sample was dried and submitted for analysis. *Anal.* Calcd. for $C_{14}H_{14}O_5$: C, 64.05; H, 5.34. Found: C, 64.41; H, 5.55.

A typical acetone-insoluble copolymer was washed thoroughly with acetone and water. It was treated with an excess of 20% aqueous sodium hydroxide on a steam-bath. The sodium salt was removed by filtration, washed thoroughly and dried. On treating with dilute hydrochloric acid, the free carboxylic acid form of the copolymer was regenerated, showing that the cross-linked copolymers are capable of functioning as ion exchange resins. *Anal.* (sodium salt). Calcd. for $C_{21}H_{20}O_{10}Na_4$: Na, 17.6. Found: Na, 12.2. *Anal.* (acid form). Calcd. for $C_{21}H_{24}O_{10}$: C, 57.8; H, 5.50. Found: C, 58.03; H, 5.74. These results prove conclusively that the allyl side chains enter into the free radical catalyzed polymerization to a sufficient extent to cross-link the copolymer.

Second-stage Polymerization and Copolymerization of Linear Polymers.—The linear polymers resulting from ionic polymerization of the vinyl ethers of unsaturated phenols, when heated at 100° for 24 hours with 0.5% each of benzoyl peroxide and 60% *t-butyl hydroperoxide* as catalyst resulted in formation of hard, insoluble polymers showing that the residual unsaturated linkages took part in the free radical catalyzed thermosetting of the polymer. Equivalent quantities of these linear polymers with maleic anhydride or styrene under the above catalytic conditions resulted in the

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(5) M. L. Van Natta, G. B. Butler and A. H. Gropp, unpublished results.

(6) A product of Monsanto Chemical Company.

formation of insoluble, cross-linked copolymers. The copolymerization with maleic anhydride was rapid and quite exothermic.

Discussion of Results.—The infrared absorption data presented in this paper is the first conclusive evidence that these two-stage polymerizations proceed through a course involving only the vinyloxy group in the first stage, and the resulting linear polymer, which possesses the allyl-type double bond, is then cross-linked or thermoset through this system. Previous evidence was based on the known preferential reactivity of vinyloxy compounds toward cationic reagents, and the failure of this group, when present as the only unsaturated system in the compound, to lend itself to free radical catalyzed polymerization. The absence of the 8.32-μ band and the pronounced diminished intensity of the 6.08–6.18 μ region in the polymers represents quite a marked change in absorption.

The linear copolymers resulting from cationic catalyzed copolymerization of compounds described in this paper with vinyl alkyl ethers, and subsequent cross-linking with free radical producing catalysts, either alone or through copolymerization with other monomers, suggests their use in coatings, elastomers or castings. The pronounced reactivity of the unsaturated linear polymers with maleic anhydride suggests the use of maleic anhydride as a cross-linking agent or vulcanizing agent for other unsaturated polymers of the hydrocarbon type, such as polybutadiene, polycyclopentadiene, the copolymer of styrene and butadiene, or natural rubber latex.

Acknowledgment.—The author is indebted to Miss Mary L. Van Natta and Dr. A. H. Gropp of this department for the infrared curves used in this investigation.

GAINESVILLE, FLORIDA

Alkaloid Studies. V.[1] Synthesis of 1-Isopropyl and 1-Isobutyl-2-methyl-6,7-dimethoxy-1,2,3,4-tetrahydroisoquinoline

BY CARL DJERASSI, J. J. BEEREBOOM,[2a] S. P. MARFEY AND S. K. FIGDOR[2b]

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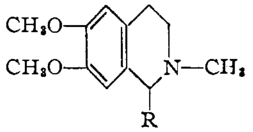
In connection with the characterization of certain cactus alkaloid degradation products, it was necessary to have available for comparison the previously unknown 1-isobutyl-2-methyl-6,7-dimethoxy-1,2,3,4-tetrahydroisoquinoline (I) and to know the composition of the acids arising from the oxidation of this substance.

N-Isovaleryl homoveratryl amide was subjected to the conventional Bischler–Napieralski reaction[3] using phosphorus pentoxide[4] as the cyclization agent. The resulting 1-isobutyl-6,7-dimethoxy-3,4-dihydroisoquinoline, obtained in 90% yield, was converted to the methiodide and reduced with sodium borohydride[5] to furnish the desired tetrahydroisoquinoline (I) in 85% yield The homogeneity of the product was demonstrated by chromatography and preparation of solid derivatives from the various eluates; the alternate cyclization structure (1-isobutyl-2-methyl-7,8-dimethoxy-1,2,-3,4-tetrahydroisoquinoline) was excluded by permanganate oxidation to N-methyl-3,4-dimethoxyphthalimide[6] (N-methyl imide of *m*-hemipinic acid) and direct comparison with an authentic sample[7] of the derived dimethyl ester.

Of particular interest for our purposes was the identification of the volatile "stench acids" produced in the oxidation As demonstrated first by paper chromatography and subsequently by actual isolation of the anilides, the main product isobutyric acid always was accompanied by a small amount of isovaleric acid arising from ring opening.

For reference purposes, the above sequence of steps was carried out also with N-isobutyryl homoveratryl amide leading ultimately to 1-isopropyl-2-methyl-6,7-dimethoxy-1,2,3,4-tetrahydroisoquinoline (II)



I, R = $CH_2CH(CH_3)_2$
II, R = $CH(CH_3)_2$

Acknowledgment.—We are indebted to the American Heart Association for financial assistance which enabled S.K.F. to participate in this investigation as a postdoctorate fellow.

Experimental[8]

1-Isobutyl-2-methyl-6,7-dimethoxy-1,2,3,4-tetrahydroisoquinoline (I).—Homoveratrylamine[9] was treated with isovaleryl chloride in benzene solution to yield the corresponding **amide** in 88% yield, m.p. 64–65.5°.

Anal. Calcd. for $C_{15}H_{23}NO_3$: C, 67.89; H, 8.74. Found: C, 67.75; H, 8.97.

Phosphorus pentoxide (50 g.) was added rapidly to a solution of 20 g. of the amide in 300 cc. of dry toluene and the mixture was refluxed for 15 minutes. An additional 30 g. of the pentoxide was added and refluxing was continued for 1 hour. The excess reagent was decomposed by the cautious addition of water and the resulting **1-isobutyl-6,7-dimethoxy-3,4-dihydroisoquinoline** isolated in the conventional manner, was distilled; yield 17 g., b.p. 136–139° at 1.2 mm., $n^{25}D$ 1.5536.

Anal. Calcd. for $C_{15}H_{21}NO_2$: C, 72.84; H, 8.56. Found: C, 73.15; H, 8.45.

The corresponding **methiodide** (prepared in benzene solution) was obtained in 96% yield after recrystallization from methanol–ether, m.p. 202–204°.

Anal. Calcd. for $C_{16}H_{24}NIO_2$: C, 49.36; H, 6.21. Found: C, 49.42; H, 6.15.

The above methiodide (12.2 g.) in 400 cc. of methanol was refluxed for one hour with 7 g. of sodium borohydride and then concentrated to near dryness. After addition of 10% hydrochloric acid, the solution was made basic with potassium hydroxide and extracted with ether. Evaporation of the ether and distillation of the residue furnished 7.2

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[6] R. A. Labriola, V. Deulofeu and B. Berinzaghi (*J. Org. Chem.*, **16**, 90 (1951)) isolated this imide directly in the permanganate oxidation of erysotrine methohydroxide.

[7] H. Richtzenhain, *Acta. Chem. Scand.*, **4**, 206 (1950). We are indebted to Dr. Richtzenhain for sending us a sample of this substance.

[8] Melting points are uncorrected. The microanalyses were carried out by Miss Phyllis Tocco and Mr. Robert French.

[9] We are indebted to Dr. F. B. Zienty, Monsanto Chemical Company, St. Louis, Mo., for a supply of this amine.