acid under cooling. The solution was extracted three times with ethyl ether; the ether extracts were washed with water, dried over sodium sulfate, and evaporated to dryness. The oily residue crystallized on standing; on recrystallization from 1800 ml. of benzene–petroleum ether (1:1) 15.8 g. of (−)-α-methyltropic acid were obtained, m.p. 89–90°; $[\alpha]_D^{20}$ −28.3° (*c* = 2, ethanol).

Anal. Calcd. for $C_{10}H_{12}O_3$: C, 66.60; H, 6.71. Found: C, 66.85; H. 6.87.

(b) (+)-*α-Methyltropic acid.* To a warm solution of 13.51 g. of *dl*-α-methyltropic acid,[5,6] m.p. 89–90°, in 54 ml. of absolute ethanol was added 20.6 g. of brucine free base in 54 ml. of warm water. The mixture was refluxed until complete solution was obtained, then allowed to stand overnight. The precipitate, 10 g., was collected by suction, dried *in vacuo* and recrystallized from 250 ml. of a 1:1 mixture of ethyl acetate–95% ethanol with the addition of charcoal. After standing some hours 4.6 g. of brucine (+)-α-methyltropate were collected; m.p. 209–212°; $[\alpha]_D^{20}$ −19.22° (*c* = 2, ethanol).

Anal. Calcd. for $C_{23}H_{26}N_2O_4{\cdot}C_{10}H_{12}O_3$: N, 4.87. Found: N, 5.11.

The brucine (+)-α-methyltropate may also be prepared from the mother liquors of the first crystallization of quinine (−)-α-methyltropate after separating the free acid by acidification.

The brucine (+)-α-methyltropate (3.8 g.) was treated as described above for quinine (−)-α-methyltropate. The crude product was recrystallized from 60 ml. of benzene–petroleum ether (1:1) with addition of charcoal. Yield 0.5 g. of colorless needles melting at 88–90°; $[\alpha]_D^{20}$ +27° (*c* = 2, ethanol).

Anal. Calcd. for $C_{10}H_{12}O_3$: C, 66.60; H, 6.71. Found: C, 66.46; H, 6.69.

β-Acetoxy-α-methyl-α-phenylpropionyl chlorides. Example for dl-derivative. A mixture of 13.5 g. of *dl*-α-methyltropic acid and 27 ml. of acetyl chloride was refluxed for 0.5 hour, then the excess of acetyl chloride was removed *in vacuo*. The oily residue was treated with 70 ml. of thionyl chloride and refluxed 1 hr. The excess thionyl chloride was distilled and the residue distilled from a Claisen flask to give 11.2 g. of product, b.p. 113–116°/1 mm. The distilled compound solidified on standing and was recrystallized from 70 ml. of petroleum ether: yield 10.6 g. (59%), m.p. 66–69°.

Anal. Calcd. for $C_{12}H_{13}ClO_3$: Cl, 14.74. Found: Cl, 14.51.

The (+)- and (−)-derivative were prepared, starting from the (+)- and (−)-α-methyltropic acid respectively, as described for the *dl*-derivative. The (+)- and (−)-isomers were not distilled from the Claisen flask and isolated in a pure state but employed as such for the following condensation with tropine.

α-Methylatropine (tropine dl-α-methyltropate). *dl*-β-Acetoxy-α-methyl-α-phenylpropionyl chloride (5.8 g.) and tropine free base[10] (4.2 g.), thoroughly mixed, were heated for 5 hr. at 150°. The mixture turned to brown and gas was evolved. After cooling to room temperature, the mixture was treated with 60 ml. of warm water, then with charcoal, and filtered from the scanty undissolved residue. The filtrate was adjusted to *p*H 9 with a saturated solution of sodium carbonate, extracted with ethyl ether and the ether extract dried over sodium sulfate and filtered. The filtrate was made acidic to Congo red by treatment with a saturated ether solution of hydrogen chloride. A thick oil separated, which was decanted from the ether and dissolved in 20 ml. of water. Two drops of 10% hydrochloric acid were added to this solution and the mixture was allowed to stand 15 hr. at room temperature, in order to hydrolyze the *O*-acetyl group. A saturated solution of sodium carbonate was then added, the separated oil extracted with ethyl ether, dried over sodium sulfate, and concentrated to a final volume of 20 ml. On cooling and rubbing α-methylatropine precipitated in the form of white fine crystals. Yield 0.9 g.; m.p. 131–133°.

Anal. Calcd. for $C_{18}H_{25}NO_3$: C, 71.25; H, 8.30; N, 4.61. Found: C, 71.04; H, 8.29; N, 4.79.

(−)-*α-Methylhyoscyamine [tropine (−)-α-methyltropate].* A mixture of 3.74 g. of tropine free base, 6.24 g. of (−)-β-acetoxy-α-methyl-α-phenylpropionyl chloride and 4 ml. of anhydrous toluene was heated for 4 hr. at 120–125°, then cooled, treated with 65 ml. of water and acidified to *p*H 1 with 10% hydrochloric acid. The mixture was extracted with ethyl ether,, the aqueous layer adjusted to *p*H 8.3 with a saturated solution of sodium carbonate and extracted with ethyl ether. This ether extract was dried over sodium sulfate, and acidified to *p*H 1 with a saturated ether solution of hydrogen chloride. The ether was decanted and the oily residue treated with 35 ml. of water, acidified with 5 drops of 10% hydrochloric acid, and allowed to stand 15 hr., to hydrolyze the *O*-acetyl group. The mixture was adjusted to *p*H 8.5 with a saturated solution of sodium carbonate, extracted with ethyl ether, the extract washed with water, dried over sodium sulfate and made acidic with a saturated ether solution of hydrogen chloride. The ether was decanted, the residual oil treated with boiling ethyl acetate with the addition of charcoal and filtered. After standing some days 0.470 g. of crystalline (−)-α-methylhyoscyamine hydrochloride were collected; m.p. 210–212°; $[\alpha]_D^{20}$ −6.8° (*c* = 1, water).

Anal. Calcd. for $C_{18}H_{25}NO_3{\cdot}HCl$: C, 63.51; H, 7.42; N, 4.12; Cl, 10.4. Found: C, 64.01; H, 7.50; N, 4.09; Cl, 10.2.

(+)-*α-Methylhyoscyamine [tropine (+)-α-methyltropate]* was prepared exactly as described for (−) isomer starting from 3.99 g. of tropine free base, 6.63 g. of (+)-β-acetoxy-α-methyl-α-phenylpropionyl chloride and 4 ml. of anhydrous toluene. Yield, 0.735 g. of crystalline (+)-α-methylhyoscyamine hydrochloride, m.p. 210–211.5°: $[\alpha]_D^{20}$ +7.3° (*c* = 1, water).

Anal. Calcd. for $C_{18}H_{25}NO_3{\cdot}HCl$: C, 63.61; H, 7.42; N, 4.12; Cl, 10.4. Found: C, 63.49; H, 7.95; N, 3.70; Cl, 10.85.

Acknowledgment. We wish to thank Prof. R. Fusco for the useful discussion on this subject during our experimental work and Dr. A. Wittgens for the assistance in the preparation of the manuscript. We also gratefully acknowledge Dr. G. G. Gallo and Mr. L. Chiesa who carried out the infrared spectra and measured the optical dispersion curve. The microanalyses have been carried out by Mr. Restelli of the Microanalytical Department of Lepetit S.p.A.

RESEARCH LABORATORIES OF LEPETIT S.P.A.
MILANO, ITALY

(10) Fluka, A. G., Buchs (Switzerland).

Autoxidation of Trialkylboranes

N. L. ZUTTY AND F. J. WELCH

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It has been postulated by Johnson and Van Campen[1] that the oxidation of trialkylboranes to the corresponding alkylboronates (II) proceeds through an intermediate (I) containing a boron

(1) J. R. Johnson and M. G. Van Campen, *J. Am. Chem. Soc.*, **60**, 121 (1938).

$$R_3B + O_2 \longrightarrow [R_3B \longleftarrow O_2] \longrightarrow RB(OR)_2$$
$$\text{I} \qquad \text{II}$$

oxygen dative bond. More recently it has been shown that peroxides of the structure, R_2BOOR, are also intermediates in this autoxidation.[2,3] We wish to describe some observations which indicate that a molecular complex between oxygen and the trialkylborane is an intermediate in the formation of the boron peroxides.

Studies were made on the rate of formation of peroxide in dilute hydrocarbon solutions of tri-*n*-butylborane through which oxygen had been bubbled. In these experiments a molar equivalent of oxygen was passed rapidly through the dilute boron alkyl solution. Nitrogen was then passed through the solution to remove unreacted, dissolved oxygen and to provide an inert atmosphere, whereupon aliquots were withdrawn at intervals and the yield of peroxide determined iodometrically. The results of a typical experiment are illustrated in Figure 1.

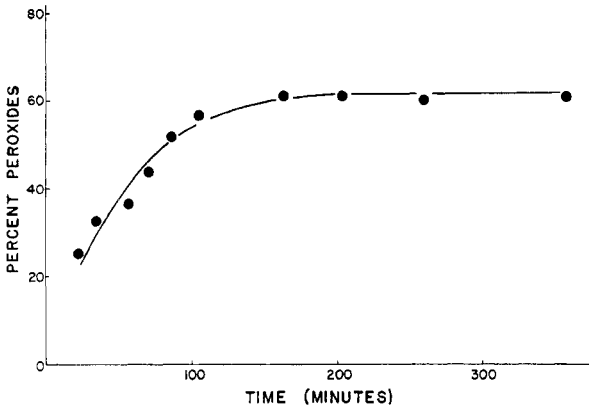

Fig. 1. Peroxide formation at 26°

Although there was presumably no dissolved oxygen in the system it is apparent that the yield of peroxide increased with time. This can best be explained by the initial and rapid formation of a nonperoxidic compound of oxygen with the trialkylborane, perhaps having the structure (I); followed by the slower rearrangement of this complex to the peroxide.

At temperatures of −10° or above in the presence of excess oxygen one mole of peroxide was produced per mole of boron alkyl (Table I). This is in agreement with the observations of Petry and Verhoek.[2] At lower temperatures, however, the stoichiometry is not so well defined, but it is apparent that considerably more than one mole of peroxide results. Another difference noticed at the lower temperatures was an increased rate of peroxide formation.

TABLE I

PREPARATION OF *n*-BUTYLBORON PEROXIDES BY THE PASSAGE OF A TEN-FOLD MOLAR EXCESS OF OXYGEN THROUGH A ONE-WEIGHT PER CENT SOLUTION OF TRI-*n*-BUTYLBORANE

Run	Solvent	Moles Peroxide / Moles Bu_3B	T, °
1	Benzene	0.96	26
2	Benzene	1.04	26
3	Iso-octane	1.00	−10
4	Iso-octane	1.05	−10
5	*n*-Heptane	1.92	−78
6	*n*-Heptane	1.55	−78

The reason for the more rapid formation of peroxide in increased yield at the lower temperatures is not evident from our data. It may indicate that at low temperatures where the concentration of oxygen is high the initial complex of boron and oxygen reacts further with oxygen to rapidly form a diperoxide.

The decomposition of one-weight per cent solutions of the resulting boron peroxide in iso-octane was also studied briefly. No significant decomposition was observed at 25° in fifty hours. However, at 50° and 100° the half-lives for the decomposition were forty-three and one and a half hours, respectively.

EXPERIMENTAL

Purification of materials. Reagent grade hydrocarbons were dried over sodium and distilled. Center cuts were used.

The tri-*n*-butylborane was obtained from the Callery Chemical Co. and distilled at reduced pressure. Center cuts were used, b.p. 48° at 0.5 mm.

The oxygen and nitrogen (Linde Co.) were of very high purity and used as obtained.

Preparation of peroxides. A 1-l., three-necked, round-bottomed flask which had an outer jacket for circulating liquid of the desired temperature was equipped with a "Tru-Bore" stirrer, a fritted glass gas delivery tube, a thermometer, and a Dry Ice condenser to catch vapors swept over by the incoming gas.

To this flask was added 495 g. of the desired solvent. This solvent was purged with nitrogen to rid it of any dissolved air. Then 5.0 g. of tri-*n*-butylborane was added. A known amount of oxygen was admitted through a flowmeter to the stirred solution. The amount of gas passing through the flask was noted on another flowmeter. The rate of oxygen passage was approximately 1 min. per molar equivalent of gas introduced. After the desired amount of oxygen had been passed into the flask the solution was well purged with nitrogen.

Analyses of solutions. The Dry Ice condenser was then replaced by a tube extending to the bottom of the flask which allowed a known volume of solution to be withdrawn from the flask. These aliquots were analyzed for peroxide iodometrically by the method of Siggia.[4]

Tri-*n*-butylborane, di-*n*-butyl(*n*-butoxy)borane, *n*-butyl-(di-*n*-butoxy)borane and dissolved oxygen did not liberate iodine from sodium iodide under these conditions. The sol-

(2) R. C. Petry and F. H. Verhoek, *J. Am. Chem. Soc.*, **78**, 6416 (1956).

(3) A. G. Davies and M. H. Abraham, *Chem. & Ind. (London)*, 1622 (1957).

(4) S. Siggia, *Quantitative Organic Analyses Via Functional Groups*, John Wiley and Sons, Inc., New York, 1949, p. 101.

vents used did not form peroxides, as determined iodometrically, under experimental conditions.

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RESEARCH DEPARTMENT
UNION CARBIDE CHEMICALS CO.
SOUTH CHARLESTON, W. VA.

Reaction of 1-Bromo-2,3-epoxybutane with Phenol in the Presence of Boron Trifluoride

ROBERT F. BRIDGER AND ROBERT R. RUSSELL

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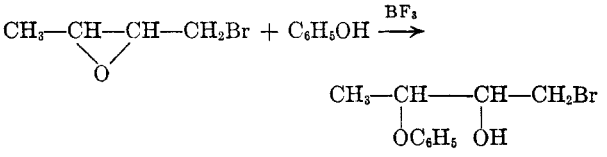
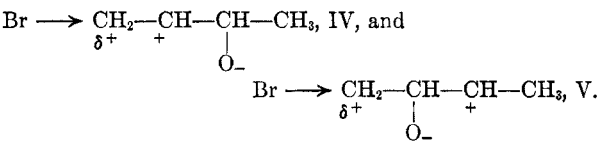
The reaction between 1-bromo-2,3-epoxybutane, I, and phenol in basic solution has been reported[1] to yield 3-phenoxy-1,2-epoxybutane.

In the present work phenol was allowed to react with I in the presence of boron trifluoride to find whether the direction of epoxide ring opening was the same as that reported for the reaction conducted in basic medium. The product of the acid-catalyzed reaction was found to consist chiefly of 1-bromo-3-phenoxy-2-butanol, II.



Dehydrobromination[2] of II at room temperature produced 3-phenoxy-1,2-epoxybutane, III. Upon treatment with silver oxide, III was oxidized to 2-phenoxypropionic acid.

The acid-catalyzed opening[3] of the epoxide ring of I may proceed in either direction, giving two possible carbonium ions:



Species IV would be predicted to be the less stable ion because of the presence of two positive charges (one real, one partial) on adjacent carbon atoms. Since V leads to the formation of II, the adjacent charge rule[3a,4] may be used to explain the predominant formation of that isomer. Such an interpretation is successful in accounting for the exclusive formation of 3-phenoxy-1-chloro-2-propanol[5] during the reaction of epichlorohydrin with phenol in the presence of boron trifluoride.

EXPERIMENTAL

Boiling points and melting points are uncorrected. 1-Bromo-2,3-epoxybutane, b.p. 143–145°, was prepared by the method of Petrov.[6]

Reaction of 1-bromo-2,3-epoxybutane, I, *with phenol.* In a 1-l., three-necked flask was placed a solution of 94 g. (1 mole) phenol and 1 g. boron trifluoride dissolved in 500 ml. benzene. While the temperature was maintained in the range −2° to +2°, 37.7 g. (0.25 mole) of I were added dropwise and with vigorous agitation. The addition required about 30 min. After the addition of I was complete, the solution was stirred for an additional 30 min. Water was then added to destroy the catalyst. The water was removed and the benzene was distilled at reduced pressure. At 15 mm. pressure phenol was removed by distillation in the range 78–90°. The product was 36.7 g. (60% yield) of clear, colorless oil, b.p. 100–105° at 0.3 mm., $n_D^{22°}$ 1.5500, which was found to be 1-bromo-3-phenoxy-2-butanol, II. An attempt to oxidize this compound with sodium hypoiodite was not successful.

Anal. Calcd. for $C_{10}H_{13}O_2Br$: C, 49.10; H, 5.35; Br, 32.60. Found: C, 49.78; H, 5.56; Br, 32.52.

Dehydrobromination of 1-bromo-3-phenoxy-2-butanol, II. A mixture of 35.2 g. of II, 200 ml. ethanol, and 50 ml. of 6*N* sodium hydroxide was shaken vigorously at room temperature for 1 hr. One liter of water was then added, and the product was removed by three extractions with diethyl ether. Analysis of the aqueous phase by the Mohr method indicated 96% removal of the bromine. The ether solution of epoxide was washed with water until neutral and dried over anhydrous calcium sulfate. The residue after removal of the ether was fractionated through a short Vigreux column to give 18.8 g. (80% yield) of 3-phenoxy-1,2-epoxybutane, III, b.p. 74–77° at 0.3 mm., $n_D^{21°}$ 1.5188. The residue was 3 g. of yellowish oil which gave a positive qualitative test for bromine.

Oxidation of 3-phenoxy-1,2-epoxybutane, III. Oxidation of III was carried out by stirring 3 g. of III with 17 g. silver oxide and 50 ml. of 10% sodium hydroxide solution for 18 hr. on the steam bath. The metallic silver was removed by filtration, and the solution was acidified with dilute hydrochloric acid. Several ether extractions yielded 3 g. of crude crystals upon evaporation of the ether. Recrystallization from hot water produced 2.4 g. (79% yield) of 2-phenoxypropionic acid, m.p. 115–116°. The amide and anilide were prepared and found to melt at 131° and 117–118°, respectively. These values are in good agreement with the literature values for 2-phenoxypropionic acid and derivatives.

DEPARTMENT OF CHEMICAL ENGINEERING
MISSOURI SCHOOL OF MINES AND METALLURGY
ROLLA, MO.

(1) R. L. Rowton and R. R. Russell, *J. Org. Chem.*, **23**, 1057 (1958).

(2) The presence of 1-bromo-2-phenoxy-3-butanol was neither proved nor disproved. A small quantity of bromine-containing material remained after treatment of II with sodium hydroxide, but no attempt was made to identify it.

(3) Unimolecular ring opening of the oxonium complex is often accepted as the mechanism of such reactions in acid media. (a) A. A. Petrov, *Chem. Tech. (Berlin)*, 6, 639 (1954). (b) S. Winstein and R. B. Henderson, *Heterocyclic Compounds*, R. C. Elderfield, Ed., John Wiley & Sons, New York, N. Y., 1950, Vol. 1, p. 37.

(4) A. E. Remick, *Electronic Interpretations of Organic Chemistry*, 2nd Ed., John Wiley & Sons, New York, N. Y., 1950, p. 150.

(5) E. Levas, *Ann. chim.*, [12], **3**, 145 (1948).

(6) A. A. Petrov, *J. Gen. Chem. (U.S.S.R.)*, **11**, 713 (1941).