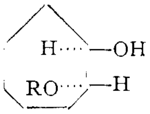
annular reaction" in addition to the expected *trans*-1,2-cyclooctanediol,[1] it was of interest to determine what products were formed on solvolysis of cycloheptene oxide. Transannular oxidations of cyclodecene to 1,6-cyclodecanediol[2] and cyclononene to 1,5-cyclononanediol[3] have also been observed; Prelog, Schenker and Küng[3] state that only *trans*-1,2-cycloheptanediol is formed from cycloheptene and performic acid.

Addition of formic acid to cycloheptene oxide formed a mixture from which 42% of *trans*-1,2-cycloheptanediol monoformate (I) and 28.5% of 2,2′-dihydroxydicycloheptyl ether diformate (III) were isolated. Formation of the ether III was favored by a high concentration of cycloheptene oxide compared to formic acid, for reversal of the order of addition changed the yields to 60% of I and 19% of III. The structure of the monoformate I was established by saponification to the known *trans*-1,2-cycloheptanediol (II),[4] m.p. 62.1–63° (85%), and by preparation of an identical sample from II and formic acid in 88% yield. Presumably esterification of II proceeds only as far as formation of the monoformate I under the conditions employed because of hydrogen bonding between the hydroxyl and carbonyl groups of I.

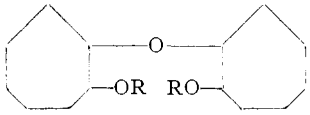
The structure of the ether III was established by saponification to 2,2′-dihydroxydicycloheptyl ether (IV) (73%), which was re-esterified with formic acid to III in 82% yield. An identical authentic sample of III was prepared in 59% yield from cycloheptene oxide and *trans*-1,2-cycloheptanediol in the presence of boron trifluoride.

No evidence was obtained for the presence of any product from the reaction of cycloheptene oxide and formic acid derived from a cycloheptanediol other than 1,2-cycloheptanediol. Accordingly, no chemical "transannular effect" appears to influence this reaction of cycloheptene oxide.



I, R = $-\underset{\overset{\|}{O}}{C}H$

II, R = H



III, R = $-\underset{\overset{\|}{O}}{C}H$

IV, R = H

Experimental[5]

Solvolysis of Cycloheptene Oxide with Formic Acid.—Cycloheptene oxide was prepared from 75 g. of cycloheptene and 220 ml. of commercial 40% peracetic acid to which 36 g. of sodium acetate trihydrate had been added (to neutralize the sulfuric acid present), by a procedure similar to the one used for preparation of cyclooctene oxide from cyclooctene (ref. 1, p. 5887); the yield was 69.5 g. (80%), b.p. 83–85° (50 mm.), n^{25}_D 1.4615–1.4620. A 40-g. sample of the cycloheptene oxide was heated at 100°, and 150 ml. of 87% formic acid was added dropwise with stirring during a period of 30 minutes, after which the solution was heated under reflux for 30 minutes. Excess formic acid was removed under reduced pressure and the residue was distilled through a semimicro column, yielding 23.5 g. (42%) of *trans*-1,2-cycloheptanediol monoformate (I), b.p. 81–83° (0.5 mm.), n^{25}_D 1.4632–1.4644. A redistilled analytical sample had b.p. 82° (0.5 mm.), n^{25}_D 1.4641, d^{25}_4 1.1202.

Anal. Calcd. for $C_8H_{14}O_3$: C, 60.74; H, 8.92. Found: C, 60.96; H, 8.97.

2,2′-Dihydroxydicycloheptyl ether diformate (III) was isolated in a yield of 15.2 g. (28.5%) by fractionation of the residue from the distillation of I; b.p. 155–160° (0.3 mm.), n^{25}_D 1.4848–1.4861. A redistilled analytical sample had b.p. 155° (0.25 mm.), n^{25}_D 1.4861, d^{25}_4 1.0734.

Anal. Calcd. for $C_{16}H_{26}O_5$: C, 64.40; H, 8.78. Found: C, 64.34; H, 9.05.

In a reaction in which the order of addition was reversed, 20 g. of cycloheptene oxide was added during a period of 20 minutes to 50 ml. of 87% formic acid with cooling in an ice-bath, after which the mixture was heated on a steam-bath for 30 minutes; the yield of I was 17 g. (60%), while the yield of III was 5 g. (19%).

***trans*-1,2-Cycloheptanediol Monoformate (I).**—A 5-g. sample of I prepared by the method described above was saponified by stirring and heating on a steam-bath for 15 minutes with 100 ml. of 10% aqueous sodium hydroxide. The cooled solution was extracted with two 100-ml. portions of methylene chloride, which were dried over magnesium sulfate and concentrated, yielding 3.7 g. (91%) of II, m.p. 61.1–62.3°. Two recrystallizations from toluene yielded 3.5 g. (85%) of pure I, m.p. 62.1–63°, identical with a sample prepared in 87% yield by the procedure of ref. 4 (hydrolysis of 4.0 g. of cycloheptene oxide with 100 ml. of 0.1 *N* hydrochloric acid by heating under reflux for several hours).

A 3.5-g. sample of the glycol II was heated under reflux with 20 ml. of 87% formic acid for 1 hour, after which distillation yielded 3.75 g. (88%) of the monoformate I, identical in physical properties and infrared spectrum with the sample prepared from cycloheptene oxide and formic acid.

2,2′-Dihydroxydicycloheptyl Ether Diformate (III).—A 4.5-g. sample of III was heated under reflux on a steam-bath for 20 hours with 100 ml. of a 20% solution of potassium hydroxide in aqueous ethanol. The ethanol was removed at 35 mm., and the aqueous residue was extracted with two 100-ml. portions of methylene chloride. The extracts were dried over magnesium sulfate, concentrated, and the residue was crystallized from 30–60° petroleum ether. After two recrystallizations from this solvent, the yield of 2,2′-dihydroxydicycloheptyl ether (IV) was 2.67 g. (73%), m.p. 85.7–86.2°.

Anal. Calcd. for $C_{14}H_{26}O_3$: C, 69.37; H, 10.81. Found: C, 69.24; H, 10.82.

A 2.0-g. sample of IV was heated under reflux with 15 ml. of 87% formic acid for 1 hour, after which distillation under reduced pressure yielded 2.0 g. (82%) of the diformate III with physical properties and an infrared spectrum identical with III obtained from cycloheptene oxide and formic acid.

2,2′-Dihydroxydicycloheptyl Ether (IV).—An authentic sample of IV was prepared by adding several drops of boron trifluoride etherate to a solution of 1.0 g. of the glycol II and 0.87 g. of cycloheptene oxide in 10 ml. of dry ether, and heating the solution under reflux for 3 days.[6] The solution was washed with dilute sodium hydroxide, dried over magnesium sulfate, concentrated, and the residue was crystallized from 30–60° petroleum ether. After recrystallization to a constant melting point of 85.5–86.1° the yield of IV was 1.1 g. (59%); this sample and IV obtained by saponification of III were identical (mixed m.p.).

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[2] V. Prelog and K. Schenker, *Helv. Chim. Acta*, **35**, 2044 (1952).

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[4] J. Böeseken and H. Derx, *Rec. trav. chim.*, **40**, 529 (1921).

[5] Melting points are corrected and boiling points are uncorrected. We are indebted to Dr. S. M. Nagy and his associates for analyses.

[6] Conditions similar to those used by A. A. Petrov, *J. Gen. Chem. U.S.S.R.*, **10**, 981 (1940); *C. A.*, **35**, 3603 (1941), for the reaction of cyclohexene oxide with alcohols.

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Polarographic Reduction of Furfural

BY R. A. DAY, JR.

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Data in the literature on the polarographic reduction of furfural are in disagreement. Korshunov and Ermolayeva[1] obtained two waves with this aldehyde in buffers of *p*H 4–7, the height of the first wave decreasing and that of the second increasing with increase in *p*H. This behavior is unusual. The two acidic waves of simple carbonyl compounds are usually of about equal height and merge as the *p*H is increased. The half-wave potentials reported by these workers also are considerably more negative than those reported by Tachi,[2] who found only one wave over the *p*H range 1–13. Likewise the potentials reported by Tachi are slightly more negative than those found by MacKenney and Temmer[3,4] in the *p*H range 3–7.

The behavior of furfural upon polarographic reduction would be expected to be similar to that of benzaldehyde and of simple aromatic ketones, such as benzophenone. The principal difference would be that the metal ketyl produced in the first step of reduction in basic solutions should dimerize more strongly than the corresponding ketyl from benzophenone, since the aldehyde contains a hydrogen atom in place of a phenyl group.[5–7] Likewise the ketyl produced from furfural should dimerize more strongly than that from benzaldehyde, since a furyl group, from both steric and resonance considerations, should stabilize the dimer to a greater extent than a phenyl group.

The polarography of furfural was studied in 25% ethanol–water media in buffered solutions of *p*H 1–13. The aldehyde concentration was 0.001 *M*. In acid solution two waves of about equal height were observed only at a *p*H of 5.0.[8] Below a *p*H of 4.0 the single wave was about half the height of the wave at *p*H 6 and 7, the second wave being masked by decomposition of the supporting electrolyte. The half-wave potentials were in good agreement with those reported by Tachi.[2] The values reported by MacKenney and Temmer[3] in this region were obtained in aqueous solution. Somewhat more negative values would be expected in alcohol solutions.[6]

The unusual behavior reported by Korshunov and Ermolayeva[1] in this region was probably caused by insufficient buffering. These results were obtained with about 0.01 *M* aldehyde and at such a concentration it is difficult to have sufficiently high buffer concentration to maintain constant *p*H at the mercury drop. Several runs were made with 0.01 *M* furfural which indicated that this was true. Increasing the concentration of a citrate–phosphate buffer of *p*H 5.5 to the saturation point consistently shifted the half-wave potentials to more positive values. These values were still more negative, however, than those obtained with 0.001 *M* aldehyde in well buffered solutions. The unusual behavior reported for benzaldehyde in acid solution[9] is also probably caused by insufficient buffering.

As the *p*H was increased in basic solutions the current decreased slowly, falling to about half-value in 0.01 and 0.1 *M* sodium hydroxide. The second wave is again masked by decomposition of the supporting electrolyte. Ashworth[5] has shown that a second wave can be obtained with benzaldehyde in basic media by addition of calcium and tetraalkylammonium ions. This was found to be true also for furfural in a calcium chloride–calcium hydroxide buffer of *p*H 12.1.[10] With benzaldehyde in this same buffer the two waves were actually merged. In 0.01 *M* tetramethylammonium hydroxide the second wave of benzaldehyde is observed, but that of furfural is still masked. This indicates that the dimer produced from furfural is more stable than that produced from benzaldehyde, as was expected.

Furfural also produces two waves in solutions of calcium chloride and tetramethylammonium bromide as has been reported for benzaldehyde.[11] The half-wave potentials observed in these salt solutions correspond to those obtained in basic media. In such unbuffered solutions a local decrease in hydrogen ion concentration at the mercury drop would lead to this behavior.

Experimental

The procedure and apparatus were the same as previously described.[6,7] Both furfural and benzaldehyde were freshly distilled under vacuum before use.

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[8] All *p*H values herein are of the aqueous buffer.

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Basic Ethers of Some Piperidine Alcohols

BY BILL ELPERN

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This note reports one of the attempts to prepare compounds having pure curariform activity. The ethers were synthesized by treating the hydroxy substituted piperidines with sodamide and *t*-amino substituted alkyl halides. The resultant dibasic ethers were quaternized with methyl iodide in an inert solvent.

Experimental[1]

Alcohols.—4-Hydroxymethyl-1-methylpiperidine,[2] 3-hydroxymethyl-1-methylpiperidine[2] and 4-hydroxy-1-methyl-4-phenylpiperidine[3] were prepared by published procedures.

4-Hydroxymethyl-1-methyl-4-phenylpiperidine.[4]—Isonipecaine (284 g., 1 mole) was dissolved in water (500 ml.), made strongly alkaline with 35% sodium hydroxide solution and the free base extracted with benzene. To the benzene

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[1] All melting points are corrected. Analyses were carried out by Messrs. M. E. Auerbach, K. D. Fleischer and staff.

[2] R. F. Feldkamp, John Faust and Anna Cushman, This Journal, **74**, 3831 (1952).

[3] Aktieselkabet "Ferrosan," Danish Patent 60592; *C. A.*, **40**, 4086 (1946).

[4] S. Schauman, *Arch. Exptl. Path. Pharmakol.*, **196**, 109 (1940). The procedure given was supplied by Dr. S. Archer of this Laboratory.