composed of 30 g. of silica[14] impregnated with 21 ml. of ethylene glycol, was loaded with one-third (143 mg.) of the steroid mixture from the Florisil column and developed successively with mixtures of cyclohexane and methylene chloride in the following proportions: 10:1 (360 ml.)[15]; 2:1 (1,020 ml.) and 1:2 (1,620 ml.). A paper chromatographic examination of the ultraviolet absorbing bands recorded by the fraction cutter indicated the 17α-hydroxycorticosterone was eluted by the 1:2 cyclohexane–methylene chloride mixture. The remaining two-thirds of the steroid residue was similarly chromatographed and the 1:2 cyclohexane–methylene chloride effluents from the three columns were combined and concentrated to an ethylene glycol residue containing the 17α-hydroxycorticosterone. The residue was dissolved in 300 ml. of water and the steroid extracted with three 200-ml. portions of ethylene chloride. Following removal of the solvent, the residue was dissolved in acetone from which 17α-hydroxycorticosterone crystallized (112.2 mg., m.p. 193–195°). Recrystallization from methanol gave 98.8 mg. of a product which melted at 208–210°; $[\alpha]^{25}_{\mathrm{D}}$ +160° (*c* 0.324 in acetone).[16] The characterization of the compound as 17α-hydroxycorticosterone was confirmed by mixed melting point, infrared absorption data and paper chromatographic behavior.

Anal. Calcd. for $C_{21}H_{30}O_5$: C, 69.58; H, 8.34. Found: C, 69.54; H, 8.80.

The acetate of the above-mentioned 17α-hydroxycorticosterone was prepared in the usual manner with an acetic anhydride–pyridine mixture. This derivative melted at 212–215°; $[\alpha]^{24.6}_{\mathrm{D}}$ +159° (*c* 0.486 in dioxane). As judged by infrared absorption data, paper chromatographic behavior and the sulfuric acid chromogen test,[17] the 17α-hydroxycorticosterone 21-acetate was pure.

Anal. Calcd. for $C_{23}H_{32}O_6$: C, 68.29; H, 7.98. Found: C, 68.21; H, 7.72.

Acknowledgments.—We are indebted to Dr. J. L. Johnson and Mrs. G. S. Fonken for the infrared analyses, to Mr. W. A. Struck and his associates for the microanalyses and optical rotations, and to Mrs. B. B. Haynes and Messrs. J. J. Appleyard, B. L. Davis, G. H. Lund and H. C. Vanderberg for technical assistance. To Dr. G. F. Cartland, Dr. M. H. Kuizenga and Dr. J. S. Evans we are grateful for their continued support and interest.

KALAMAZOO, MICHIGAN

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(14) Silica for chromatographic columns, manufactured by the G. Fredrick Smith Chemical Company, Columbus, Ohio.

(15) Ratios expressed in volumes of solvent before mixing. The solvent mixtures were saturated with ethylene glycol.

(16) T. Reichstein, *Helv. Chim. Acta*, **20**, 953 (1937).

(17) A. Zaffaroni, THIS JOURNAL, **72**, 3828 (1950).

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY OF DUKE UNIVERSITY]

Brominative Decarboxylation of Silver Salt of Apocamphane-1-carboxylic Acid[1]

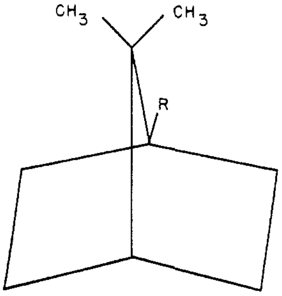
BY PELHAM WILDER, JR., AND ANTHONY WINSTON[2]

RECEIVED FEBRUARY 26, 1953

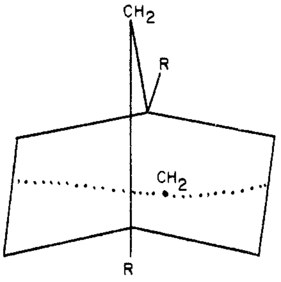
When silver apocamphane-1-carboxylate is brominated in hydrocarbon solution, 1-bromoapocamphane is obtained. When bromination is effected in carbon tetrachloride, a product containing both bromine and chlorine is obtained. The mechanism of the reaction is discussed in terms of these results.

When the silver salt of apocamphane-1-carboxylic acid (I) was treated with bromine in hydrocarbon solution, a neutral substance with a mildly camphoraceous odor was obtained. This substance which contained bromine was inert to alcoholic silver nitrate[3] and was easily reduced by sodium in alcohol to apocamphane (II).[4] It seems certain, then, that the product of the bromination of silver apocamphane-1-carboxylate is 1-bromoapocamphane (III).

Recently Arcus, Campbell and Kenyon reported that active silver α-phenylpropionate gave on reaction in carbon tetrachloride solution α-phenylethyl bromide with inversion of configuration accompanied by some racemization.[5,6] Arcus and his co-workers concluded that inversion of configuration was to be expected and that the reaction was the first established example of a class of replacement reactions in which a bimolecular substitution reaction occurs "with inversion of configuration effected by the electrophilic reagent positive bromine."[7]



I, R = -COOH
II, R = -H
III, R = -Br



IV, R = -Br
V, R = -COOH

These conclusions of Arcus, Campbell and Kenyon seem difficult to defend in light of the isolation of 1,3-dibromoadamantane (IV) by the smooth brominative decarboxylation of the silver salt of adamantane-1,3-dicarboxylic acid (V).[8] This dicarboxylic acid is of such structure that the approach to the rear of the carbon atom bearing the carboxyl group is blocked by the cage formed

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(1) Presented in part at the Southeastern Regional Meeting of the American Chemical Society in Auburn, Alabama, October 25, 1952.

(2) Taken from a thesis submitted by Anthony Winston to the Graduate School of Duke University in partial fulfillment of the requirements for the degree of Master of Arts, May, 1952.

(3) (a) P. D. Bartlett and L. H. Knox, THIS JOURNAL, **61**, 3184 (1939); (b) W. von E. Doering and E. F. Schoenewaldt, *ibid.*, **73**, 2333 (1951).

(4) G. Komppa and T. Hasselstrom, *Ann.*, **496**, 164 (1932).

(5) C. L. Arcus, A. Campbell and J. Kenyon, *J. Chem. Soc.*, 1510 (1949).

(6) Arnold and Morgan have reported that the product of the reaction of bromine with (+)-α-ethylhexanoic acid was optically inactive [THIS JOURNAL, **70**, 4248 (1948)]. They did not determine whether an optically pure sample of the bromide would racemize under the conditions of the reaction. See also the case of bicyclo-[2,2,2]-octane-2-carboxylic acid of Doering and Farber [*ibid.*, **71**, 1514 (1949)].

(7) Reference 5, p. 1511.

(8) V. Prelog and R. Seiweith, *Ber.*, **74B**, 1769 (1941).

by the remainder of the molecule. In the present investigation the isolation of 1-bromoapocamphane[9] furnishes additional evidence to support an hypothesis that decarboxylation need not necessarily, and in some case may not, proceed by a bimolecular displacement mechanism. If the decarboxylation of apocamphane-1-carboxylic acid does proceed by a displacement mechanism, then the displacement must be of a frontal or sideward type, such as the internal (S_Ni) type.

When silver apocamphane-1-carboxylate was brominated in carbon tetrachloride solution at the boiling point of the solvent, a product was obtained which was not identical with 1-bromoapocamphane. The product contained both bromine and chlorine. In an additional experiment, the temperature of the carbon tetrachloride solution was held at −10° until the addition of bromine was complete. The vessel was then allowed to come to room temperature where a brown complex decomposed ,and silver bromide precipitated. The product isolated under these conditions contained considerably less chlorine. These mixed halides were recovered unchanged when refluxed in alcoholic silver nitrate solution; they also produced apocamphane on chemical reduction. All attempts to separate the mixed halides by fractional vacuum sublimation failed.

The isolation of a chlorinated product on bromination of the silver salt in carbon tetrachloride medium indicates strongly a free radical mechanism for this reaction.[10] This observation is consistent with the fact that 1-chloroapocamphane is isolated (in 35% yield) from the decomposition of apocamphoyl peroxide in carbon tetrachloride solution.[11,12] Additional support for a radical mechanism is found in the preparation of neopentyl bromide from silver *t*-butylacetate[13] and in the isolation of small amounts of chlorobenzene in the bromination of silver benzoate in carbon tetrachloride solution.[14]

Experimental[15]

Silver Salt of Apocamphane-1-carboxylic Acid.—The silver salt was prepared according to the method of Smith and Hull[13] with the following modifications. Apocamphane-1-carboxylic acid (26.6 g., 0.158 mole), prepared by the method of Bartlett and Knox,[16] was dissolved in an excess of warm ammonia. Ammonia was boiled off until acid began to precipitate. A few drops of ammonia was then added to redissolve the precipitated acid. Twenty-seven grams (0.158 mole) of silver nitrate in water solution was added dropwise with stirring to the hot ammoniacal solution. The solution was cooled; the silver salt was separated by filtration and washed first with water, then with alcohol and finally with ether. The product was dried over phosphorus pentoxide in a modified Fischer pistol at 80° for several days. A yield of 40 g. (92%) of dry salt was obtained.

Anal. Calcd. for $C_{10}H_{15}O_2Ag$: Ag, 39.2. Found: Ag, 38.9, 39.0.

Bromination of Silver Salt of Apocamphane-1-carboxylic Acid. Procedure A.—To a three-neck flask, fitted with a condenser, dropping funnel and mercury-sealed stirrer, was added 10.0 g. (0.0364 mole) of silver salt along with 150 ml. of unsaturate-free petroleum ether (30–60°), which had been dried over sodium. The reaction vessel was cooled to −10° by an ice–salt-bath and was maintained at that temperature during the addition of 5.9 g. (0.0364 mole) of bromine, dissolved in 5 ml. of petroleum ether. At this point a brown mass was formed; but when the temperature of the vessel was allowed to come to room temperature, the brown complex was decomposed and silver bromide precipitated. The mixture was refluxed for an hour and was then cooled. Silver bromide, which was removed by filtration, was washed with warm solvent. The filtrate was extracted with 10% sodium carbonate solution which upon acidification yielded a small amount of acidic material. The petroleum ether solution was dried and excess solvent removed by distillation. Final traces of solvent were evaporated on a watch glass. A colorless, crystalline solid with a distinctive camphoraceous odor was obtained in 50% yield (3.7 g.). The melting point after five vacuum sublimations was 165–169°.

Anal.[17] Calcd. for $C_9H_{15}Br$: C, 53.21; H, 7.44. Found: C, 53.54; H, 7.13.

Procedure B.—The reaction was carried out in a manner similar to that in procedure A above with the following modifications. The solvent in this case was carbon tetrachloride which had been previously dried over calcium chloride before distillation. Bromine in carbon tetrachloride was added to the silver salt–carbon tetrachloride mixture at the reflux temperature of the solvent. The mixture was refluxed for an hour after the addition of bromine was complete. The product was recovered exactly as in procedure A above. From 9.3 g. (0.034 mole) of silver salt and 5.8 g. (0.036 mole) of bromine was isolated after a single sublimation 4.0 g. of colorless material, with a camphoraceous odor similar to the product above. Material recovered after three sublimations had m.p. 165–169°.

Anal.[17] Calcd. for $C_9H_{15}Br$: C, 53.21; H, 7.44; Br, 39.35; Cl, 0.00. Found: C, 61.09; H, 7.98; Br, 14.56; Cl, 16.06.

Procedure C.—The reaction was carried out under precisely the conditions of procedure A except for the use of carbon tetrachloride as solvent. From 15.0 g. (0.055 mole) of silver salt and 8.8 g. (0.055 mole) of bromine was isolated 6.7 g. of alkyl halide. The melting point after three sublimations was 165–169°.

Anal.[17] Calcd. for $C_9H_{15}Br$: C, 53.21; H, 7.44; Br, 39.35; Cl, 0.00. Found: C, 57.69; H, 7.56; Br, 26.55; Cl, 7.10.

Action of Silver Nitrate upon 1-Bromoapocamphane.—To a solution of 0.50 g. of 1-bromoapocamphane in 50 ml. of ethanol was added 2.0 g. of silver nitrate dissolved in 10 ml. of water. The mixture was refluxed for 48 hours without the appearance of turbidity. The mixture was diluted with water whereupon unreacted bromoapocamphane precipitated. The bromide was recovered and twice sublimed, m.p. 169–171°. On admixture with 1-bromoapocamphane the melting point was 166–169°. Recovery was 0.37 g.

Similar results were obtained when the products of procedures B and C were treated in this manner.

Apocamphane.—To a solution of 1.00 g. of halide in 50 ml. of absolute ethanol was added 2 g. of sodium over a period of two hours at the reflux point of the solution. The solution was then poured into an equal volume of water and about half of the solution was (steam) distilled into a flask immersed in ice-water. When the distillate was diluted with water, a colorless solid resulted. The compound was, though camphoraceous in odor, clearly different from the starting material and extremely volatile. After several

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[9] Cope and Synerholm [THIS JOURNAL, **72**, 5228 (1950)] in their work on the synthesis of carbonyl bridged compounds converted bicyclo[3,3,1]nonan-9-one-1-carboxylic acid into 1-bromobicyclo-[3,3,1]nonan-9-one. The bicyclo[3,3,1]nonane system is less rigid than the apocamphane system and less thoroughly investigated in nucleophilic reactions than 1-chloroapocamphane. [*Cf.* W. von E. Doering, M. Levitz, A. Sayigh, M. Sprecher and W. P. Whelan, Jr., *ibid.*, **75**, 1008 (1953).]

[10] *Cf.* C. C. Price, "Mechanism of Reactions at Carbon–Carbon Double Bonds," Interscience Publishers, Inc., New York, N. Y., 1946, p. 55.

[11] M. S. Kharasch, F. Engelmann and W. H. Urry, THIS JOURNAL, **65**, 2428 (1943).

[12] *Cf.* M. J. S. Dewar, "The Electronic Theory of Organic Chemistry," Oxford University Press, London, 1949, p. 263.

[13] W. T. Smith, Jr., and R. L. Hull, *ibid.*, **72**, 3309 (1950).

[14] W. G. Dauben and H. Tiles, *ibid.*, **72**, 3185 (1950).

[15] Melting points are uncorrected.

[16] Reference 3a, p. 3189.

[17] Microanalysis by Clark Microanalytical Laboratory, Urbana, Ill.

sublimations only 0.10 g. remained, m.p. 86–92° (reported 86°).[4]

Acknowledgment.—The authors wish to express their appreciation to Professor W. C. Vosburgh for his advice and encouragement and to the Duke University Research Council for a grant to one of them (A.W.) during the course of this investigation. The authors also wish to thank the referee for his valuable comment.

DURHAM, N. C.

[CONTRIBUTION FROM THE CHEMISTRY DIVISION, OAK RIDGE NATIONAL LABORATORY]

Molecular Rearrangements. I. The 1,2,2-Triphenylethyl System[1]

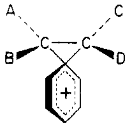
BY WILLIAM A. BONNER AND CLAIR J. COLLINS

RECEIVED MAY 1, 1953

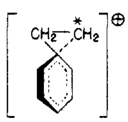
1,2,2-Triphenylethanol-1-C^{14} (I) has been acetylated and the acetate (II) deacetylated with no radiochemical rearrangement. When the carbinol (I) was dehydrated with phosphoric anhydride in xylene, the resulting 1,1,2-triphenylethylene-1,2-C_1^{14} (III) had an equal distribution of radioactivity in the ethylenic carbons. Similarly, when one mole of the acetate (II) was warmed in glacial acetic acid containing a mole of *p*-toluenesulfonic acid, the reisolated acetate contained an equal amount of carbon-14 in each ethylenic position. This rearrangement of acetate II was not observed when sodium acetate was present in the reaction mixture. Formolysis of the tosylate (IV) of carbinol I proceeded with elimination, yielding olefin III in which a net 50% phenyl migration had taken place. Acetolysis of tosylate IV proceeded with 39% phenyl migration, whereas hydrolysis of IV in aqueous acetone proceeded with 22% phenyl migration. The lithium aluminum hydride reduction of IV was attended by 9% phenyl migration. These results are discussed in terms of the presumed symmetrical phenonium ion intermediates.

Introduction

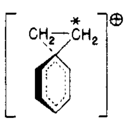
Amplifying the concept of a bridged cationic intermediate originally suggested[2] by Lane and Wallis to account for the stereochemical consequences of certain intramolecular rearrangements, Cram in 1949 introduced[3,4] the concept of the symmetrical phenonium ion (A) as a discrete reaction intermediate of geometrical stability to explain the clear-cut stereochemical results he observed on acetolyzing the *p*-toluenesulfonate esters of the diastereomeric 3-phenyl-2-butanols. This simple interpretation was later expanded[5] to the view that bridged cations such as A existed in solution with tosylate anions as ion pairs. Later the stereochemical consequences of the solvolyses of various 4-phenyl-3-hexanol derivatives[6] and the radiochemical consequences of the nitrous acid deamination of 2-phenylethylamine-1-C^{14} were studied,[7] and the results of neither investigation could be explained in terms of a symmetrical phenonium ion alone. Roberts, in fact, proposed[7] structures similar to B and C as symbolic of the cationic intermediate formed during nitrous acid conversion of 2-phenylethylamine-1-C^{14} to 2-phenylethanol-1,2-C_1^{14}, and suggested that cation B underwent reaction with hydroxyl ion more rapidly than it equilibrated with C. This hypothesis rationalized Roberts' observation that neither phenyl nor substituted phenyl migration ever approached 50% as should be the case if the symmetrical phenonium ion D were in fact the sole intermediate.



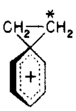
A



B



C



D

In a series of investigations[8] originated with the intention of providing facile synthetic routes to carbon-14 labeled polynuclear aromatic hydrocarbons we became interested in the comparative migration ratios of phenyl and substituted phenyl groups, as well as in the nature of the intermediate formed during dehydration–rearrangement of carbon-14 labeled 2,2-diarylethanols. Following an unsuccessful attempt[9,10] to obtain mechanistic information on such reactions in the acenaphthene series, we report in the present paper, and the one following, our results on rearrangement studies in the triphenylethanol series. These observations, we believe, have a direct bearing on the present concept of the symmetrical phenonium ion.

Methods and Results

In order to have an "open chain" analog of the 2-phenyl-1-acenaphthenol-1-C^{14} previously studied,[10] the synthesis of 1,2,2-triphenylethanol-1-C^{14} (I) was undertaken. It was anticipated that the 1,2,2-triphenylethyl system would offer nearly optimum chemical reactivity for phenyl group participation during the solvolyses and elimination reactions, particularly since either one of two neighboring phenyl groups might participate in the rate-determining steps. If the formation of a symmetrical phenonium ion[3] were not a general phenomenon, then there was considerable promise that more than 50% phenyl migration might occur during one of the reactions studied. Such an observation, of course, would prove the non-generality of the symmetrical phenonium ion concept. As indicated in Chart I, carbinol I was readily prepared from benzhydryl chloride, the

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[1] This document is based upon work performed under Contract Number W-7405-eng-26 for the Atomic Energy Commission at the Oak Ridge National Laboratory. Reprint requests should be addressed to C. J. C.

[2] J. F. Lane and E. S. Wallis, THIS JOURNAL, **63**, 1674 (1941).

[3] D. J. Cram, *ibid.*, **71**, 3863, 3875 (1949).

[4] D. J. Cram and R. Davis, *ibid.*, **71**, 3871 (1949).

[5] D. J. Cram, *ibid.*, **74**, 2129, 2137, 2195 (1952).

[6] D. J. Cram and F. A. Abd Elhafez, *ibid.*, **75**, 3189 (1953).

[7] J. D. Roberts and Clare M. Regan, *ibid.*, **75**, 2069 (1953).

[8] Paper VI, C. J. Collins and B. M. Benjamin, *ibid.*, **75**, 1644 (1953).

[9] W. A. Bonner and C. J. Collins, *ibid.*, **75**, 2308 (1953).

[10] W. A. Bonner and C. J. Collins, *ibid.*, **75**, 3831 (1953).