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

Allylic Rearrangements. IV. The Composition of Butenyl Bromides Prepared from Crotyl Alcohol and Methylvinylcarbinol[1,2]

BY WILLIAM G. YOUNG AND JOHN FERO LANE

The composition of butenyl bromides obtained from crotyl alcohol and methylvinylcarbinol by the action of hydrogen bromide or phosphorus tribromide under various conditions has never been established accurately. Communications[3] from this Laboratory have pointed out the following facts: (1) the butenyl bromides prepared by the usual methods of synthesis are always mixtures of crotyl and methylvinylcarbinyl bromides; (2) both bromides are very susceptible to thermal rearrangement into an equilibrium mixture; (3) the compositions of the bromide mixtures obtained from both alcohols depend not only on the method of synthesis but also on the method of isolation and purification; (4) previous investigators have always employed methods of purification which caused thermal rearrangement. As a result the composition of their products was independent of the method of synthesis.

Consequently, it was the purpose of the present investigation to determine what compositions of butenyl bromides actually are formed from crotyl alcohol and methylvinylcarbinol by the action of several different reagents under *controlled* conditions. The work was planned so as to distinguish clearly between allylic rearrangements which arise during the act of forming the bromides and those which are brought about by the method of isolation and purification. Such distinction necessitated the development of the analytical procedure described below.

Analysis of Butenyl Bromide Mixtures by Measurement of Refractive Index.—All butenyl bromide mixtures under consideration were analyzed by the method of Winstein and Young.[3c] It was necessary, however, to apply a small correction to the refractive index of most of the samples before the analytical method could be applied. This was necessary because the bromide mixtures had been freed from tarry products by rapid vaporization at low temperatures, no attempt having been made to strip out traces of volatile impurities. Although this procedure accomplished its purpose, namely, to avoid changes in composition due to thermal rearrangement or partial fractionation, and gave products containing the correct amount of bromine as determined by Carius analysis, nevertheless these products contained traces of inert impurities which produced a slight increase or decrease of the refractive index. This contamination was discovered when small portions of most of the samples, on thermal rearrangement at 100°, failed to give the equilibrium refractive index, $n^{25}\text{D}$ 1.4767, previously obtained with highly purified butenyl bromides.[3c] The differences between the observed refractive indices and the value $n^{25}\text{D}$ 1.4767 were never larger than 0.0013 and averaged about 0.0007 for thirty mixtures of bromides. It was therefore feasible to obtain the correct refractive index of any given sample by adding algebraically to its observed refractive index the difference between the refractive index of the equilibrium mixture prepared from that sample and the true equilibrium value, $n^{25}\text{D}$ 1.4767. For example, a certain bromide mixture gave the value $n^{25}\text{D}$ 1.4755. It rearranged at 100° to give $n^{25}\text{D}$ 1.4763 instead of $n^{25}\text{D}$ 1.4767. Since this rearranged mixture had had ample opportunity to attain equilibrium,[3c] the discrepancy of 0.0004 must have been caused by impurities. It was thus considered legitimate to change the value for the original mixture from $n^{25}\text{D}$ 1.4755 to 1.4759.

This procedure of correcting refractive indices was justified by the fact that in some cases as many as five duplicate runs were made. The corrections differed not only in magnitude but frequently in sign, yet the corrected values all agreed within experimental error of ±0.0001.

Stability of Butenyl Bromides under Controlled Experimental Conditions.—In order to determine the best experimental conditions for synthesizing and isolating the butenyl bromides without causing thermal rearrangement, several modifications of the general methods of Charon,[4]

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[1] This work was accomplished with the aid of a grant from the Board of Research of the University of California.

[2] This paper was abstracted from a dissertation submitted by John Fero Lane in partial fulfilment of the requirement for the degree Master of Arts.

[3] (a) Young and Prater, THIS JOURNAL, **54**, 404 (1932); (b) Young and Winstein, *ibid.*, **57**, 2013 (1935); (c) Winstein and Young, *ibid.*, **58**, 104 (1936).

[4] Charon, *Ann. chim. phys.*, [7] **17**, 216 (1899).

TABLE I

THE EFFECT OF VARIOUS EXPERIMENTAL CONDITIONS ON THE STABILITY OF BUTENYL BROMIDES

Standard experimental method	Composition of sample before treatment		Composition of Sample After Treatment					Change in % primary bromide due to treatment
	$n^{25}\mathrm{D}$	% primary	$n^{25}\mathrm{D}$, uncorr.	$n^{25}\mathrm{D}$ of equilibrium mixture obtained at 100°	Correction	$n^{25}\mathrm{D}$, corr.	% primary bromide	
A. 48% Hydrobromic acid at 20°	1.4615	6.7	1.4661	1.4767	0.0000	1.4661	30.6	+23.9
	1.4785	94.8	1.4776	1.4763	+ .0004	1.4780	92.2	− 2.6
1. 48% Hydrobromic acid at −15°	1.4615	6.7	1.4627	1.4779	− .0012	1.4615	6.7	0.0
	1.4628	13.5	1.4641	1.4780	− .0013	1.4628	13.5	.0
	1.4785	94.8	1.4782	1.4764	+ .0003	1.4785	94.8	.0
	1.4785	94.8	1.4790	1.4772	− .0005	1.4785	94.8	.0
2. 48% Hydrobromic acid acid + H_2SO_4 at −15°	1.4615	6.7	1.4623	1.4771	− .0004	1.4619	8.8	+ 2.1
	1.4628	13.5	1.4636	1.4777	− .0010	1.4626	12.4	− 1.1
	1.4785	94.8	1.4783	1.4769	− .0002	1.4781	92.8	− 2.0
	1.4785	94.8	1.4790	1.4775	− .0008	1.4782	93.4	− 1.4
3. Saturated hydrobromic acid at 0°	1.4602	0.0	1.4612	1.4774	− .0007	1.4605	1.6	+ 1.6
	1.4704	52.8	1.4710	1.4769	− .0002	1.4708	54.4	+ 1.6
	1.4785	94.8	1.4778	1.4761	+ .0007	1.4785	94.8	0.0
4. Hydrogen bromide gas at −20°	1.4602	0.0	1.4610	1.4772	− .0005	1.4605	1.6	+ 1.6
	1.4602	0.0	1.4608	1.4773	− .0006	1.4602	0.0	0.0
	1.4602	0.0	1.4602	1.4768	− .0001	1.4601	0.0	0.0
	1.4785	94.8	1.4782	1.4761	+ .0006	1.4788	97.4	+ 1.6
5. Phosphorus tribromide at −15°	1.4615	6.7	1.4608	1.4756	+ .0011	1.4619	8.8	+ 2.1
	1.4628	13.5	1.4631	1.4772	− .0005	1.4626	12.4	− 1.1
	1.4785	94.8	1.4790	1.4776	− .0009	1.4781	92.8	− 2.0

Bouis,[5] and Claisen and Tietze[6] were devised. In each of these methods a uniform procedure of synthesis, washing, drying and purification was adopted. Pure samples of crotyl bromide, methylvinylcarbinyl bromide, and known mixtures of these were then subjected to the conditions of each of the standard methods. This series of experiments enabled us to choose the standard methods to be studied further. They are summarized in Table I.

Column 1 gives the standard method used. Columns 2 and 3 list the refractive index and the corresponding content of primary (crotyl) bromide in the butenyl bromide being tested. Column 4 records the uncorrected and column 7 the corrected refractive index of the sample after treatment with a given reagent. Column 5 lists the refractive index of the equilibrium mixture obtained by rearranging each treated sample, from which the corrected values were computed for column 7; while column 6 gives the corrections applied in each case. Column 8 lists the primary bromide content of the sample after treatment with the reagent and the last column shows the change in primary bromide content due to the treatment in question.

Method (A) using 48% hydrobromic acid at 20° caused considerable rearrangement of the secondary bromide and was consequently eliminated as a method of synthesis of bromide mixtures from the alcohols. The maximum change in primary bromide content brought about by the other standard methods of treatment was 2.1% and the average change was approximately 1%. Since the experimental error is of this order of magnitude (±0.5%), it may be concluded that those methods do not cause a serious change in the composition of the butenyl bromides actually formed. It should be noted that the small changes observed are not entirely due to experimental error since they were generally in the direction of the equilibrium composition.

The Composition of Butenyl Bromides Prepared from Crotyl Alcohol and Methylvinylcarbinol under Controlled Conditions.—The data on the butenyl bromide mixtures prepared from crotyl alcohol and methylvinylcarbinol by the several procedures described in the experimental part are summarized in Table II. In the first column is listed the standard method used, in the second the alcohol, whether methylvinylcarbinol (secondary) or crotyl alcohol (primary). The percentages of primary and secondary bromides in each product appear in columns seven and eight, respectively, while in the last column is listed the average difference between the percen-

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[5] Bouis, *Bull. soc. chim.*, [4] **41**, 1160 (1927).

[6] Claisen and Tietze, *Ber.*, **59**, 2344 (1926).

TABLE II

THE COMPOSITION OF BUTENYL BROMIDES OBTAINED FROM CROTYL ALCOHOL AND METHYLVINYLCARBINOL UNDER CONTROLLED CONDITIONS

Standard experimental method	Alcohol used	n^{25}_D of bromide mixture uncorr.	n^{25}_D of equilibrium mixture obtained at 100°	Correction applied	n^{25}_D of bromide mixture corr.	Composition of product		Average diff. in % primary bromide from the primary and secondary alcohols
						% primary bromide	% secondary bromide	
1. 48% Hydrobromic acid at −15°	Primary	1.4761	1.4760	+0.0007	1.4768	86.0	14.0	
	Primary	1.4756	1.4755	+ .0012	1.4768	86.0	14.0	2.9
	Secondary	1.4752	1.4756	+ .0011	1.4763	83.4	16.6	
	Secondary	1.4759	1.4764	+ .0003	1.4762	82.9	17.1	
2. 48% Hydrobromic acid + H_2SO_4 at −15°	Primary	1.4751	1.4754	+ .0013	1.4764	84.0	16.0	4.7
	Secondary	1.4752	1.4764	+ .0003	1.4755	79.3	20.7	
3. Saturated hydrobromic acid at 0°	Primary	1.4742	1.4754	+ .0013	1.4755	79.3	20.7	
	Primary	1.4750	1.4765	+ .0002	1.4752	77.7	22.3	4.7
	Secondary	1.4744	1.4765	+ .0002	1.4746	73.6	26.4	
	Secondary	1.4735	1.4757	+ .0010	1.4745	74.1	25.9	
4. Hydrogen bromide gas at −20°	Primary	1.4760	1.4766	+ .0001	1.4761	82.4	17.6	6.2
	Secondary	1.4752	1.4770	− .0003	1.4749	76.2	23.8	
5. Phosphorus tribromide + pyridine at −15°	Primary	1.4775	1.4759	+ .0008	1.4783	93.8	6.2	47.2
	Secondary	1.4680	1.4755	+ .0012	1.4692	46.6	53.4	
6. Phosphorus tribromide + pyridine at −75°	Primary	1.4776	1.4756	+ .0011	1.4787	95.8	4.2	
	Primary	1.4783	1.4762	+ .0005	1.4788	96.3	3.7	48.6
	Secondary	1.4695	1.4765	+ .0002	1.4697	49.8	50.2	
		1.4696	1.4774	− .0007	1.4689[a]	45.1	54.9	

[a] 0.5 g. of diphenylamine used in this run.

tage of primary bromide in the products from the primary and secondary alcohols.

Not only does the composition of products actually differ from method to method, but also the product obtained from the primary alcohol is different from that obtained from the secondary alcohol by any given method. The conclusion of certain previous workers[4–8] that only one product, crotyl bromide, results from the action of either phosphorus tribromide or hydrobromic acid is obviously in error. Indeed, it is quite evident that neither isomeric bromide is produced in a pure form from the corresponding alcohol by any of these methods.

Inspection of Table II shows that the experiments naturally fall into two groups: those involving hydrobromic acid in some form and those involving phosphorus tribromide. These groups of experiments will be discussed separately.

Experiments Involving Hydrobromic Acid.—In all of the methods (one to four, Table II) both the primary and secondary alcohols give products containing primary and secondary bromides showing that allylic rearrangements occur. These rearrangements are a result of the act of forming the bromides since the bromides themselves do not rearrange appreciably under the experimental conditions used. Although there is a consistent, well-defined difference in the primary bromide content of the products obtained from the two alcohols, this difference is small enough to indicate that the composition in each case is tending toward some sort of equilibrium value but from opposite sides. It should be emphasized that the observed differences are reproducible and are well beyond the limit of experimental error (±0.5%). Differences of this sort have been observed before by Meisenheimer and Link[9] in the preparation of pentenyl chlorides, but no satisfactory explanation has yet been offered.

The effect of variation in concentrations of hydrobromic acid on the composition of products is likewise significant. The products prepared from both alcohols by methods one to four differ considerably from one another. The differences between the primary bromide contents of the products from the primary and secondary alcohols are likewise affected. They range from 2.9% in method one to 6% in method four. Further work now in progress indicates that this difference may be increased to 12–15% by increasing the activity

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(7) Prévost, *Ann. chim.*, [10] **10**, 113, 147 (1928).

(8) Juvala, *Ber.*, **63**, 1989 (1930).

(9) Meisenheimer and Link, *Ann.*, **479**, 256 (1930).

of the hydrogen bromide through using other solvents than water.

Finally, it should be pointed out that all of the products prepared by these methods contain more secondary bromide than does the equilibrium mixture obtained by rearranging either pure bromide at room temperature. This mixture has a refractive index $n^{25}\text{D}$ 1.4770, corresponding to 87% primary bromide. This fact leads to the conclusion that the character of the reaction medium plays an important role determining the composition of the products formed.

Additional controlled experiments on the synthesis of bromides are now in progress and indications are that it will be possible to present in the near future a mechanism for reactions of this type which will explain all of the experimental facts now available.

Experiments Involving Phosphorus Tribromide.—As might be expected, phosphorus tribromide reacts with crotyl alcohol and methylvinylcarbinol to produce entirely different mixtures of butenyl bromides than do the reagents containing hydrobromic acid. Phosphorus tribromide is of course a non-polar anhydride in contrast with the strongly polar hydrobromic acid.

According to the theory suggested by Meisenheimer,[9] based on the reactions of thionyl chloride, we would expect to obtain mainly secondary bromide from the primary alcohol and *vice versa.* Actually this is not the case. Crotyl alcohol gives 96–97% primary bromide and methylvinylcarbinol gives 51–53% secondary bromide. Although the pure bromides did not rearrange under the conditions of the experiment, it was first thought that the large amount of rearrangement from the secondary alcohol might be due to local heating effects attending reaction of the drops of phosphorus tribromide with the alcohol. However, the presence of powdered solid carbon dioxide in the reaction mixture failed to change the composition of the products appreciably. The introduction of diphenylamine, an antioxidant, to retard thermal rearrangement due to local heating, also gave similar results. Consequently it seems that the rearrangement occurs during the act of forming the bromides and is not a thermal effect.

The present work serves to reëmphasize the fact that the results of previous workers[8,10] were erroneous due to the use of high temperature technique in isolating the products.

It should be pointed out that in any experiments involving butenyl bromides, it is necessary to work at low temperatures and to correct the refractive index of the bromides before using this physical property for analytical purposes. Had this latter information been available to Kharasch, Margolis and Mayo,[11] they undoubtedly would have obtained the same refractive index for the two equilibrium mixtures which they list in Table III. Likewise, the discrepancies between the compositions of bromide mixtures as determined by density and refractive index methods (Tables I and II)[11] would have disappeared.

Incidentally, the recent conclusions of Ganguly[12] on the composition of butenyl bromides from the addition of hydrogen bromide to butadiene are scarcely tenable. This worker concluded that the addition product was pure crotyl bromide. He arrived at this conclusion by comparing the properties of his addition product with those of a bromide which had been prepared from methylvinylcarbinol and which could be converted into crotyl acetate. Unfortunately, Ganguly was unaware of the extreme mobility of the butenyl bromides and carried out most of his work in a manner which would give rise to allylic rearrangements and vitiate any comparison which might have been possible. In view of the peculiar behavior of such halide mixtures upon distillation,[3c] it is not surprising that the two bromide preparations which he compared possessed similar properties. It is known that the distillation of different butenyl bromide mixtures from the same apparatus at atmospheric pressure may give identical distillates regardless of the composition of the mixture being distilled.[3c] This is due to the rapid establishment of an equilibrium mixture in the boiler.

Experimental Part

Alcohols.—Crotyl alcohol, b. p. 119–122°, was prepared by the aluminum isopropoxide method.[13,14] Methylvinylcarbinol, b. p. 95.5–96.5°, was obtained by the method of Delaby as described by Prévost.[7]

Preparation of Pure Crotyl and Methylvinylcarbinyl Bromides.—Crotyl (primary) and methylvinylcarbinyl (secondary) bromides and known mixtures of them were prepared from crotyl alcohol essentially as previously described.[3c] However, the preparation of the nearly pure

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(10) Gredy and Piaux, *Bull. soc. chim.*, [5] **1**, 1481 (1934).

(11) Kharasch, Margolis and Mayo, *J. Org. Chem.*, **1**, 397 (1936).

(12) Ganguly, *J. Indian Chem. Soc.*, **13**, 580 (1936).

(13) Young, Hartung and Crossley, THIS JOURNAL, **58**, 100 (1936).

(14) The crotonaldehyde used in preparing the crotyl alcohol was kindly furnished by the Niacet Chemicals Corporation, through the courtesy of Mr. G. M. Bramann.

secondary bromide by fractional distillation of an equilibrium mixture of the primary and secondary bromides at atmospheric pressure was modified to advantage. Mr. Zene Jasaitis of this Laboratory found that when a gram or two of decolorizing carbon is placed in the boiler it is possible to remove the secondary bromide from the top of the column five times as rapidly (80–100 g. per hour) as was formerly possible. The carbon ensures maintenance of equilibrium in the boiler at all times.

Synthesis of Butenyl Bromide Mixtures from Crotyl Alcohol and Methylvinylcarbinol.—Several of the general methods of preparing butenyl bromides, referred to previously,[3c] have been studied. Since it was necessary to use controlled conditions at all times, it is advisable to describe most accurately the procedures followed in converting the crotyl alcohol and methylvinylcarbinol into mixtures of bromides. The general methods were modified wherever it seemed necessary in order to avoid thermal rearrangements of the products.

Method 1. Use of 48% Hydrobromic Acid at −15°.—Crotyl alcohol or methylvinylcarbinol (0.3 mole) and 100 cc. of 48% hydrobromic acid were cooled separately to −25° and mixed together in a glass-stoppered bottle. The mixture was allowed to stand with occasional shaking at −15° until the bromide layer was no longer increasing in volume. This required approximately four days. The reaction mixture was then rapidly transferred to a cold separatory funnel and the bromide layer was isolated. This crude bromide was washed first with a mixture of crushed ice and dilute sodium bicarbonate solution and then with ice water; finally it was dried with calcium chloride for several hours at −15°. This crude bromide mixture was distilled completely and without fractionation at 3 mm. pressure. Both of the butenyl bromides boil below 0° at this pressure. This procedure removes the small quantities of high boiling impurities which are always present and gives a product consisting almost entirely of crotyl and methylvinylcarbinyl bromides.

Method 2. Use of a Mixture of 48% Hydrobromic Acid and Concentrated Sulfuric Acid at −15°.—The desired butenol (0.3 mole) and a mixture of 7.2 cc. of concd. sulfuric acid and 72 cc. of 48% hydrobromic acid were cooled to −25° and mixed together. The resulting mixture was then subjected to the treatment described in method (1) above.

Method 3. Use of a Saturated Aqueous Solution of Hydrogen Bromide at 0°.—Fifty cc. of 48% hydrobromic acid was placed in a 250-cc. glass-stoppered Erlenmeyer flask and saturated with pure hydrogen bromide at 0°. The flask was then placed in a mixture of salt and ice and 0.3 mole of the butenol cooled to −25° was added dropwise. The rate of addition was such that the temperature of the reaction mixture remained between −1 and +1°. The addition required about ten minutes. The flask was stoppered and allowed to stand at 0° for ten minutes longer during which time it was shaken frequently. The reaction mixture was cooled to −10° and transferred to a cold separatory funnel for the removal of the bromide layer. The crude bromide was washed, dried and purified as described in method (1).

Method 4. Use of Dry Hydrogen Bromide at −20°.—The butenol (0.3 mole) was placed in a 25 × 2.5-cm. cylindrical glass trap which had an inlet tube, a thermometer well and an outlet tube sealed in the top. Both the inlet and outlet tubes were connected to calcium chloride tubes. Some mercury and a toluene thermometer were placed in the well, and the trap was immersed in a mush of dry ice and alcohol. When the butenol had cooled to −25°, a supply of dry hydrogen bromide gas was passed into the trap through the inlet tube at such a rate that the temperature of the reaction mixture remained between −20 and −25°. The reaction mixture gradually became discolored. After about thirty minutes, the mixture separated into two phases. The bromide phase rose to the top and the heavier aqueous phase began to crystallize. At the end of one hour the aqueous phase had solidified completely. The inlet and outlet tubes were then capped with rubber policemen and the trap was placed in a mixture of ice and hydrochloric acid at −20° for fifteen minutes. At the end of this time the oily bromide phase reeking with hydrogen bromide was poured into a mixture of crushed ice and sodium bicarbonate solution. The bromide was washed, dried and purified as described in method (1).

Method 5. Action of Phosphorus Tribromide and Pyridine at −15°.—The butenol (0.3 mole) and 8.0 cc. of dry pyridine were mixed together in a 100-cc. distilling flask. The neck of the flask was closed with a two-holed rubber stopper carrying a toluene thermometer and a dropping funnel, and the side-arm was attached to a calcium chloride train. The bulb of the flask was placed in a mixture of ice and hydrochloric acid and when the reaction mixture had cooled to −20°, 11.5 cc. of phosphorus tribromide was added dropwise over a period of one and one-half hours at such a rate that the temperature of the reaction mixture was maintained between −15 and −20°. The flask was shaken vigorously at intervals to minimize the possibility of local heating. After the phosphorus tribromide had all been added, the stopper was replaced by one carrying a capillary tube and the crude bromide mixture was distilled carefully from the solid residue at a pressure of 3 mm. The crude product was washed, dried and purified as described in method (1).

Method 6. Action of Phosphorus Tribromide and Pyridine at −75°.—The following changes were made in method (5): the alcohol and pyridine were mixed with 15 g. of powdered dry ice and the cooling mixture of ice and hydrochloric acid was replaced by a mush of dry ice in alcohol. The temperature of the reaction mixture was maintained between −73 and −78° during the addition of the phosphorus tribromide. The flask was warmed slowly to −25° to remove the excess dry ice and the reaction mixture was treated as in method (5). A summary of the results obtained by methods (1)–(6) is given in Table II.

Effect of Experimental Conditions on the Thermal Rearrangement of Crotyl and Methylvinylcarbinyl Bromides.—In order to determine the composition of butenyl bromide mixtures actually formed during the reaction of crotyl alcohol and methylvinylcarbinol with various reagents it was necessary to show that pure crotyl and methylvinylcarbinyl bromides, or known mixtures of these bromides, are not affected by the conditions used in preparing and isolating the product as described in methods

1 to 6 above. This was accomplished in the following manner. The crotyl alcohol or methylvinylcarbinol called for in methods 1 to 6 was replaced by the same number of moles of water and of the pure bromides or known mixtures of them. Each method of synthesis was then carried out exactly as described and the bromide was washed, dried and distilled. The corrected refractive index of the product was then compared with the refractive index of the bromide at the start of the procedure to see if any allylic rearrangement had occurred. The results of these experiments are listed in Table I.

Determination of the Equilibrium Mixture from the Butenyl Bromides.—In order to analyze butenyl bromide samples it is necessary to apply a small correction to the observed refractive index as described above. This correction is calculated with the aid of the refractive index of the equilibrium mixture obtained by thermally rearranging the sample under consideration at 100°. For the determination of the equilibrium values, small samples of the purified bromides from the low temperature distillations as described in synthesis (1) above, were sealed in 8-cm. test-tubes and placed in boiling water for one hour. The tubes were then removed, chilled in a mixture of ice and hydrochloric acid and opened. The refractive indices of the rearranged mixtures were then taken. Four or five tubes were ordinarily used and the average refractive index obtained is the value reported in the columns marked "refractive indices of equilibrium mixture" listed in Tables I and II.

The authors are indebted to Dr. G. Ross Robertson and Mr. Saul Winstein for helpful suggestions during the course of the investigations.

Summary

Crotyl alcohol and methylvinylcarbinol have been converted into butenyl bromide mixtures by the action of hydrogen bromide and phosphorus tribromide under controlled low-temperature conditions.

The experiments were designed to distinguish between allylic rearrangements which arise during the act of forming the bromides and those which are due to the method of isolation and purification of the product.

Known samples of butenyl bromides were subjected to the same conditions used in the synthesis, washing, drying and purifying of a product without undergoing appreciable change in composition.

Mixtures of crotyl and methylvinylcarbinyl bromides are formed from either crotyl alcohol or methylvinylcarbinol by all methods investigated. The composition of these mixtures depends on the butenol employed and on the character of the reagent used in converting the alcohol into the bromide mixture.

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[CONTRIBUTION FROM THE NICHOLS CHEMICAL LABORATORY OF NEW YORK UNIVERSITY]

Thioethers of Formocholine and their Sulfones. Onium Compounds. XVII

BY R. R. RENSHAW AND D. E. SEARLE[1]

Due to the interesting pharmacological properties of the thiol derivatives of choline, $(CH_3)_3N(Br)CH_2CH_2SH$,[2] it seemed desirable to prepare and investigate the properties of other derivatives of choline in which the oxygen atom had been replaced by sulfur. We have, therefore, prepared a series of thioethers of the formocholine type, $R_3N(I)CH_2SR$, and have oxidized some of these to the corresponding sulfones.

Schneider[3] prepared the methyl and ethyl thioethers of choline from beta-aminoethyl thioethers, formed from the interaction product of bromoethylphthalimide and the appropriate thiol. The pharmacological properties of these thiocholine ethers were not investigated. Schneider[4] was unsuccessful in the preparation of thioether of the formocholine type.

In this work, advantage was taken of the interesting reactions of McLeod and Robinson[5] for the preparation of tertiary aminomethyl ethers by condensing secondary amines with formaldehyde and an alcohol, in the presence of potassium carbonate. These workers also obtained propyl and ethyl thioethers by replacing the alcohol with propyl and ethylthiol. As was to be expected, this method was found to be of very general application, giving yields of the tertiary aminothioethers of 60–72%.

The onium compounds were prepared by condensing the tertiary amines with methyl or

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[1] This is the second paper from a thesis presented by D. S. Searle, June, 1930, for the degree of Doctor of Philosophy at New York University; Paper I, THIS JOURNAL, **55**, 4951 (1933).

[2] Hunt and Renshaw, *J. Pharmacol.*, **44**, 154 (1932).

[3] Schneider, *Ann.*, **386**, 339 (1911).

[4] Schneider, *ibid.*, **386**, 349 (1911).

[5] McLeod and Robinson, *J. Chem. Soc.*, **119**, 1470 (1921).