[CONTRIBUTION FROM THE HERCULES EXPERIMENT STATION, HERCULES POWDER CO.]

The Dehydration of Some Tertiary Alcohols Containing the Cyclohexane Ring

BY WILLIAM A. MOSHER

Although many tertiary alcohols containing the cyclohexane ring have been prepared, especially by Sabatier and Mailhe,[1] it appears that none has been subjected to a careful study of its dehydration products. In dehydration only one of the expected products has been reported. The properties of the olefins formed are such as to make physical separation extremely difficult, if not impossible, when only small amounts of materials are used.

In order to obtain data on the manner of dehydration of certain of these alcohols, as well as to gain some insight into the process as applied to the group as a whole, we have prepared and dehydrated 1-methylcyclohexanol, 1-ethylcyclohexanol, 1-isopropylcyclohexanol, and dimethylcyclohexylcarbinol. The alcohols were prepared by means of the Grignard reaction. The dehydration was effected by heating with iodine under a column so that the olefins and water distilled out of the mixture as formed. The use of ozonolysis offers a simple and satisfactory approach to the problem as it makes physical separation of the isomers unnecessary. If we assume that no shifting of the double bonds occurs after dehydration, one of the products of each dehydration will give rise to formaldehyde, acetaldehyde, or acetone; in the case of dimethylcyclohexylcarbinol both acetone and formaldehyde may be formed. These facts greatly simplify the problem as it is only necessary to ozonize the olefin mixture obtained by dehydration and analyze, both qualitatively and quantitatively, for the appropriate carbonyl compounds. From the analyses the ratios of the isomers in the dehydration products may be determined. The accuracy of such a method is approximately 10%. A very complete discussion of the technique of ozonolysis is given by Church, Whitmore and McGrew.[2]

The absence of isomerization concomitant with, or subsequent to, dehydration is indicated by the following facts. In the case of dimethylcyclohexylcarbinol the summation of acetone and formaldehyde was within 5% of the theoretical. In the case of 1-methylcyclohexanol, analysis for methyl ketone in the ozonolysis product gave a value of 93% of the theoretical. Finally, the method of dehydration used minimizes secondary reactions by removing the dehydrated product from the action of the dehydrating agent. The absence of polymerization is indicated by the recovery of yields of olefin always better than 97% having the properties of the monomer.

We may look upon dehydration as a competitive reaction indicating the relative affinities of structurally different carbon atoms for a proton. According to the concept of Whitmore[3] the hydroxyl group is removed leaving a carbon atom with only six electrons. To stabilize this organic fragment a proton may be lost from an adjacent carbon atom. The determination of the ratio in which different carbon atoms lose protons measures the affinities of the groups in question and gives a relative indication of the bond strengths.

In the dehydration of 1-methylcyclohexanol no formaldehyde was detected in the products of ozonolysis indicating that no methylenecyclohexane was formed and that only 1-methylcyclohexene was formed by the dehydration. In the case of 1-ethylcyclohexanol only a trace of acetaldehyde was found, indicating that less than 1% of ethylidenecyclohexane was formed. Presumably the other 99% was present as 1-ethylcyclohexene. An amount of acetone corresponding to approximately 5% of the theoretical was found in the products from 1-isopropylcyclohexanol, indicating this percentage of isopropylidenecyclohexane in the olefin mixture. The analysis of the products from dimethylcyclohexylcarbinol gave values of approximately 50% each for acetone and formaldehyde indicating equal amounts of isopropylidenecyclohexane and isopropenylcyclohexane in the mixture.

Dehydration apparently will take place in such a manner that the double bond occurs principally in the ring when this is possible. In other words the hydrogen atoms attached to the ring are less firmly bound than those of a more aliphatic nature. In the case of 1-isopropylcyclohexanol a cyclic hydrogen is lost in preference to the tertiary

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[1] Sabatier and Mailhe, *Compt. rend.*, **138**, 1321 (1904); *Bull. soc. chim.*, (3) **33**, 75 (1905); *Ann. chim.*, (8) **10** 527 (1907).

[2] Church, Whitmore and McGrew, THIS JOURNAL, **56**, 176 (1934).

[3] Whitmore, *ibid.*, **54** 3274 (1932).

hydrogen of the isopropyl group. At first sight the case of dimethylcyclohexylcarbinol seems more unusual in that a primary hydrogen from a methyl group is lost in equality with a tertiary hydrogen from the ring. It must be remembered, however, that there are six primary hydrogens on adjacent carbons while only one adjacently attached tertiary hydrogen. On this basis the tertiary hydrogen is lost relatively more readily than a primary hydrogen.

Experimental

Apparatus and Methods.—The column under which the dehydrations were carried out was of the type described by Whitmore and Lux.[4] It was packed with single turn glass helices and had an efficiency equivalent to 12 theoretical plates. Its nichrome resistance windings were connected in series with a "variac" for temperature control of the column jackets.

The ozone was generated by passing dry oxygen through a generator obtained from the U. S. Ozone Co., Scottdale, Pa. The generator was calibrated so that a measured amount of ozone could be delivered by controlling the rate and time of oxygen flow. The ozonolyses of the olefin mixtures were conducted as described by Whitmore and Church.[5] In all cases the theoretical amount of ozone just saturated the olefin.

Preparation of Materials.—The cyclohexanol derivatives were prepared by the usual Grignard procedure; their boiling points, refractive indices ($n^{20}\text{D}$), and yields based upon the halides used were, respectively, as follows: 1-methyl- 70° at 25 mm., 1.4546, 60%; 1-ethyl- 78° at 20 mm., 1.4642; 1-isopropyl- 80° at 18 mm., 1.4579, 35%; dimethylcyclohexylcarbinol 96–98° at 18 mm., 1.4700, 40%. In the reaction of isopropylmagnesium bromide and cyclohexanone a 7% yield of cyclohexanol, α-naphthyl urethan m. p. 128°, was obtained. Cyclohexylidenecyclohexanone[6] amounting to 34% of the original cyclohexanone was isolated and identified through its semicarbazone, m. p. and mixed m. p. 177°.

Dehydration of the Alcohols.—In all cases the dehydrations were carried out by heating 0.15 to 0.20 mole of the alcohol with 0.05 to 0.1 g. of iodine. The jackets of the column under which the dehydrations were performed were set at a temperature which would allow water and olefin to distil out of the mixture but which prevented loss of undehydrated alcohol. In all cases dehydration was rapid and complete. Both the water and olefin obtained were weighed; the yields of water from all four alcohols were 95–95.5% and the yields of olefin were 97.5–99%. The olefin mixtures were dried over anhydrous sodium sulfate at 10°. The olefins were treated in no other way before ozonolysis.

Analysis.—The ozonolyses were conducted by the method referred to above.[5] Formaldehyde was detected by the resorcinol-sulfuric acid test; methyl ketone by the iodoform reaction; sodium nitroprusside was used to indicate acetone. In cases where acetone was expected it was isolated as such by distilling it out of the aqueous solution and identified by preparing the 2,4-dinitrophenylhydrazone. Formaldehyde was determined by iodimetric titration when no acetone or other methyl ketone was present. When acetone was present with formaldehyde the two were determined together by titration with iodine in basic solution and the formaldehyde determined separately on an aliquot part with hydrogen peroxide and standard base.[2] Acetone was determined by Messinger's method,[7] as was the methyl ketone from 1-methylcyclohexanol.

The aqueous distillate from the decomposition of the ozonide from 1-methylcyclohexanol gave no test for formaldehyde, nor methyl ketone. The solution failed to give a positive Schiff test. After removing the zinc from the residue in the decomposition flask iodimetric titration showed the presence of methyl ketone, 93% calculated as 6-ketoheptaldehyde.

In the case of 1-ethylcyclohexanol the aqueous distillate gave no test for aldehyde or methyl ketone. The contents of the dry-ice trap attached to the condenser outlet gave a positive test for aldehyde with Schiff reagent. Alcohol was added to the trap contents and then 2,4-dinitrophenylhydrazone and concd. hydrochloric acid. After refluxing, evaporating most of the low boiling solvent, water was added to effect a complete separation of the hydrazone. The dried product corresponded to a 0.5% yield of acetaldehyde. On recrystallizing twice from alcohol, the derivative melted at 163° and showed no depression when mixed with an authentic specimen of the 2,4-dinitrophenylhydrazone of acetaldehyde.

In the case of 1-isopropylcyclohexanol the distillate gave a positive iodoform test. Analysis showed a 2.5% yield of acetone. The distillate gave no test for aldehyde; the residue in the decomposition flask gave no iodoform reaction.

The presence of both formaldehyde and acetone was demonstrated in the products from dimethylcyclohexylcarbinol. Analysis showed yields of 53% formaldehyde and 42.5% acetone. Methyl cyclohexyl ketone, one of the products, would interfere with the acetone analysis. However, it was not allowed to distil over; water was allowed to distil out but the ketone, being an insoluble oil, was returned to the decomposition flask by proper adjustment of the take off stopcock on the decomposition apparatus. Acetone was distilled out of the aqueous solution using the 12-plate column; a 35% yield was obtained in this way, 2,4-dinitrophenylhydrazone m. p. and mixed m. p. 126°.

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Summary

1. 1-Methylcyclohexanol, 1-ethylcyclohexanol, 1-isopropylcyclohexanol, and dimethylcyclohexylcarbinol have been dehydrated with iodine and the resulting olefin mixtures ozonized. From the analysis of the ozonolysis products

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[4] Whitmore and Lux, This Journal, **54**, 3448 (1932).

[5] Whitmore and Church, *ibid.*, **54**, 3710 (1932).

[6] Kohler and Thompson, *ibid.*, **55**, 3822 (1933).

[7] Messinger, *Ber.*, **21**, 3366 (1888).

the ratios of dehydration have been determined.

2. Dehydration tends to take place in such a manner that the double bond formed enters the ring when this is possible.

3. It is noted that a proton is lost from the cyclohexane ring more readily than from a methyl, ethyl or isopropyl group.

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Lupine Studies. XV.[1] The Alkaloids of *Lupinus sericeus* Pursh

BY JAMES FITTON COUCH

The silky lupine, *Lupinus sericeus*, occurs in the plains and canyons of the pinyon and yellow pine belts from Saskatchewan to South Dakota, Wyoming, Oregon, and Washington.[2]

A collection made by the late A. B. Clawson has been examined and found to contain two alkaloids, spathulatine previously isolated[3] and a new alkaloid now named nonalupine, $C_{15}H_{24}ON_2$, isomeric with lupanine and differing from it in important respects.

The discovery of spathulatine in another lupine presented an opportunity for a revision of the chemistry of the alkaloid, particularly in the light of new developments in our knowledge of the lupine alkaloids since spathulatine was first described. The formula then assigned to the alkaloid on the basis of analyses of the base and the mercuric iodide compound as well as the molecular weight determination is $C_{33}H_{64}O_5N_4$. This formula cannot easily be harmonized with the series of sparteine derivatives now known. The molecular weight is more than twice that of lupanine but is supported by the high melting point reported, 227° (uncor.). Moreover, the large content of hydrogen precludes a combination of structures with a sparteine skeleton and requires a largely aliphatic structure with not more than two 6-membered rings.

Analyses of both the anhydrous and the hydrated alkaloid for carbon, hydrogen, and nitrogen gave figures that agree with the previously assigned formula. The newly prepared compound with potassium iodide which is analogous to the mercuric iodide compound previously described also furnishes analytical evidence consistent with the previously assigned formula. In this study no evidence has been obtained to indicate that the formula requires revision.

The behavior of spathulatine suggests the presence of amine-oxide groups, possibly adjacent to a carbonyl group, for three of the nitrogen atoms, the function of the fourth being undetermined. This view is supported by the slight basicity of spathulatine and the inability to prepare crystalline salts with the usual acids and by its sparing solubility in acetone and ether. The formation of a compound with three molecules of potassium iodide also supports this view since compounds with one molecule of potassium iodide to each amine-oxide group are readily formed. When treated with sulfur dioxide spathulatine is converted into an unidentified base probably as a result of reduction of the amine-oxide groups.

When boiled with hydrochloric acid spathulatine is converted into an isomer of spartyrine, $C_{15}H_{24}N_2$, which is positive to the modified Grant's test.[4] This behavior indicates the probability of hydrolysis with subsequent ring closure to form the sparteine skeleton. This relates spathulatine to the other lupine alkaloids.

The other alkaloid in the plant, nonalupine, is of interest because of its non-basic character. When a solution of nonalupine and camphor-sulfonic acid is evaporated to dryness the free alkaloid may be dissolved out of the residue by ether. No salts with mineral acids have been obtained. This behavior is difficult to explain. Since the alkaloid contains two nitrogen atoms and but one oxygen atom it cannot have lost its basicity because of amine-oxide formation or because of ad-

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(1) Paper XIV, THIS JOURNAL, **61**, 3327 (1939).

(2) W. W. Eggleston in I. Tidestrom, "Flora of Utah and Nevada," *Contr. U. S. Nat. Herbarium*, **25**, 297 (1925).

(3) J. F. Couch, THIS JOURNAL, **46**, 2507 (1924). The alkaloid was isolated from a lupine collected by the writer and identified by W. W. Eggleston as *L. spathulatus* Rydb. whence the name spathulatine given to the new base. Since that time there has arisen a difference in opinion among botanists as to the proper name of the species used, I. Tidestrom (personal communication) referring it to *L. marianus* Rydb. and being confirmed by C. P. Smith. Eggleston considered *marianus* a synonym of *spathulatus* and recombined the species. Material of a species identified by C. P. Smith as *L. spathulatus* collected near Puffer's Lake, Utah, has been examined and found free from spathulatine. The alkaloid has, it appears, been misnamed since, unless there is a reversal of botanical opinion, it does not occur in *L. spathulatus*.

(4) J. F. Couch, *Am. J. Pharm.*, **97**, 36 (1925).