[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY OF THE UNIVERSITY OF CALIFORNIA AT LOS ANGELES]

Neighboring Groups in Addition. II. Hydroxyl and Acetoxy Groups in Allyl Derivatives[1,2]

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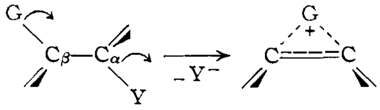
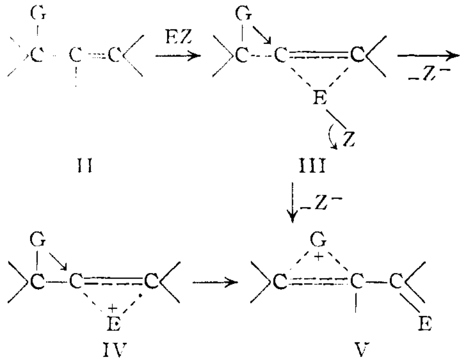
Participation of neighboring groups in the process of addition of an electrophilic reagent to the carbon–carbon double bond is analogous to similar participation in substitution. Just as in substitution, neighboring group intervention in the addition process competes with participation of solvent or added solutes. Groups with the largest driving forces in substitution can be expected to compete the best for involvement in addition reactions. Orienting studies of halogen addition to allyl alcohol and allyl acetate show that no appreciable participation of the primary hydroxyl and acetoxy groups occurs in the respective addition reactions. Under the conditions which are shown to permit survival of the expected epihalohydrins or orthoesters, no products from participation have been obtained. These observations help to delimit the scope of the contemplated phenomenon of participation of groups in addition reactions.

Participation of a neighboring group G in nucleophilic displacement processes (I) is a general phenomenon.[2,3] G may be a functional group (*e.g.*, Br, OAc, etc.), a carbon substituent (*e.g.*, R, aryl) or hydrogen. This phenomenon may control stereochemistry and rate of reaction, the driving forces due to this kind of participation often being of an important order of magnitude.

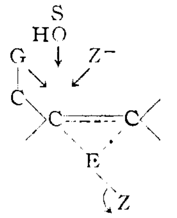


I

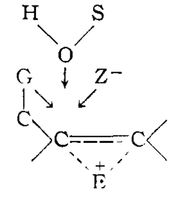
In the above phenomenon, the neighboring group G, with its associated electron cloud, assists in the toleration of electron-deficiency created by ionization of Y (I). It is obvious that similar participation by neighboring groups should be induced by other means of producing electron-deficiency, for example, attack of an electrophilic agent EZ on an olefinic linkage. Without attempting here to exhaust the possible mechanistic variations, we can illustrate mechanisms for the intervention of neighboring groups in processes of addition to multiple carbon–carbon linkages with those involving formation from II of III, an olefin–EZ complex, which gives the G-bridged structure V either directly or by way of the E-bridged structure[4] IV. Examples of IV are bromonium ions in bromium addition[5] or the mercurinium ions in mercuration[6] of olefins.



Just as in substitution, neighboring group participation competes with participation by solvent or added solutes, so here the neighboring group competes with solvent molecules (SOH) or solutes such as Z^- for attack on carbon. In VI is symbolized the competition in which the process III → V is involved, and in VII is shown the competition in which IV → V is involved.



VI



VII

Thus neighboring group participation may be submerged in competition with other available processes for reaction of olefins with reagents EZ.

The literature contains many reports of formation of cyclic products from olefinic materials. For example, the formation of heterocyclic products from bromination[7] or mercuration[8] of *o*-allylphenol and the mercuration[9] of 1-penten-4-ol may represent pertinent cases of hydroxyl participation. However, in the great majority of available possible examples of neighboring group participation in addition processes, it is not clear to what extent the heterocyclic material is a primary product and not derived from conversion of a normal addition

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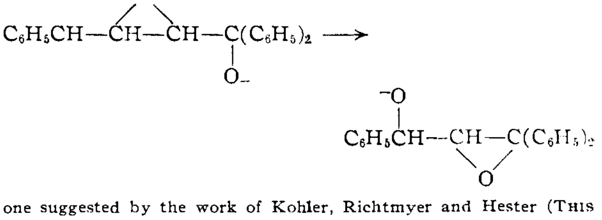
(1) Paper I. S. Winstein, L. Goodman and R. Boschan, THIS JOURNAL, **72**, 2311 (1950).

(2) Some of the material of this paper was presented in summary: (a) before the Organic Division of the American Chemical Society at St. Louis, September, 1948; (b) in Abstracts of Eleventh National Organic Symposium, 1949, page 65.

(3) S. Winstein, *Bull. soc. chim.*, [5] **18**, 55C (1951).

(4) There are classical analogs of the process IV → V, for example the



one suggested by the work of Kohler, Richtmyer and Hester (THIS JOURNAL, **53**, 205 (1931)).

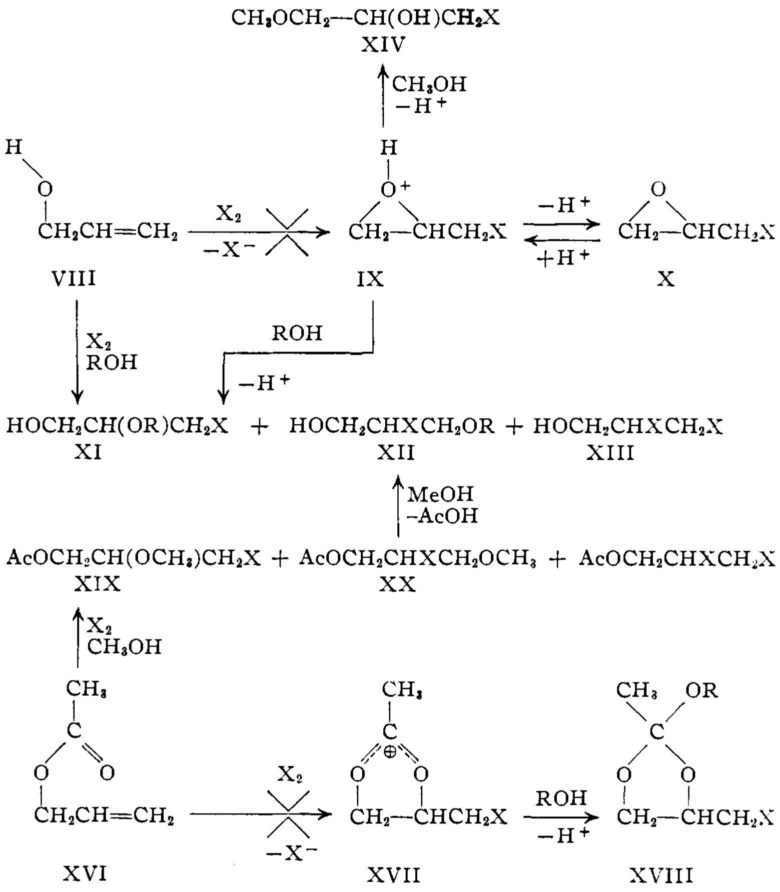
(5) (a) I. Roberts and G. E. Kimball, *ibid.*, **59**, 947 (1937); (b) S. Winstein and H. J. Lucas, *ibid.*, **61**, 1576 (1939).

(6) H. J. Lucas, F. R. Hepner and S. Winstein, *ibid.*, **61**, 3102 (1939).

(7) R. Adams and R. E. Rindfusz, *ibid.*, **41**, 648 (1919).

(8) R. Adams, F. L. Roman and W. N. Sperry, *ibid.*, **44**, 1781 (1922).

(9) A. N. Nesmeyanov and I. F. Lutsenko, *Bull. acad. sci.* (*U.S.S.R*), *classe sci. chim.*, 296 (1943); *C. A.*, **38**, 5498 (1944).



product subsequent to its formation. This is not the case for the classical example of carboxylate ion-group involvement of Tarbell and Bartlett,[10] who showed that the halo-β-lactone is the primary product from halogenation of sodium dimethyl maleate or dimethyl fumarate.

We have carried out several orienting studies on the occurrence of neighboring group participation in halogen addition to the olefinic linkage and these are reported in this series of papers. The search for participation in the unfavorable simple cases of addition to allyl alcohol and allyl acetate is reported in the present article.

Participation of hydroxyl in the process of halogen addition to allyl alcohol VIII would be expected to give rise to epihalohydrin X, by way of the intermediate IX under conditions which permit survival of the epoxide. Reaction without participation can give rise to the various products of addition symbolized by XI, XII and XIII. In the present studies, chlorine and bromine were added to aqueous allyl alcohol VIII in the presence of sodium bicarbonate and the ether extracts, which would include any epihalohydrin X and dihalide XIII were examined. Under these reaction conditions, a control experiment showed epibromohydrin X to be recoverable to the extent of 83%. The chlorination reaction gave no material boiling in the epichlorohydrin range and the bromination reaction gave only several drops of material in the boiling range for epibromohydrin. Similarly, the addition of bromine to allyl alcohol in an aqueous suspension of silver oxide yielded no appreciable amount of epibromohydrin.

The products of the addition of chlorine to allyl alcohol in anhydrous methanol, in the presence of silver acetate to remove chloride ion, were more fully examined. Careful distillation gave less than 1% of material in the proper boiling range for epichlorohydrin X, and even this fraction possessed much too low a refractive index. The main product apparently contained the isomers XI and XII, not easily separated by fractionation. The distillation fractions differ in reactivity toward base, the lower-boiling ones consuming more alkali, the higher boiling ones, very little. The product is apparently predominantly the 1,3-halohydrin (XI, R = CH_3, X = Cl) together with some 1,2-halohydrin (XII, R = CH_3, X = Cl). From 2 different fractions, 3,5-dinitrobenzoates were obtained, one, m.p. 69–72.5°, related to XI, the other, m.p. 56–59°, related to XII. For comparison, the third isomeric chloromethoxypropanol, 1-chloro-3-methoxy-2-propanol (XIV), was prepared by acid-catalyzed opening of epichlorohydrin with methanol. This opening[11] gives very predominately the secondary alcohol XIV, but clearly a little primary alcohol XI (CH_3, X = Cl) is also formed. Fractionation gave a large fraction of material with the correct equivalent weight toward base for a 1,2-halohydrin; however, the higher boiling fractions showed very much decreased base consumption The third isomer XIV yielded a 3,5-dinitrobenzoate, m.p. 74–75°, nearly the same as that of the derivative from XI (R = CH_3, X = Cl), but the melting point of the mixture was depressed.

The use of N-bromosuccinimide as a positive bromine source with allyl alcohol in methanol also appeared to yield a mixture predominantly XI (R = CH_3, X = Br). The higher boiling fractions consumed only small amounts of base in the titration procedure, consisting mainly of the 1,3-halohydrin XI.

Participation of the acetoxy group in the process of addition of halogen to allyl acetate XVI would give rise to the intermediate XVII. From what is known regarding the behavior of such intermediates,[2,12] we can expect XVII to yield orthoester XVIII in anhydrous alcoholic solution. For example, solvolysis of *trans*-2-acetoxycyclohexyl *p*-toluenesulfonate in absolute ethanol yields *cis*-cyclohexene ethyl orthoacetate.[12] To study their ability to survive the reaction conditions employed

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[10] D. S. Tarbell and P. D. Bartlett, THIS JOURNAL, 59, 407 (1937).

[11] S. Winstein and R. B. Henderson, "Ethylene and Trimethylene Oxides," in R. C. Elderfield, "Heterocyclic Chemistry," John Wiley and Sons, Inc., New York, N. Y., 1950.

[12] S. Winstein and R. E. Buckles, THIS JOURNAL, 65, 613 (1943).

for halogen addition to allyl acetate, three orthoesters XVIII were prepared by the acid-catalyzed exchange reaction employed previously[12] in the preparation of the cyclohexene ethyl orthoacetates. The glycerol α-monochlorohydrin or α-monobromohydrin was treated with either methyl or ethyl orthoacetate, the information on the products being summarized in Table I. All three of the orthoesters prepared were water-insoluble compounds with a distinct camphoraceous odor, which dissolved instantly in water on addition of a trace of mineral acid. Control experiments showed that the chloro-orthoester XVIII ($R = CH_3$, $X = Cl$) would survive the conditions employed for chlorine addition to allyl acetate in methanol and working up the product. Similarly, the bromo-orthoester XVIII ($R = CH_3$, $X = Br$) was recoverable from a methanolic solution containing silver acetate and acetic acid when care was taken, in the working-up procedure, to neutralize not only the acetic acid originally present but also a little which is generated from reaction of the bromo-orthoester in the medium.

TABLE I

PROPERTIES OF ORTHOESTERS XVIII

R X	C_2H_5 Cl	CH_3 Cl	CH_3 Br
B.p., °C. (mm.)	85.8–87.0 (15.2–15.6)	79.0–79.8 (15.1)	89.2–89.7 (15.0)
d^{25}_4	1.1332	1.1839	1.4625
$n^{25}\text{D}$	1.4367	1.4385	1.4620
MR_D	41.74	36.96	39.68
MR_D (calcd.)	42.12	37.50	40.40
C, %, H, % (found)	46.56, 7.38	43.17, 6.73	34.15, 5.57
C, %, H, % (calcd.)	46.54, 7.25	43.25, 6.67	34.14, 5.25
Yield, %	64–75	68	57–76

The addition of chlorine to a methanolic solution of allyl acetate containing suspended silver acetate gave a mixture boiling over a wide range, but none of the fractions appeared to contain the orthoester XVIII ($R = CH_3$, $X = Cl$). The composition and properties of the major product were consistent with a mixture of isomers XIX and XX ($X = Cl$). Transesterification of this product by heating in methanol with a catalytic amount of sodium methylate gave a mixture whose properties resembled that of the mixture of chloromethoxypropanols XI and XII obtained by the action of chlorine on methanolic allyl alcohol. Preparation of the 3,5-dinitrobenzoate from one of the fractions gave the derivative of 2-chloro-3-methoxy-1-propanol (XII). The results of bromine addition to methanolic allyl acetate were analogous to those for chlorine addition, no bromo-orthoester XVIII ($R = CH_3$, $X = Br$) being obtained.

The failure of the neighboring hydroxyl and acetoxy groups to participate in the process of halogen addition to allyl alcohol and acetate is helpful in outlining the scope of such participation. This is especially true if the present results are taken in conjunction with those described in the following papers for cases more favorable to such involvement of the neighboring group. In general, there should be considerable correlation between the incidence of neighboring group participation in addition processes and the size of the driving forces due to participation of the same neighboring groups in substitution. Groups with the largest driving forces in substitution can be expected to compete the best for involvement in addition reactions. From this point of view, the fact that the hydroxyl group in allyl alcohol is primary[13] makes it less likely to compete than a tertiary hydroxyl group, whose more favorable competition is described in the following paper.

The present results are of some interest in connection with the direction of addition of electrophilic reagents to unsymmetrical olefins. The formation of mixtures of Markownikow (XI, XIX) and non-Markownikow (XII, XX) addition products from the action of chlorine and bromine on methanolic allyl alcohol and allyl acetate in the present work parallels the results obtained by Smith[14] in aqueous solution.

Experimental Part

All melting and boiling points are uncorrected.

Equivalent Weight Determination of Halohydrins.—To a weighed sample of halohydrin, 0.1–0.6 g., was added 20 ml. of methanol. Three drops each of phenolphthalein and brom thymol blue indicator solutions were added. An excess of standard base (usually 75–150% excess) was added, and the solution allowed to stand, with occasional shaking, for a definite period of time (15 min. was sufficient for all the 1,2-halohydrins encountered in this work). An excess of standard sulfuric acid was added and the solution was brought to the end-point with standard base. A blank was always run on the methanol. This method gave results within 0.5% for a sample of glycerol α-monochlorohydrin prepared by opening epichlorohydrin with water. Frequently the time the solution was allowed to stand with excess base was varied and the dependence of the equivalent weight on this time was noted. Trimethylene chlorohydrin, a redistilled Eastman white label product, b.p. 75.0–76.5° (30 mm.), consumed less than 2% of the base calculated for conversion to trimethylene oxide and this amount did not change whether the compound was left with excess base 8 or 25 minutes.

Addition of Bromine to Aqueous Allyl Alcohol.—Allyl alcohol, 43.5 g. (0.75 mole), was dissolved in 750 ml. of water containing sodium bicarbonate, 67 g. (0.80 mole). Bromine, 120 g. (0.75 mole), was added to this stirred solution, cooled to 0°, over a two-hour period. At the end of this period 2 g. of allyl alcohol was added to decolorize the solution. The final solution was neutral to litmus. The solution was extracted with four 150-ml. portions of ether and the extract was dried over potassium carbonate. The ether was distilled through a 12-inch center-rod column and the residue was fractionated through the same column to give the following fractions: (1) 2 drops, b.p. 23–78° (50 mm.) (reported[15] for epibromohydrin, b.p. 61–62° (50 mm.)); (2) 2.45 g., b.p. 62–64° (15 mm.), $n^{25}\text{D}$ 1.4280 (reported[16] for L-glycidol, b.p. 56–56.5° (11 mm.), $n^{16}\text{D}$ 1.4293); (3) 1.06 g., b.p. 65–104° (15 mm.), $n^{25}\text{D}$ 1.4530; (4) 0.60 g., b.p. 104–104.5° (15 mm.), $n^{25}\text{D}$ 1.5190; (5) 33.36 g., b.p. 105.8–107.0 (15 mm.), $n^{25}\text{D}$ 1.5542 (reported[17] for allyl alcohol dibromide, b.p. 101° (12 mm.), $n^{25}\text{D}$ 1.5577); (6) 10.20 g., b.p. 97–98° (10 mm.); $n^{25}\text{D}$ 1.5530. Considering fractions 5 and 6 as allyl alcohol dibromide, the yield of this material was 26%.

To verify the stability of epibromohydrin toward the reaction conditions, a solution was prepared from 22.5 g. (0.27 mole) of sodium bicarbonate, 26 g. (0.25 mole) of sodium bromide and 750 ml. of water. This was cooled to 0°

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(13) S. Winstein and E. Grunwald, THIS JOURNAL, **70**, 828 (1948).

(14) L. Smith and J. Laudon, *Ber.*, **66B**, 899 (1933).

(15) "Organic Syntheses," Coll. Vol. II, John Wiley and Sons, Inc., New York, N. Y., 1943, p. 257.

(16) J. C. Sowden and H. O. L. Fischer, THIS JOURNAL, **64**, 1291 (1942).

(17) (a) M. O. Forster and J. C. Withers, *J. Chem. Soc.*, **101**, 496 (1912); (b) J. C. Philip, *ibid.*, **101**, 1868 (1912).

and 64.5 g. (0.47 mole) of redistilled epibromohydrin (Eastman white label, b.p. 57–59.2° (50 mm.)) was added. The resulting mixture was stirred for 1.5 hours and then worked up as in the above case of bromine addition to allyl alcohol. Distillation yielded 53.5 g. (83%) recovery of epibromohydrin, b.p. 57–60° (50 mm.).

A well-stirred suspension of 70 g. (0.30 mole) of silver oxide in a mixture of 29 g. (0.50 mole) of allyl alcohol and 750 ml. of water was cooled to 0°, and 80 g. (0.50 mole) of bromine was added over a 1.5-hour period. The solution was filtered, the weight of recovered solid indicating complete conversion of 0.25 mole of silver oxide to bromide. The solution was extracted with four 100-ml. portions of ether, the ether extract was dried, and then it was distilled. No fraction in the boiling range for epibromohydrin was observed, but 9 g. of material, b.p. 49–90° (15 mm.), was obtained and not investigated further.

Vacuum distillation of the water solution remaining after ether extraction gave 13.4 g. of material, b.p. 94–98° (5 mm.), n^{25}D 1.5150, and 38.4 g. of material, b.p. 101–104° (5 mm.), n^{25}D 1.5167, found in this work (see later Experimental section), b.p. 106–110° (4 mm.) n^{25}D 1.5133–1.5144; (reported for glycerol α-monobromohydrin,[18] b.p. 90° (0.8 mm.), n^{20}D 1.5191; for glycerol β-monobromohydrin,[14] b.p. 106° (6 mm.), n^{25}D 1.5228).

Action of N-Bromosuccinimide (NBS) on Methanolic Allyl Alcohol.—A 29-g. (0.50 mole) quantity of allyl alcohol was added with stirring to a suspension of 89 g. (0.50 mole) of recrystallized NBS in 280 ml. of anhydrous methanol. Then a solution of 0.35 g. of concd. sulfuric acid in 35 ml. of methanol was added, the temperature slowly rising about 25°, the NBS dissolving. When the spontaneous reaction ceased the solution was maintained at 55° for 2 hours. The acid was neutralized with calcium carbonate, and the methanol was distilled through a 12-inch center-rod column until the pot temperature reached 95°. About 70 ml. of water was added, and the solution was continuously extracted, first with pet. ether, b.p. 35–41°, then with ether. The combined extracts were dried and distilled through a 65-plate column, to give a 73% yield (including some material recovered from the trap) of distillate, calculated as bromomethoxypropanol. The product was thermally unstable and long distillation gave a large, tarry residue. The fractions collected were: (1)–(6), 28.2 g., b.p. 88–94° (12.0–12.7 mm.), n^{25}D 1.4767–1.4820; (7) 2.6 g., b.p. 94.3° (12.7 mm.), n^{25}D 1.4822; (8) 8.1 g., b.p. 94.3° (12.7 mm.), n^{25}D 1.4822, d^{25}_4 1.5425, MRD 31.25 (calcd. for 2-methoxy-3-bromo-1-propanol, 31.61); (9) and (10), 13.0 g., b.p. 94° (12.7 mm.), n^{25}D 1.4822; (11) 2.3 g., b.p. 93° (12.7 mm.), n^{25}D 1.4854. The equivalent wt. toward base of fraction 8 was 9400 (10 min.) and 8620 (60 min.). Fraction 8 yielded an α-naphthylurethan, m.p. 67–69° after several recrystallizations.

Anal. Calcd. for $C_{13}H_{16}O_3NBr$: C, 53.27; H, 4.77. Found: C, 53.58; H, 4.65.

Redistillation of fractions 7–10 gave, as a main cut, material, b.p. 93.6° (12 mm.), n^{25}D 1.4819.

Anal. Calcd. for $C_4H_9O_2Br$: C, 28.42; H, 5.37. Found: C, 28.29; H, 5.46.

Addition of Chlorine to Allyl Alcohol Solutions.—Chlorine, 35.5 g. (0.50 mole), generated by the method of Fieser,[19] was added over a period of 1.7 hours to a mixture of 29.4 g. (0.50 mole) of allyl alcohol, 45 g. (0.54 mole) of sodium bicarbonate and 750 ml. of water, stirred at 0°. Working up as in the case of the analogous bromination and distillation of the ether extract gave a 0.78 g. of lachrymatory forerun, b.p. 40–48° (100 mm.) (reported[20] for epichlorohydrin, b.p. 60–61° (100 mm.)), and a 1.99-g. fraction, b.p. 76–84° (15 mm.) (reported for allyl alcohol dichloride,[21] b.p. 81–81.5° (13.5 mm.)).

To a mixture of 29 g. (0.50 mole) of allyl alcohol, 125 g. (0.75 mole) of dry silver acetate and 650 ml. of anhydrous methanol, cooled to 0°, was added 35.5 g. (0.50 mole) of chlorine over a period of 3 hours. The solution was filtered and the filtrate was neutralized with 262.2 ml. of 1.564 *N* dry sodium methylate solution, the amount determined necessary by titration of an aliquot of the reaction mixture. The methanol was distilled through a 12-inch center-rod column until the distillation flask contained *ca.* 150 ml. of solution. A liter of dry ether was added to precipitate salts and the resulting mixture was filtered. The ether and methanol were distilled through the above column and the residue was fractionated to yield the fractions: (1) and (2) 0.8 g., b.p. 43–65° (99 mm.), n^{25}D 1.3890–1.3945; (3) 0.86 g., b.p. 75–82° (15 mm.), n^{25}D 1.4371; (4) 3.73 g., b.p. 82–83° (15 mm.), n^{25}D 1.4492; (5) 7.55 g., b.p. 83–83.5° (15 mm.), n^{25}D 1.4505, equivalent wt. toward base, 616 (8 min.), 364 (16 min.), 291 (25 min.), 226 (60 min.), 3,5-dinitrobenzoate, m.p. 56–59°, d^{25}_4 1.1870, MRD 28.23 (calcd. for chloromethoxypropanol, 28.71); (6)–(9), 22.6 g., b.p. 83.2–86.8 (15 mm.), n^{25}D 1.4508 ± 0.0002; (10) 4.04 g., b.p. 88–90° (15 mm.), n^{25}D 1.4490; (11) 1.85 g., b.p. 90–95° (15 mm.), n^{25}D 1.4489, equiv. wt., 2580 (8 min.), 2010 (25 min.) (reported[22] for 2-methoxy-3-chloropropanol-1, b.p. 68–69° (5 mm.), n^{20}D 1.4535); (12) and (13), 2.4 g., b.p. 100–126° (15 mm.), n^{25}D 1.4500–1.4615. Considering fractions 4–11 as chloromethoxypropanol, the yield was 64%.

Fraction 10 yielded a 3,5-dinitrobenzoate, m.p. 69–72.5°. This derivative was prepared conventionally, using dry triethylamine and 3,5-dinitrobenzoyl chloride, and the derivative was recrystallized from Skellysolve B.

Anal. Calcd. for $C_{11}H_{11}N_2O_7Cl$: C, 41.46; H, 3.48. Found: C, 41.07; H, 3.63.

Acid-catalyzed Opening of Epichlorohydrin with Methanol.—A mixture of 1.5 g. of concd. sulfuric acid, 180 g. of dry methanol and 46.2 g. (0.50 mole) of epichlorohydrin, b.p. 114.5°, was held under reflux 3 hours. Then it was neutralized with 36.5 ml. of 0.825 *N* methanolic sodium methylate. The excess methanol was distilled through a 12-inch center-rod column, salts were filtered out, and then vacuum fractionation yielded the fractions: (1) and (2), 1.2 g., b.p. 29–82° (30 mm.), n^{25}D 1.4310–1.4397; (3) 1.2 g., b.p. 82–83.2° (30 mm.), n^{25}D 1.4422; (4), 12.5 g., b.p. 83.0–83.6° (30 mm.), n^{25}D 1.4444; (5), 27.4 g., b.p. 83.5–84.0 (30 mm.), n^{25}D 1.4442, d^{25}_4 1.1595, MRD 28.54 (calcd. 28.71), equiv. wt. 126.1 (8 min.), 126.0 (16 min.) (reported[23] for 1-chloro-3-methoxy-2-propanol, b.p. 76.5° (20 mm.), n^{25}D 1.4422, d^{25}_4 1.1570); (6) 4.20 g., b.p. 84.0–84.2° (30 mm.), n^{25}D 1.4445; (7) and (8) 3.0 g., b.p. 86–91° (30 mm.), n^{25}D 1.4450, equiv. wt. 141 (8 min.); (9) 1.13 g., b.p. 92–97° (30 mm.), n^{25}D 1.4470, equiv. wt. 235 (8 min.); (10) 1.78 g., b.p. 101–119° (30 mm.), n^{25}D 1.4569. Considering fractions 2–9 as chloromethoxypropanol, the yield was 81%. Fraction 5 yielded a 3,5-dinitrobenzoate, m.p. 74–75°.

Anal. Calcd. for $C_{11}H_{11}N_2O_7Cl$: C, 41.46; H, 3.48. Found: C, 41.16; H, 3.79.

A mixed m.p. between this 3,5-dinitrobenzoate and the one, m.p. 69–72.5°, from the product of addition of chlorine to methanolic allyl alcohol was 59–67°.

Glycerol α-Monohalohydrins.—Refluxing a mixture of 50 g. of epichlorohydrin, b.p. 114.5°, 50 ml. of water and 0.1 g. of *p*-toluenesulfonic acid for 7 hours, neutralization of the acid with sodium bicarbonate and distillation yielded 47.1 g. (72%) of α-monochlorohydrin, b.p. 113–114.6° (10 mm.), n^{25}D 1.4778–1.4780, d^{25}_4 1.3163, MRD 23.76 (calcd. 23.97) (reported[18] b.p. 83° (1 mm.), n^{20}D 1.4809, d^{20} 1.3209).

Similar treatment of epibromohydrin, b.p. 57–60° (50 mm.), gave a 64.5% yield of α-monobromohydrin, b.p. 106–110° (4 mm.), n^{25}D 1.5133–1.5144, d^{25}_4 1.7591 (for sample with n^{25}D 1.5133), MRD 26.51 (calcd. 26.87) (reported[18] b.p. 90° (0.8 mm.), n^{20}D 1.5191, d^{20} 1.770).

Preparation of Orthoesters.—A few crystals of *p*-toluenesulfonic acid were added to an equimolar mixture of the glycol and either methyl or ethyl orthoacetate. The mixture was heated under a 12-inch center-rod column until *ca.* 90% of the theoretical amount of methanol or ethanol distilled over. Then the acid catalyst was neutralized with calcium carbonate and the orthoesters were isolated by fractionation (Table I).

Addition of Chlorine to Methanolic Allyl Acetate.—With stirring at 0°, 14.2 g. (0.20 mole) of chlorine was passed over

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(18) B. Sjöberg, *Svensk. Kem. Tid.*, **53**, 390 (1941); *C. A.*, **36**, 2812 (1942).

(19) L. F. Fieser, "Experiments in Organic Chemistry," 2nd Ed., D. C. Heath and Co., Boston, Mass., 1942, p. 392.

(20) A. Fairbourne, G. P. Gibson and D. W. Stephens, *J. Chem. Soc.*, 1965 (1932).

(21) J. Read and E. Hurst, *ibid.*, **121**, 989 (1922).

(22) B. L. Emling, R. R. Vogt and G. F. Hennion, THIS JOURNAL, **63**, 1624 (1941).

(23) A. Flores-Gallardo and C. B. Pollard, *J. Org. Chem.*, **12**, 831 (1947).

a 1.5-hour period into a mixture of 67 g. (0.40 mole) of dry silver acetate, 20 g. (0.20 mole) of allyl acetate and 650 ml. of dry methanol. The solution was filtered and the solid well-washed with dry ether. The methanol and ether were distilled through a center-rod column. Several filtrations were required to remove silver salts which appeared on concentration. The acetic acid was distilled at 55 mm. and fractionation of the residue gave the following fractions, none of which possessed the characteristic orthoester odor: (1)–(4) 4.90 g., b.p. 86.5–90.8° (15 mm.), n^{25}D 1.4380–1.4350; (5) 6.85 g., b.p. 91–92.2° (15 mm.), n^{25}D 1.4340, d^{25}_4 1.1448, *MR*D 37.90 (calcd. for chloromethoxypropyl acetate, 38.09); (6)–(8), 5.89 g., b.p. 92.2–95° (15 mm.), n^{25}D 1.4345–1.4354. Fractions 1–8 represent a 54.5% yield, calculated as chloromethoxypropyl acetate.

Anal. Calcd. for $C_6H_{11}O_3Cl$: C, 43.25; H, 6.67. Found for fraction 5: C, 42.88; H, 6.78.

A 12.9-g. quantity of mixed fractions 1–8 was added to a solution of 3 drops of 1.14 *N* sodium methylate solution in 10 ml. of dry methanol. The mixture was distilled at high reflux ratio, the distillate coming over at 60–63°. A 90-ml. quantity of methanol and 3 drops of the sodium methylate solution was added and the methanol was distilled through a 12-inch center-rod column. The residue gave fractions: (1)–(3), 4.51 g., b.p. 75–82.5° (15 mm.), n^{25}D 1.4460–1.4491; (4) 2.12 g., b.p. 82.8–84.2° (15 mm.), n^{25}D 1.4495; (5) 1.64 g., b.p. 84.2–85° (15 mm.), n^{25}D 1.4499. Fraction (4) gave a 3,5-dinitrobenzoate (50% crude yield), m.p. 57–59°.

Anal. Calcd. for $C_{11}H_{11}O_7N_2Cl$: C, 41.46; H, 3.48. Found: C, 41.34; H, 3.59.

Admixture with the 3,5-dinitrobenzoate, m.p. 56–59°, from the product of the addition of chlorine to methanolic allyl alcohol did not depress the melting point.

In another addition of chlorine to methanolic allyl acetate, anhydrous potassium acetate was employed instead of silver acetate; also, methanolic sodium methylate was used to neutralize the generated acetic acid in the working-up procedure. The main product, apparently largely transesterified, b.p. 81–85° (15.5 mm.), n^{25}D 1.4473, d^{25}_4 1.1717, was water-soluble.

Anal. Calcd. for $C_4H_9O_2Cl$ (chloromethoxypropanol): C, 38.56; H, 7.29. Calcd. for $C_6H_{11}O_3Cl$ (chloromethoxypropyl acetate): C, 43.25; H, 6.67. Found: C, 39.12; H, 7.56.

The chloro-orthoester (XVIII, R = CH_3, X = Cl) proved to be recoverable after being subjected to the general reaction conditions employed above. It was recovered, b.p. 80.1–80.9° (15 mm.), n^{25}D 1.4382, in 69% yield from stirring with potassium acetate and acetic acid in methanol, neutralization of the acid with sodium methylate solution, and distillation. Similarly, it was recovered, b.p. 78–79° (15 mm.), n^{25}D 1.4382, in 55% yield (neglecting hold-up, etc.) from distillation of a mixture of 10 g. of orthoester, 3.6 g. of glacial acetic acid and 20 g. of methanol.

A mixture of 12.5 g. (0.075 mole) of dry silver acetate, 5.00 g. (0.083 mole) of glacial acetic acid, 14.4 g. (0.087 mole) of orthoester and 250 ml. of methanol was cooled to 0° and stirred for half an hour. It was left at room temperature for one hour, and the acid was neutralized with 77.7 ml. of 1.071 *N* methanolic sodium methylate. The solution was filtered and concentrated to *ca.* 50 ml. Dry ether (500 ml.) and 10 ml. of the sodium methylate solution were added, the solution was filtered, and the ether was distilled off. There was recovered: 0.98 g., b.p. 63–67° (15 mm.), n^{25}D 1.4317; 1.34 g., b.p. 66–78° (15 mm.), n^{25}D 1.4363; 4.68 g. (32.5% in this fraction alone), b.p. 78–79.5° (15 mm.), n^{25}D 1.4383.

Addition of Bromine to Methanolic Allyl Acetate.—To a mixture of 83.5 g. (0.50 mole) of dry silver acetate, 25.4 g. (0.25 mole) of allyl acetate and 600 ml. of dry methanol was added, in 1.5 hours at room temperature, 40.6 g. (0.25 mole) of bromine. The solution was stirred another hour and was neutralized with 207.4 ml. of 1.375 *N* sodium methylate solution (a small excess was found necessary in stability tests on the orthoester). The solution was filtered and the filtrate was concentrated to a volume of about 150 ml. by distillation through a 12-inch center-rod column. About 800 ml. of dry ether was added, the precipitated salts were filtered, and the filtrate concentrated using the center-rod column. Fractionation of the residue gave: (1) 0.72 g., b.p. 74–83.8° (15 mm.), n^{25}D 1.4487; (2) 0.96 g., b.p. 83.8–89° (15 mm.), n^{25}D 1.4648; (3) 0.93 g., b.p. 89.5–91.5° (15 mm.), n^{25}D 1.4738; (4)–(6), 4.90 g., b.p. 92–99° (15 mm.), n^{25}D 1.4774–1.4779; (7) and (8), 5.54 g., b.p. 99–104.2° (15 mm.), n^{25}D 1.4764–1.4732; (9) 5.03 g., b.p. 104.8–115°, n^{25}D 1.4561. None of the fractions possessed the odor of the orthoester. Fraction 2 was water-soluble and gave an impure 3,5-dinitrobenzoate, m.p. 53–57°.

When the silver acetate was replaced by potassium acetate in the above procedure or the acetic acid was left unneutralized in the working-up, again no orthoester was detected in the product.

A mixture of 17 g. (0.10 mole) of dry silver acetate, 5.80 g. (0.097 mole) of glacial acetic acid, 21.3 g. (0.101 mole) of bromoörthoester (XVIII, R = CH_3, X = Br) and 250 ml. of methanol was treated to simulate the conditions of the addition reaction described above, 79.1 ml. of 1.266 *N* methanolic sodium methylate being used for neutralization of the acetic acid. There was recovered: 4.00 g., b.p. 88–90° (15 mm.), n^{25}D 1.4593, and 8.02 g., b.p. 90–90.5° (15 mm.), n^{25}D 1.4616, for a total recovery of 57%. The orthoester reacted to an appreciable extent in the above treatment, the filtered silver salts containing some silver bromide. This reaction produces acetic acid, and when insufficient sodium methylate to neutralize this additional acid was used, no orthoester was recovered. Similarly, distillation of a mixture of orthoester, acetic acid and methanol gave no orthoester recovery.

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