after recrystallization from petroleum ether (reported[27] 49–50°).

2-Chloro-1-propanol.—Literature data for propyl alcohol[14] are b.p. 97°, $n^{20}\text{D}$ 1.3850, and for 2-chloro-1-propanol[28] b.p. 53° (29 mm.), $n^{20}\text{D}$ 1.4390. Thus fraction 3 was pure 2-chloro-1-propanol, fraction 2 contained 15% of the chlorohydrin and 85% propyl alcohol and fraction 1 was assumed to be a mixture of propyl alcohol and ether containing 17% of the former. Thus the total yield of propyl alcohol is 2.2 g. (15%) and that of the chlorohydrin 14.95 g. (63%). In the reduction carried out in the presence of methanol, fraction 1 appeared to be mainly methanol (b.p. 65°, $n^{20}\text{D}$ 1.3286), fraction 2 was calculated to contain 85% of propyl alcohol and fraction 3 contained 14% propyl alcohol and 86% 3-chloro-1-propanol. Thus the total yield of the chlorohydrin was 11.1 g. (47%) and that of propyl alcohol 3.5 g. (23.5%).

3-Chloro-1-propanol.—Fraction 1 was derivatized to propyl 3,5-dinitrobenzoate, m.p. 73.5–75°, undepressed by admixture of an authentic sample. Fraction 2 had an infrared spectrum identical to that of the starting material. From the literature data already cited[12–14] 1 appears to be essentially pure propyl alcohol and 2 to contain 91% of 3-chloro-1-propanol and 9% of propanol-1. Thus the yield of the chlorohydrin is 6.0 g. (32%) and that of the alcohol 5.7 g. (47%).

3-Chloro-1-butanol.—Fraction 1 was shown to contain butyl alcohol by preparation of the 3-nitrophthalate, m.p. 137–139°, undepressed by admixture of an authentic sample. Fraction 2 gave an α-naphthylurethan melting at 84–85° which did not depress the melting point of the analytical sample of 3-chloro-1-butyl N-α-naphthylcarbamate previously described. From the refractive index, fraction 2 is calculated to contain 91% chlorohydrin or 14.6 g. (68% recovery). The maximum amount of butyl alcohol isolated is therefore 3.25 g. (22%), the actual amount being probably less, since fraction 1 appeared to contain water.

4-Chloro-1-butanol.—From the data already cited,[19] fraction 2 appears to be pure 4-chloro-1-butanol, recovered in 41% yield.

5-Chloro-1-pentanol.—Fraction 1 contained amyl alcohol as evidenced by the formation of a phenylurethan melting at 44–47°, undepressed by admixture of authentic amyl N-phenylcarbamate. Fraction 2 was recovered 5-chloro-1-pentanol as evidenced by formation of an α-naphthylurethan melting at 70–72°, undepressed by admixture with the same derivative of the authentic chlorohydrin. From the refractive index data fraction 1 appears to contain 77% of pentanol-1 and 23% of pentamethylene chlorohydrin, while fraction 2 is pure chlorohydrin. Thus the yield of alcohol is 2.1 g. (12%) and that of chlorohydrin 15.2 g. (62%).

6-Chloro-1-hexanol.—Fraction 2, from its refractive index, appeared to be pure starting material. The maximum yield of hexanol-1 (assuming all of fraction 1 to be this material) is 5%. Hexanol-1 was proved to be present in this fraction by the preparation of its phenylurethan, m.p. 39–40° (lit.[29] 42°), undepressed by admixture of an authentic sample.

Acknowledgment.—We are very grateful to Research Corporation for supporting this work through Frederick Gardner Cottrell grants.

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NOTRE DAME, INDIANA

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, PURDUE UNIVERSITY]

The Ethanolysis of 1,1,1-Trifluoro-2,3-epoxybutane and 2-Methyl-1,1,1-trifluoro-2,3-epoxypropane

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The ethanolysis of 1,1,1-trifluoro-2,3-epoxybutane and 2-methyl-1,1,1-trifluoro-2,3-epoxypropane under acidic and basic conditions results in exclusive cleavage of the carbon–oxygen bond not adjacent to the trifluoromethyl group. The $-\text{I}_s$ effect of the trifluoromethyl group is more significant in orienting cleavage than steric factors or hyperconjugative stabilization.

Discussion

The acid and base-catalyzed ring cleavage reactions of 1,1,1-trifluoro-2,3-epoxypropane (I) have been shown[2] recently to proceed with exclusive scission of the terminal ether linkage. Although propylene oxide (II) undergoes an essentially analogous cleavage with basic reagents, the reaction with acids[3] and alcohols under acid conditions[4] favors the formation of a primary alcohol.

Analogous ethoxyalcohols are formed by the ethanolysis of 2,3-epoxybutane (III)[5] and isobutylene oxide (IV).[6] Ethanolysis of III can result in only one positional isomer, but IV has been observed to form two positional isomers, predominantly the primary alcohol under acidic conditions[6] and mixtures of primary and tertiary alcohols under neutral conditions.[6b] The reaction of IV with basic reagents such as amines[7] results in exclusively tertiary alcohols while halohydrins containing the primary alcohol grouping predominate in the reactions with hydrogen halides.[8]

A study has been made of the ethanolysis reactions of 1,1,1-trifluoro-2,3-epoxybutane (V) and 2-methyl-1,1,1-trifluoro-2,3-epoxypropane (VI). Whereas exclusive terminal cleavage of I may have arisen in part through the greater accessibility of

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[1] A portion of a thesis submitted by C. E. Hathaway to Purdue University in partial fulfillment of the requirements for the degree of Doctor of Philosophy, January, 1956.

[2] E. T. McBee, C. W. Roberts and C. E. Hathaway, THIS JOURNAL, **78**, 3851 (1956).

[3] C. A. Stewart and C. A. VanderWerf, *ibid.*, **76**, 1259 (1954).

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[7] (a) K. Krassusky, *J. Russ. Phys. Chem. Soc.*, **40**, 155 (1908); (b) S. A. Glickman and A. C. Cope, THIS JOURNAL, **67**, 1012 (1945).

[8] (a) A. A. Petrov, *J. Gen. Chem.* (*U.S.S.R*), **15**, 690 (1945); (b) L. Smith and S. Skyle, *Acta Chem. Scand.*, **5**, 1415 (1951).

the terminal carbon–oxygen bond to displacement by a nucleophilic reagent, V is essentially sterically symmetrical and the mode of cleavage should be completely a function of the $-I_s$ effect of the trifluoromethyl group.[9]

The ethanolysis of V and VI under both acidic and basic conditions gives the products arising through cleavage of the ether linkage furthest removed from the trifluoromethyl group. Quantitative infrared analysis shows these products to be, respectively, 3-ethoxy-1,1,1-trifluoro-2-butanol (VII) and 3-ethoxy-2-methyl-1,1,1-trifluoro-2-propanol (VIII). The isomeric ethoxyalcohols, 3-ethoxy-4,4,4-trifluoro-2-butanol (IX) and 2-ethoxy-2-methyl-3,3,3-trifluoro-1-propanol (X), were synthesized for comparison by a series of reactions analogous to that used for the preparation of 2-ethoxy-3,3,3-trifluoro-1-propanol (see Experimental).[2]

These data support the concept[2] that the epoxide has a polarizable electron system which is distorted in the presence of an electron-withdrawing group. The most important single factor governing the relative extent of cleavage of the two carbon–oxygen bonds appears to be the relative transition state energies required for the concerted displacement reactions as influenced by electronic factors from substituent groups. The complete lack of cleavage of an ether linkage adjacent to a trifluoromethyl group in I, V and VI indicates a relatively high energy for heterolytic cleavage at that site. Though hyperconjugation with a methyl group may favor cleavage at an adjacent carbon atom, a trifluoromethyl group on the same site counteracts this cleavage completely.[10]

The physical properties of the cleavage products are listed in Table I. The analytical procedure involved separation of the possible isomers from each reaction by rectification followed by quantitative infrared analysis of the end fractions in each case. The infrared spectra of the individual alcohols are shown in Figs. 1 and 2.

Table I

Physical Properties of Isomeric Ethoxyalcohols

Compound	B.p. °C.	Mm.	$n^{20}{}_D$	d^{25}_4
3-Ethoxy-1,1,1-trifluoro-2-butanol (VII)	60.0	49.0	1.3631	1.1498
3-Ethoxy-4,4,4-trifluoro-2-butanol (IX)	67.6	48.0	1.3680	1.169
3-Ethoxy-2-methyl-1,1,1-trifluoro-2-propanol (VIII)	60.6	49.5	1.3631	1.1504
2-Ethoxy-2-methyl-3,3,3-trifluoro-1-propanol (X)	70.0	50.0	1.3750	1.198

The preparation of V was accomplished by a sequence of reactions involving the Claisen condensation of ethyl trifluoroacetate and ethyl propionate, ketonic hydrolysis, bromination, reduction and dehydrobromination. The sample used for the cleavage study had a boiling point range of only 1°, though there was a variation of 0.0010 unit in the refractive index over a series of fractions. The infrared spectrum of this sample was identical with that of an analytical sample.[11] The ethanolysis product VII appears on the basis of refractive index and infrared spectra to be stereoisomerically pure since the non-fluorinated *erythro*- and *threo*-ethoxybutanols differ[5c] in this respect. This could only arise from a single geometrical isomer.

The preparation of VI was achieved by the low temperature addition of methylmagnesium bromide to 3-bromo-1,1,1-trifluoropropanone followed by dehydrobromination. The conversion of 2-methyl-3,3,3-trifluoropropene by direct epoxidation using peroxytrifluoroacetic acid[13] or by the addition of hypohalous acids proved unsuccessful.[14]

Acknowledgment.—The authors wish to express their appreciation to the Westinghouse Electric Corporation for financial assistance during the course of this work.

Experimental[15]

Ethyl 3-Keto-2-methyl-4,4,4-trifluorobutyrate.[16]—A solution of 426 g. (3.0 moles) of ethyl trifluoroacetate in an equal volume of ether was added slowly to a stirred, cooled suspension of 3.0 moles of sodium ethoxide in 1.5 l. of anhydrous ether. A 50% ether solution of 336 g. (3.3 moles) of ethyl propionate was added slowly with stirring during 6 days without heating. The reaction mixture was gently refluxed for an additional 6 days during which a slight darkening occurred. Excess solvent and volatile reagents were removed first at atmospheric pressure and then under reduced pressure on a steam-bath since superheating of a mantle leads to violent decomposition of the reaction mixture. To the dried sodium salt was gradually added 1500 ml. of 10% sulfuric acid with stirring. The upper layer was separated, combined with two ether extracts of the aqueous layer, washed with cold sodium carbonate solution and dried. Rectification gave 196.5 g. (33.3%) of ethyl 3-keto-2-methyl-4,4,4-trifluorobutyrate, b.p. 57.8° (26 mm.), $n^{20}{}_D$ 1.3650.

Anal. Calcd. for $C_7H_9F_3O_3$: C, 42.42; H, 4.55. Found: C, 41.65; H, 4.65.

1,1,1-Trifluoro-2-butanone.—Ethyl 3-keto-2-methyl-4,4,-4-trifluorobutyrate (146 g., 0.74 mole) was mixed with 300 ml. of acetic acid and 30 ml. of water. Sulfuric acid (15 ml.) was then added and the mixture was heated to reflux under a 10-cm. glass-helices-packed column and the liquid boiling below 50° was slowly removed through a variable take-off reflux head. The distillate and contents of the Dry-Ice cooled trap were combined, cooled with Dry Ice and dried with phosphorus pentoxide. This mixture was then rectified to give 50.0 g. (55%) of 1,1,1-trifluoro-2-butanone, b.p. 44 to 46°.[17]

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[9] The preferred cleavage of the secondary carbon–oxygen bond in II during acid-catalyzed ethanolysis has been assumed to involve a hyperconjugative stabilization of a secondary carbonium ion. The same possibility for stabilization exists in VI, but the opposing $-I_s$ effect of the trifluoromethyl group may be studied simultaneously. The latter factor should favor the formation of a tertiary alcohol, whereas the former should favor the primary alcohol.

[10] The basicity of the epoxide oxygen is reduced by the trifluoromethyl group, but the validity of the acid-catalysis assumption has been substantiated by kinetic data.[2] The possibility that terminal cleavage arises through reaction of the unprotonated species exclusively seems therefore very remote.

[11] The infrared spectra of *cis*- and *trans*-2,3-epoxybutane[12] differ markedly so it appears that V has *either* the *cis* or *trans* configuration and may not be a mixture of the two.

[12] W. A. Patterson, *Anal. Chem.*, **26**, 823 (1954).

[13] W. D. Emmons and A. S. Paganov, This Journal, **77**, 89 (1955).

[14] J. B. Dickey and E. B. Towne, U. S. Patent 2,700,686, Jan. 25, 1955.

[15] All boiling points are uncorrected; melting points were taken in capillaries. Elemental analyses were by Mrs. P. T. Yeh of this department.

[16] G. M. Wyman and W. T. Miller, Abst. Papers, 124th Meeting of A. C. S., Chicago, Ill., September, 1953, p. 37 M, have reported the preparation of this compound but give no physical constants.

[17] L. B. Barkley and R. Levine, This Journal, **75**, 2059 (1953), report b.p. 44 to 45°.

3-Bromo-1,1,1-trifluorobutanone.—1,1,1-Trifluoro-2-butanone (90.0 g., 0.71 mole) was added dropwise with stirring to 300 ml. of concentrated sulfuric acid cooled in an ice-bath. Bromine (58.0 g., 0.36 mole) was added dropwise during 2 hr. After 12 hr. the bromoketone was removed by rapid distillation at 50 mm. and gradual heating of the sulfuric acid residue to 50°. Rectification of the crude distillate yielded 96.0 g. (65.6%) of 3-bromo-1,1,1-trifluoro-2-butanone, b.p. 93.0°, n^{20}_D 1.3803, d^{25}_4 1.6303.

Anal. Calcd. for $C_4H_4BrF_3O$: C, 23.41; H, 1.95; *MR*, 28.87.[18] Found: C, 23.68; H, 1.70; *MR*, 29.03.

3-Bromo-1,1,1-trifluoro-2-butanol.—A solution of 5.0 g. (0.13 mole) of lithium aluminum hydride in 75 ml. of anhydrous ether was added to a stirred solution of 100 g. (0.49 mole) of 3-bromo-1,1,1-trifluoro-2-butanone in 500 ml. of anhydrous ether in a Dry-Ice cooled bath during 2 hr. The product was taken up in ether after hydrolysis with hydrochloric acid. The ether solution was dried and the ether removed by distillation. The residue was rectified to give 76.3 g. (76%) of product, b.p. 130 to 132.1°, n^{20}_D 1.4012 to 1.4072. Rerectification of a center fraction gave slight decomposition, but a center fraction had b.p. 60.0° (48 mm.), n^{20}_D 1.4068, d^{25}_4 1.6771.

Anal. Calcd. for $C_4H_6BrF_3O$: C, 23.21; H, 2.92; *MR*, 30.38. Found: C, 23.60; H, 3.26; *MR*, 30.21.

1,1,1-Trifluoro-2,3-epoxybutane.—3-Bromo-1,1,1-trifluoro-2-butanol (44.3 g., 0.22 mole) was added dropwise to 125 g. of a solution of 20% sodium hydroxide at 100°. The product was flashed off and was collected in a Dry-Ice cooled trap. Rectification from calcium hydride gave 14.92 g. (54%) of 1,1,1-trifluoro-2,3-epoxybutane, b.p. 58.0°, n^{20}_D 1.3168, d^{25}_4 1.1961.

Anal. Calcd. for $C_4H_5F_3O$: C, 38.10; H, 4.00; *MR*, 20.54. Found: C, 37.87; H, 4.19; *MR*, 20.61.

2-Methyl-3-bromo-1,1,1-trifluoro-2-propanol.—A solution of 1 mole of methylmagnesium bromide in 1 lb. of anhydrous ether was added to a stirred solution of 191 g. (1.0 mole) of 3-bromo-1,1,1-trifluoropropanone[19] in 2 lb. of anhydrous ether at −78° over 2 hr. The mixture was hydrolyzed by pouring into an ice–hydrochloric acid mixture. The product was taken up in ether, dried and the ether removed by distillation. Rectification of the residue gave 160 g. (77%) of product, b.p. 59.6° (48 mm.), n^{20}_D 1.4048, d^{25}_4 1.6997.

Anal. Calcd. for $C_4H_6BrF_3O$: C, 23.21; H, 2.92; *MR*, 30.38. Found: C, 23.41; H, 2.92; *MR*, 29.68.

2-Methyl-1,1,1-trifluoro-2,3-epoxypropane.—3-Bromo-2-methyl-1,1,1-trifluoro-2-propanol (30.0 g., 0.15 mole) was added dropwise to a stirred solution of 75.0 g. of 20% sodium hydroxide solution at 28°. Stirring was then stopped and the product was removed by distillation. Rectification of the distillate from calcium hydride gave 12.12 g. (64%) of product, b.p. 55.0°, n^{20}_D 1.3137, d^{25}_4 1.1935.[20]

Anal. Calcd. for $C_4H_5F_3O$: C, 38.10; H, 4.00; *MR*, 20.54. Found: C, 38.00; H, 4.01; *MR*, 20.46.

Acid-catalyzed Addition of Ethanol to 1,1,1-Trifluoro-2,3-epoxybutane.—1,1,1-Trifluoro-2,3-epoxybutane (35.00 g., 0.28 mole) was added to a solution of 1.00 g. of concentrated sulfuric acid in 140 g. of absolute ethanol, and the mixture was heated under reflux for 72 hr. The product was rapidly distilled and then rectified to give 26.02 g. (54%) of 3-ethoxy-1,1,1-trifluoro-2-butanol, b.p. 60.0° (49.0 mm.), n^{20}_D 1.3630 to 1.3632, d^{25}_4 1.1498.

Anal. Calcd. for $C_6H_{11}F_3O_2$ (VII): C, 41.85; H, 6.44; *MR*, 33.50. Found: C, 41.99; H, 6.66; *MR*, 33.06.

There was obtained an additional 3.19 g. of material, b.p. 49 to 77° (23 mm.), n^{20}_D to 1.3702, which was shown by quantitative infrared analysis to contain less than 0.11 g. (0.4%) of the isomeric 3-ethoxy-4,4,4-trifluoro-2-butanol. Of the cleavage product isolated, therefore, greater than 99.6% cleavage occurred to give VII.

A fraction, b.p. 77 to 78° (23 mm.), 3.77 g. (9%), partially solidified upon cooling, m.p. 66.5 to 67.2° from benzene, and gave no depression with an authentic sample of 1,1,1-trifluoro-2,3-butanediol.

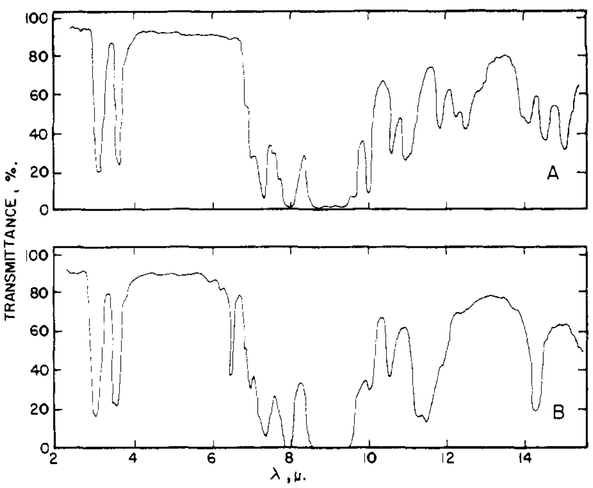

Fig. 1.—Infrared spectra: A, 3-ethoxy-1,1,1-trifluoro-2-butanol; B, 3-ethoxy-4,4,4-trifluoro-2-butanol.

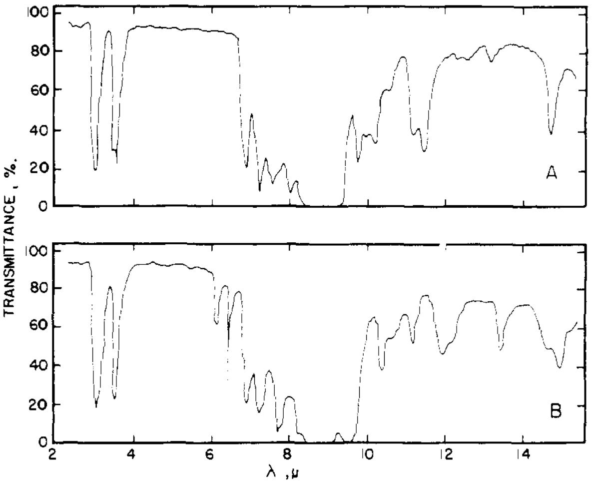

Fig. 2.—Infrared spectra: A, 3-ethoxy-2-methyl-1,1,1-trifluoro-2-propanol; B, 2-ethoxy-2-methyl-3,3,3-trifluoro-1-propanol.

Anal. Calcd. for $C_4H_7F_3O_2$: C, 33.34; H, 4.90. Found: C, 33.14; H, 4.91.

Ethoxide-catalyzed Addition of Ethanol to 1,1,1-Trifluoro-2,3-epoxybutane.—A solution of 19.0 g. (0.15 mole) of 1,1,1-trifluoro-2,3-epoxybutane was added to a solution of 3.5 g. (0.15 mole) of sodium in 55.0 g. of absolute ethanol at 0°. After 0.5 hr. the mixture was heated under reflux for 0.5 hr. The mixture was neutralized with a solution of sulfuric acid in ethanol, added to water and the product was taken up in ether and dried. Rectification gave 7.27 g. (25%) of liquid product, b.p. 59.2° to 62° (47.0 mm.), n^{20}_D 1.3654 to 1.3632. A center fraction gave an infrared spectrum almost identical with that from the acid-catalyzed reaction. Quantitative infrared analysis of the end fractions indicated a maximum of 0.03 g. (0.4%) of the isomeric 3-ethoxy-4,4,4-trifluoro-2-butanol. Over 99.6% of the monomeric product isolated from the cleavage reaction consisted therefore of 3-ethoxy-1,1,1-trifluoro-2-butanol (VII).

Acid-catalyzed Addition of Ethanol to 2-Methyl-1,1,1-trifluoro-2,3-epoxypropane.—2-Methyl-1,1,1-trifluoro-2,3-epoxypropane (35.0 g., 0.28 mole) was added to a solution of 1.00 g. of concentrated sulfuric acid in 140.0 g. of absolute ethanol, and the mixture was heated under gentle reflux for 48 hr. The bulk of the ethanol solvent and unreacted epoxide was removed by distillation. The residue was rapidly distilled to 100° (5 mm.) and then rectified to give

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[18] Atomic refraction fluorine taken as 1.24; R. D. Fowler, *et al.*, *Ind. Eng. Chem.*, **39**, 375 (1947).

[19] E. T. McBee and T. M. Burton, THIS JOURNAL, **74**, 3902 (1952).

[20] O. R. Pierce, D. D. Smith and R. M. Murch, Bimonthly Report No. 2, Contract No. AF 33(616)-2417, August 12, 1954, p. 5, report b.p. 56°, n^{25}_D 1.3125, d^{20}_4 1.192.

34.80 g. (72%) of 3-ethoxy-2-methyl-1,1,1-trifluoro-2-propanol (VIII), b.p. 60.0 to 60.7° (49.5 mm.), n^{20}_{D} 1.3631 to 1.3633, d^{25}_{4} 1.1504. After the distillation had ceased, the pressure of the system was lowered and an additional 1.87 g. of higher boiling liquid was obtained, b.p. to 92° (11 mm.), n^{20}_{D} to 1.3739, which was shown by careful quantitative infrared analysis to contain less than 20% of the isomeric 2-ethoxy-2-methyl-3,3,3-trifluoro-1-propanol. Of the total cleavage product isolated from this reaction, over 99% consisted of VIII.

Anal. Calcd. for $C_6H_{11}F_3O_2$ (VIII): C, 41.85; H, 6.44; *MR*, 33.50. Found: C, 42.12; H, 6.51; *MR*, 33.06.

Ethoxide-catalyzed Addition of Ethanol to 2-Methyl-1,1,1-trifluoro-2,3-epoxypropane.—A solution of 19.0 g. (0.15 mole) of 2-methyl-1,1,1-trifluoro-2,3-epoxypropane in 20.0 g. of ethanol was added to a solution of 3.5 g. (0.15 mole) of sodium in 55.0 g. of ethanol under nitrogen atmosphere at 0°. The mixture was stirred for 1 hr. and then heated under reflux for 0.5 hr. The mixture was made slightly acidic by the addition of a mixture of 12.0 g. of sulfuric acid dissolved in 10.0 g. of ethanol. The precipitate was removed by filtration; the filtrate was rapidly distilled and then rectified to yield 19.3 g. (63.5%) of 3-ethoxy-2-methyl-1,1,1-trifluoro-2-propanol, b.p. 46.7° (24 mm.), n^{20}_{D} 1.3632, which had an infrared spectrum identical with that for VIII.

3-Nitro-1,1,1-trifluoro-2-butanol.—Anhydrous granular potassium carbonate (10 g.) was added to a mixture of 116 g. (1.0 mole) of fluoral hydrate and 82 g. (1.1 moles) of nitroethane. The mixture was heated at 50 to 60° with stirring for 3 hr. and allowed to stand 5 hr. Water was added to dissolve the potassium carbonate and the mixture was then saturated with sodium chloride and made acidic with hydrochloric acid. The lower layer was removed. The upper layer was extracted with three 100-ml. portions of ether, combined with the lower layer and dried. The ether was distilled and the residue was rectified from a trace of boric acid to give 113.8 g. (66%) of 3-nitro-1,1,1-trifluoro-2-butanol, b.p. 76.0° (9.0 mm.), n^{20}_{D} 1.3846, d^{25}_{4} 1.4430.

Anal. Calcd. for $C_4H_6F_3NO_3$: C, 27.75; H, 3.49; *MR*, 28.24. Found: C, 27.61; H, 3.29; *MR*, 27.95.

Dehydration of 3-Nitro-1,1,1-trifluoro-2-butanol with Phosphorus Pentoxide in Xylene Dispersant.—3-Nitro-1,1,1-trifluoro-2-butanol (50.0 g., 0.29 mole) was added to a stirred suspension of 43.0 g. (0.3 mole) of phosphorus pentoxide in 250 ml. of xylene. The mixture was heated slowly to reflux under a variable take-off reflux head, allowed to cool and then reheated to reflux as all material with b.p. less than 125° was slowly removed. Rerectification of the distillate gave 27.3 g. (58%) of crude product, b.p. 95 to 110°, n^{20}_{D} 1.3940, which was assumed to be 3-nitro-1,1,1-trifluoro-2-butene.

2-Ethoxy-3-nitro-1,1,1-trifluorobutane.—A solution of 50.0 g. (0.32 mole) of 3-nitro-1,1,1-trifluoro-2-butene was added to a solution of 7.6 g. (0.33 mole) of sodium in 200 ml. of absolute ethanol at 0°. After 5 min. gaseous hydrogen chloride was passed over the mixture until it suddenly became colorless. After 12 hr. the sodium chloride was removed by filtration, and the filtrate was rectified to give 30.72 g. (47.5%) of 2-ethoxy-3-nitro-1,1,1-trifluorobutane, b.p. 57.0° (14.5 mm.), n^{20}_{D} 1.3750, d^{25}_{4} 1.2319.

Anal. Calcd. for $C_6H_{10}F_3NO_3$: C, 35.83; H, 5.01; *MR*, 37.59. Found: C, 36.10; H, 5.30; *MR*, 37.20.

3-Ethoxy-4,4,4-trifluoro-2-butanamine Hydrochloride.—A solution of 57 g. (0.29 mole) of 2-ethoxy-3-nitro-1,1,1-trifluorobutane in 200 ml. of absolute ethanol was reduced with hydrogen in the presence of Raney nickel in a Parr bomb over a period of 24 hr. The Raney nickel was removed by filtration and a calculated quantity of gaseous hydrogen chloride was passed into the mixture. Solvent was removed under reduced pressure. Recrystallization from ethyl acetate gave 10 g. (18%) of a solid, m.p. 139.5 to 140.5°.

Anal. Calcd. for $C_6H_{13}ClF_3NO$: C, 34.71; H, 6.31. Found: C, 34.72; H, 6.60.

Diazotization of 3-Ethoxy-4,4,4-trifluoro-2-butanamine.—A pre-cooled solution of 14.5 g. (0.21 mole) of sodium nitrite in 25 ml. of water was added to a solution of 15.8 g. (0.08 mole) of 3-ethoxy-4,4,4-trifluoro-2-butanamine hydrochloride in 50 ml. of water at 0°. This mixture was gradually heated to 45° as 30 ml. of 1 *N* hydrochloric acid was slowly added. A crude distillate was obtained, 2.9 g., b.p. to 76°, which was assumed to be 2-ethoxy-1,1,1-trifluoro-2-butene.

The product in the aqueous layer was taken up in three 30-ml. portions of ether, dried and rectified to give 4.06 g. (26%) of liquid, b.p. 65 to 68.5° (51 mm.), n^{20}_{D} 1.3641 to 1.3679. This product was combined with that from two other similar reactions and rerectified to 4.53 g. of liquid product, b.p. 67.6° (48.0 mm.), n^{20}_{D} 1.3680, d^{25}_{4} 1.169, which gave a weakly positive ceric nitrate test and was assumed to be 3-ethoxy-4,4,4-trifluoro-2-butanol (IX).

Anal. Calcd. for $C_6H_{11}F_3O_2$ (IX): C, 41.85; H, 6.44; *MR*, 33.50. Found: C, 41.95; H, 6.58; *MR*, 32.86.

2-Methyl-3-nitro-1,1,1-trifluoro-2-propanol.—Diethylamine (10 g.) was added slowly to a stirred mixture of 164 g. (1.47 moles) of 1,1,1-trifluoropropanone and 122 g. (2.0 moles) of nitromethane cooled to 0° in an ice-bath. After 1 hr. the mixture was allowed to warm to 25° over a 1 hr. period and poured into an ice–hydrochloric acid mixture. The product was taken up in ether, dried over magnesium sulfate and the ether was evaporated. Distillation of the residue gave 172 g. of crude liquid product. A center fraction had b.p. 82 to 83.0° (28 mm.), n^{20}_{D} 1.3842, d^{25}_{4} 1.4443.

Anal. Calcd. for $C_4H_6F_3NO_3$: C, 27.75; H, 3.49; *MR*, 28.24. Found: C, 27.95; H, 3.80; *MR*, 27.99.

Dehydration of 2-Methyl-3-nitro-1,1,1-trifluoro-2-propanol with Phosphorus Pentachloride.—A mixture of 100.0 g. (0.58 mole) of 2-methyl-3-nitro-1,1,1-trifluoro-2-propanol and 125.0 g. (0.60 mole) of phosphorus pentachloride were heated slowly to 145° and the mixture of phosphorus oxychloride and nitroölefin which formed distilled directly into a cooled flask containing 200 ml. of water. After 12 hr. the product was taken up in ether, washed with water and sodium bicarbonate solution, dried and rectified from a trace of boric acid to give 43.6 g. (40%) of a green liquid assumed to be 2-methyl-1-nitro-3,3,3-trifluoropropene, b.p. 52 to 55° (90 mm.).

2-Ethoxy-2-methyl-3-nitro-1,1,1-trifluoropropane.—A mixture of 51.7 g. (0.33 mole) of 2-methyl-1-nitro-3,3,3-trifluoropropene and 118.3 g. of absolute ethanol was heated under reflux for 40 hr. The mixture was rectified to give 13.2 g. (16%) of liquid, b.p. 71.6° (43.5 mm.), n^{20}_{D} 1.3768. The analysis corresponds to that for the original nitroolefin, but the compound was colorless and had a higher boiling point.

Anal. Calcd. for $C_4H_4F_3NO_2$: C, 30.98; H, 2.60. Found: C, 31.27; H, 2.83.

A second liquid was also obtained and was assumed to be 2-ethoxy-2-methyl-3-nitro-1,1,1-trifluoropropane. A center fraction had b.p. 86° (39.5 mm.), n^{20}_{D} 1.3854, d^{25}_{4} 1.2756.

Anal. Calcd. for $C_6H_{10}F_3NO_3$: C, 35.58; H, 5.01; *MR*, 37.59. Found: C, 35.83; H, 5.01; *MR*, 36.79.

2-Ethoxy-2-methyl-3,3,3-trifluoropropanamine Hydrochloride.—A solution of 10.4 g. (0.05 mole) of 2-ethoxy-2-methyl-3-nitro-1,1,1-trifluoropropane in 62 ml. of absolute ethanol was reduced with hydrogen over 3 g. of Raney nickel in a Parr hydrogenation apparatus. The solution was filtered to remove the nickel and treated with a calculated amount of gaseous hydrogen chloride. There was isolated by removal of solvent under reduced pressure 7.1 g. (66%) of amine hydrochloride. Recrystallization from ethyl acetate gave a white solid, m.p. 165.2 to 165.7°.

Anal. Calcd. for $C_6H_{13}ClF_3O$: C, 34.71; H, 6.31. Found: C, 34.70; H, 6.58.

Diazotization of 2-Ethoxy-2-methyl-3,3,3-trifluoropropanamine.—A precooled solution of 8.3 g. (0.12 mole) of sodium nitrite in 15 ml. of water was added to a solution of 7.0 g. (0.03 mole) of 2-ethoxy-2-methyl-3,3,3-trifluoropropanamine hydrochloride in 30 ml. of water at 0°. The mixture was allowed to warm to room temperature with occasional stirring and slow addition of 30 ml. of 1 *N* hydrochloric acid. After 1.5 hr., the mixture was heated on a steam-bath until the gas evolution stopped completely. The product was taken up in ether and dried. The residue was combined with that from a duplicate run and rectified to give 2.48 g. of 2-ethoxy-2-methyl-3,3,3-trifluoro-1-propanol, b.p. 70.0° (50.0 mm.), n^{20}_{D} 1.3750, d^{25}_{4} 1.198.

Anal. Calcd. for $C_6H_{11}F_3O_2$: C, 41.85; H, 6.44; *MR*, 33.50. Found: C, 41.53; H, 6.49; *MR*, 32.82.

Analytical Method.—The product from each cleavage reaction was carefully rectified to remove the lower boiling alcohol. The end-run fractions were analyzed quantitatively by their infrared spectra by a slight modification of the technique described previously.[1] In the case of a mixture of 3-ethoxy-1,1,1-trifluoro-2-butanol (VII) and 3-ethoxy-4,4,4-trifluoro-2-butanol (IX), a base line was drawn across absorption minima characteristic of both spectra at 6.05 and 13.35 μ. A calibration curve was established on the basis of the ratio of the distance measured from the base line to the absorption minimum at 10.3 μ and to the curve at 11.5 μ. The latter point is an absorption minimum for VII and an absorption maximum for IX. The calibration data are summarized in Table II.

Quantitative estimation of mixtures of 3-ethoxy-2-methyl-1,1,1-trifluoro-2-propanol (VIII) and 2-ethoxy-2-methyl-3,3,3-trifluoro-1-propanol (X) was accomplished on the basis of a shift in the location of a peak at 13.15 μ in VIII and 13.35 μ in the latter. The general shape of the spectra was also used since no technique analogous to the above was applicable.

TABLE II

INFRARED DATA FOR MIXTURES OF 3-ETHOXY-1,1,1-TRIFLUORO-2-BUTANOL (VII) AND 3-ETHOXY-4,4,4-TRIFLUORO-2-BUTANOL (IX)

Composition, %		Distance to base line[a]		
VII	IX	B (10.3 μ)	A (11.5 μ)	A/B
100.0	0.0	17.1	7.0	0.41
94.0	6.0	17.0	15.2	0.90
88.4	11.6	16.5	19.3	1.17
0.0	100.0	15.3	67.0	4.28

[a] Base line between absorption minima at 6.05 and 13.35 μ.

WEST LAFAYETTE, INDIANA

[CONTRIBUTION FROM THE STERLING CHEMISTRY LABORATORY, YALE UNIVERSITY]

The Preparation and Deamination of Some 1,3-Amino Alcohols

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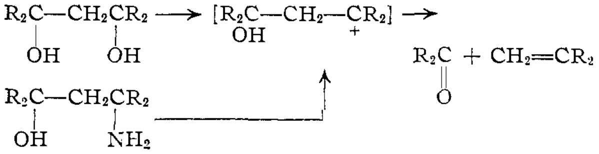
Some 1,3-amino alcohols have been synthesized and their deamination with nitrous acid studied. Evidence is presented for the cleavage of some of these substances into carbonyl compounds and olefins, analogous to the reaction observed in the dehydration of 1,3-diols.[2]

The mechanism recently proposed[2] for the acid-catalyzed cleavage of 1,3-diols leads to the prediction that other compounds capable of producing carbonium ions of analogous structure to those derived from 1,3-diols should also exhibit cleavage of carbon-to-carbon bonds. One such example would be 1,3-amino alcohols, which with nitrous acid should behave as



$$\underset{\text{OH}}{\text{R}_2\text{C}}\text{—CH}_2\underset{\text{OH}}{\text{CR}_2} \longrightarrow [\underset{\text{OH}}{\text{R}_2\text{C}}\text{—CH}_2\text{—}\overset{+}{\text{CR}_2}] \longrightarrow \text{R}_2\text{C}{=}\text{O} + \text{CH}_2{=}\text{CR}_2$$

$$\underset{\text{OH}}{\text{R}_2\text{C}}\text{—CH}_2\underset{\text{NH}_2}{\text{CR}_2}$$

We have undertaken, therefore, the study of the synthesis and nitrous acid deamination of some substituted 1,3-amino alcohols. It was predicted from the diol work[2] that substitution, especially by aromatic groups, would be favorable to the cleavage reaction and several synthetic approaches capable of leading to the desired types were investigated. The compounds synthesized are shown in Table I.

The reaction of β-amino ketones with Grignard reagents[3] and also their reduction[4] has been reported to give poor yields of amino alcohols due to loss of ammonia. Our experience has confirmed this in the reaction of diacetoneamine with methylmagnesium iodide, which gave only 2% of crude amine, and its reduction to 2-methyl-2-amino-4-pentanol (I) in 14% yield. The reduction of cyano-ketones leads in general to 1,3-amino alcohols, and this method was applied to the preparation of 1-phenyl-3-amino-1-propanol (IV). In view of the failure of these amino alcohols having the amino group on primary carbon atoms (IV and V) to undergo cleavage, this method was not further pursued. Attempts were made to react nitroethane and 2-nitropropane with ethylene oxide and with styrene oxide in basic media. This would lead to 1,3-nitro alcohols, presumably reducible to amino alcohols; in all cases, however, the nitro paraffins were recovered unchanged, accompanied by some polymerized epoxide.

A promising and apparently general method for the preparation of 1,3-amino alcohols in which R_3 and R_4 are the same (VII and VIII) was found in the reaction of Grignard reagents with acetylated β-aminoesters. Adamson[5] and McKenzie[6] report relatively poor yields in this type of reaction with free amino esters where the amino group is primary, although the secondary and tertiary analogs seem satisfactory. Protection of the amino group by acetylation apparently decreases the amount of elimination of ammonia (or amide), and we obtained the N-acetylated amino alcohols in 40–60% yield; hydrolysis to the free bases occurred smoothly and almost quantitatively.

Stühmer and Frey[7] have reported the preparation of both diastereomers of 1,3-diphenyl-1-amino-3-propanol (VI) by reduction of 3,5-diphenylisoxazoline derived from benzal-acetophenone. An analogous reduction of 3,5-diphenylisoxazole (prepared from dibenzoylmethane) gave satisfac-

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[1] Taken from the dissertation submitted by Arthur D. Bliss to the Graduate School of Yale University in partial fulfillment of the requirements for the Ph.D. degree (1955).

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