1 H), 4.38 (d, J = 3.8 Hz, 2 H), constituted about $^1/_3$ to $^1/_4$ of the distillate. The dienone **4**, bp 53–54° (6 mm), nmr (CCl_4) δ 1.81 (d of d, J = 6.7, 1.0 Hz, 3 H), 1.91 (d, J = 1.0 Hz, 3 H), 2.1 (s, 3 H), 5.98 (s, 1 H), 6.17 and 7.63 (AB part of ABX pattern, J_{AB} = 15.0, $J_{AX} \cong 1.0$, J_{BX} = 6.7 Hz), was the major product.

2,4,6-Trimethyl-2*H*-pyran (3) as Transient Intermediate.—A mixture of 0.5 g (2.1 mmol) of **1**, 100 ml of pentane, and 10 ml of water was cooled in an ice bath. To this was added 0.2 g (53 mmol) of sodium borohydride and the mixture was stirred vigorously for 20–30 sec. About 25 ml of the pentane layer was decanted into a test tube stored in a Dry Ice bath. The pentane solution had λ_{max} 277 nm, which disappeared rapidly (10 min at 25°), giving λ_{max} 272 nm for **4**. The rate of change of the spectrum at 253.5 nm followed first-order kinetics, since a plot of 2.3 log $(A_\infty - A_t)/A_\infty$ *vs.* time gave a straight line.

Reduction was carried out as described above except that spectral grade carbon tetrachloride was used in place of the pentane. The organic layer was pipetted into a cold test tube and was dried briefly ($MgSO_4$). A nmr spectrum at −22° gave a complex spectrum containing, in addition to bands associated with **2** and **4**, new bands at δ 1.18 (d, J = 6.5 Hz), 1.56 (s), 1.76 (s), 4.6 (m), 4.8 (s), and 4.9 (s). All of these bands disappear rapidly when the solution is warmed to 35°.

Registry No.—**2**, 35030-93-4; **3**, 35030-94-5; **4**, 29178-98-1.

Preparation of *trans*-2,3-*trans*-5,6-dioxane-d_4. Use of a Hindered Base to Prevent Acid-Catalyzed Side Reactions

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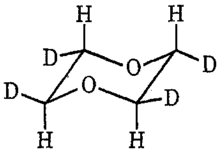
In the course of another investigation[1] it became necessary to synthesize a 1,4-dioxane, substituted with deuterium such that a definite geometric isomer, *trans*-2,3-*trans*-5,6-dioxane-d_4 (I), was obtained. The usual preparations of 1,4-dioxane (*e.g.*, the acid-catalyzed self-condensation of ethylene glycol) were not expected to lead to pure geometric isomers, and preliminary results were in accord with this expectation.



I

A double displacement on an appropriately deuterated ethane, with leaving groups in the 1 and 2 positions, by the oxygens of an appropriately deuterated ethylene glycol, would be expected to give I.

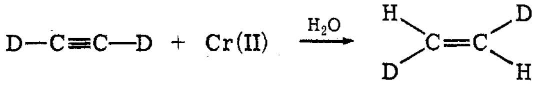
An attempt to displace the tosylate groups of ethylene glycol ditosylate with the dilithium salt of ethylene glycol in hexamethylphosphoramide yielded no 1,4-dioxane. Heating ethylene glycol directly with ethylene glycol ditosylate in *p*-dimethoxybenzene to 210° also yielded no 1,4-dioxane. When ethylene glycol and ethylene glycol ditosylate were heated together to 180°, without solvent, 1,4-dioxane was obtained in 20% yield. This dioxane may have arisen in part from the acid-catalyzed self-condensation of ethylene glycol (toluenesulfonic acid is obtained from the desired reaction and from decomposition of the tosylate). To test this possibility, 1,1,2,2-ethylene glycol-d_4 was synthesized and reacted with undeuterated ethylene glycol ditosylate. Mass spectral analysis of the dioxane product revealed parent peaks at 92 (dioxane-d_4) and 96 (dioxane-d_8), and none at 88 (dioxane-d_0). In the course of a reaction, the amount of the acid-catalyzed self-condensation product (dioxane-d_8) formed depended on the extent of conversion and varied between 25–50%.

It thus became necessary to eliminate the formation of the ethylene glycol self-condensation product. Since this undesired reaction apparently was acid-catalyzed, various bases were added to the reaction mixture. With quinoline as the added base, heating produced only a red tar and no volatiles. Evidently, base-catalyzed side reactions took precedence over the desired reaction.

Brown and Kanner[2] have reported that hindered pyridines, such as 2,6-di-*tert*-butylpyridine, act as normal bases toward free protons, but do not act as nucleophiles. Base-catalyzed eliminations would also be expected to be minimal with such a hindered base. When two equivalents of this base were heated with one equivalent each of ethylene glycol and ethylene glycol ditosylate, the yield of 1,4-dioxane went up dramatically to 70%. After removing the volatiles, the 2,6-di-*tert*-butylpyridinium-*p*-toluenesulfonate salt in the residue was recovered and recrystallized from acetone–carbon tetrachloride. When ethylene glycol-d_4 was substituted for the undeuterated ethylene glycol, mass spectral analysis of 1,4-dioxane product showed only dioxane-d_4 and no dioxane-d_8 or dioxane-d_0. As little as 2 or 3% of these side products could have been detected. When a less hindered base (2,6-lutidine) was used, a lower yield of 1,4-dioxane (20%) was obtained, although deuterium labeling experiments indicated that no or minimal self-condensation reactions had occurred.

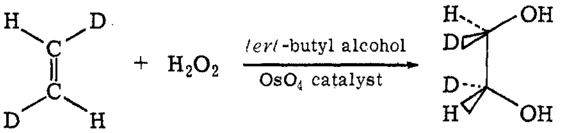
The reaction employing 2,6-di-*tert*-butylpyridine is therefore suitable for the preparation of geometric isomers of 1,4-dioxane. Synthesis of *dl*-1,2-ethylene glycol-d_2 and its ditosylate was accomplished by the following sequence of reactions.

Acetylene-d_2 was reduced to *trans*-1,2-ethylene-d_2 (eq 1) by water–chromium(II) chloride in a trans fashion.[3]



(1)

Cis hydroxylation of *trans*-1,2-ethylene-d_2, using the osmium tetroxide catalyzed hydrogen peroxide–*tert*-butyl alcohol reagent (eq 2) of Milas and Sussman,[4] gave



(2)

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[1] F. R. Jensen and R. A. Neese, *J. Amer. Chem. Soc.*, **93**, 6329 (1971).

[2] H. C. Brown and B. Kanner, *ibid.*, **88**, 986 (1966).

[3] J. Bigeleisen, S. V. Ribnikar, and W. A. Van Hook, *Zh. Fiz. Khim.*, **38**, 489 (1963).

[4] N. A. Milas and S. Sussman, *J. Amer. Chem. Soc.*, **59**, 2345 (1937).

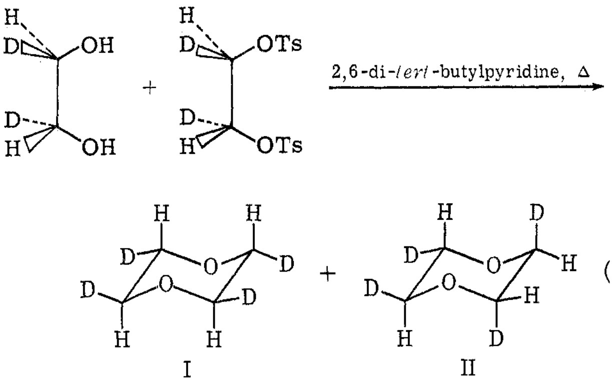
Table I

Preparation of Dioxane and Deuterated Dioxanes

Glycol[a]	Ditosylate[b]	Base	Temp, °C	Yield, %	Product
Ethylene glycol	Ethylene glycol ditosylate		180	20	Dioxane
Ethylene glycol[c]	Ethylene glycol ditosylate		210	0	No volatiles obtained
Ethylene glycol-d_4	Ethylene glycol ditosylate		180	23	Dioxane-d_4 and dioxane-d_8
Ethylene glycol	Ethylene glycol ditosylate	Quinoline (3.14 g, 0.024 mol)	195	0	Decomposition began at 150° and no volatiles were observed
Ethylene glycol	Ethylene glycol ditosylate	2,6-Di-*tert*-butylpyridine (4.66 g, 0.024 mol)	180–190	70	Dioxane
Ethylene glycol-d_4	Ethylene glycol ditosylate	2,6-Di-*tert* butylpyridine (4.66 g, 0.024 mol)	180–190	67	Dioxane-d_4
Ethylene glycol-d_4	Ethylene glycol ditosylate	2,6-Lutidine (4.0 g, 0.037 mol)	180–190	20	Dioxane-d_4
dl-1,2-Ethylene glycol-d_2	*dl*-1,2-Ethylene glycol ditosylate-d_2	2,6-Di-*tert*-butylpyridine (4.74 g, 0.025 mol)	180–190	65	*trans*-2,3-*trans*-5,6-Dioxane-d_4

[a] 0.75 g, 0.012 mol of ethylene glycol. [b] 4.5 g, 0.012 mol of ethylene glycol ditosylate. [c] 15 g of *p*-dimethoxybenzene was used as a solvent.

the desired *dl*-1,2-ethylene glycol-d_2. Conversion of this glycol to the corresponding ditosylate was carried out with *p*-toluenesulfonyl chloride–pyridine by the method of Edgell and Parts.[5] The reaction of the *dl*-glycol with the *dl*-ditosylate in the presence of 2,6-di-*tert*-butylpyridine gave the desired *trans*-2,3-*trans*-5,6-dioxane-d_4 (I), which is presumably a mixture of two stereoisomers, I and II (eq 3).



(3)

Double inversion stereochemistry is assumed from the method of synthesis. The nmr spectral evidence supports this hypothesis.

Experimental Section

Ethylene Glycol Ditosylate.—This compound was prepared by the pyridine–*p*-toluenesulfonyl chloride method of Edgell and Parts.[5] Deuterated ethylene glycols were converted to their respective ditosylates by the same method, mp 124–126°, lit. 126–127°.

1,1,2,2-Ethylene Glycol-d_4.—To a solution of 10 g of lithium aluminum deuteride (0.238 mol) in 500 ml of dry tetrahydrofuran, was added 26.3 g of diethyl oxalate (0.18 mol) dissolved in 100 ml of dry tetrahydrofuran. The heat of reaction caused the mixture to reflux. After the addition was complete, the mixture was refluxed for 6 hr. The mixture was cooled, 10 g of water was added, followed by 10 ml of 15% sodium hydroxide solution, and finally 30 ml more water was added. The solid was removed by filtration and washed with tetrahydrofuran. The combined filtrates were distilled to remove tetrahydofuran and ethyl alcohol. The remaining ethylene glycol-d_4 was distilled: bp 92-96° (13 mm) [for $HOCH_2CH_2OH$, lit.[6] bp 93° (13 mm)]; yield, 5.8 g, 49%. The nmr spectrum revealed that less than 2 or 3% of the glycol existed as $HOCD_2CHDOH$.

2,6-Di-*tert*-butylpyridine.—This compound was prepared from *tert*-butyllithium and pyridine by the procedure of Brown and Kanner,[2] bp 100–101° (23 mm) [lit.[2] 100–101° (23 mm)].

***trans*-1,2-Ethylene-d_2.**—Acetylene-d_2 was reduced with chromous chloride by the procedure of Bigeleisen, *et al.*,[3] and was used without isolation to produce the *dl*-1,2-ethylene glycol-d_2.

***dl*-1,2-Ethylene Glycol-d_2.**—*trans*-1,2-Ethylene-d_2 was oxidized in a cis fashion with the osmium tetroxide–*tert*-butyl alcohol–H_2O_2 reagent of Milas and Sussman,[4] bp 93-97° (13 mm). In the nmr spectrum, the ratio of the areas under the hydroxyl protons compared to the remaining alkyl protons was 1:1.06. The alkyl protons appeared at δ 4.02 (neat, external capillary TMS). In ethylene glycol itself, this value is δ 4.03 (neat, external capillary TMS).

1,4-Dioxane.—All 1,4-dioxanes were prepared by a general procedure, using the appropriate ethylene glycol and ethylene glycol ditosylate (illustrated with added 2,6-di-*tert*-butylpyridine). In a small round-bottomed flask, equipped with a magnetic stirring bar and a short distillation head, were placed 0.75 g (0.012 mol) of ethylene glycol, 4.5 g of ethylene glycol ditosylate (0.012 mol), and 4.66 g of 2,6-di-*tert*-butylpyridine (0.024 mol). The mixture was heated to 180° while stirring, and the volatiles were removed by distillation and collected. Purification of the 1,4-dioxane was accomplished by preparative glpc utilizing a 10 ft × 1/2 in. 20% QF-1 on 60/80 Chromosorb W column. Undeuterated 1,4-dioxane was identified by comparison of retention time, ir spectrum, nmr spectrum, and mass spectrum. The results of the various experiments are summarized in Table I.

Registry No.—2,6-Di-*tert*-butylpyridine, 585-48-8; *trans*-2,3-*trans*-5,6-dioxane-d_4, 35048-86-3.

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[5] W. F. Edgell and L. Parts, *J. Amer. Chem. Soc.*, **77**, 4899 (1955).

[6] I. Heilbron, H. M. Bunbury, A. H. Cook, E. R. H. Jones, T. G. Halsall, and J. R. A. Pollock, "Dictionary of Organic Compounds," Vol. 2, Oxford University Press, New York, N. Y., 1953, p 503.