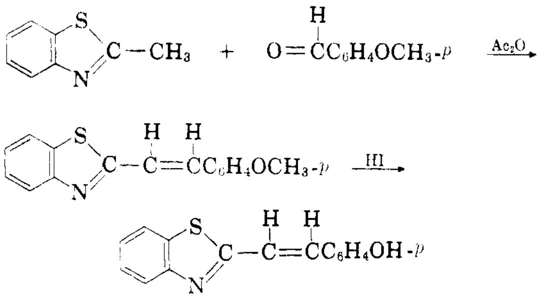
TABLE II
HYDROXYSTYRYL COMPOUNDS

				Analyses			
No.	Compound	M.p., °C.	Yield, %	S Calc'd	S Found	N Calc'd	N Found
XI	2-(*p*-Hydroxystyryl)benzothiazole	212–213[a]	84.5	12.65	12.68		
XII	2-(2',3'-Dihydroxystyryl)benzothiazole	dec. 185–190[b]	52	11.89	11.65		
XIII	2-(3',4'-Dihydroxystyryl)benzothiazole	dec. 220–230[b]	62	11.89	11.69		
XIV	2-(*p*-Hydroxystyryl)-6-hydroxyquinoline	dec. 270–275[c]	58			5.35	5.15

[a] Recrystallized from ethanol. [b] Purified by dissolving in hot glacial acetic acid and adding to an excess of water. [c] Purified by dissolving in sodium hydroxide and precipitating with dilute acetic acid.

heretofore unreported styryl derivatives of nitrogen-containing heterocycles have been prepared. A specific example of the preparation of 2-(*p*-hydroxystyryl)benzothiazole is given and illustrates the general method of synthesis employed for the reported compounds.



Although it has been indicated[3] that acetic anhydride may be inferior as a condensing agent, our results, in general, substantiate the contradictory findings of other workers.[4,5]

EXPERIMENTAL[6]

The procedures described below are typical for the preparation of the methoxystyryl compounds (Table I) and the hydroxystyryl compounds (Table II).

2-(p-Methoxystyryl)benzothiazole. A mixture of 14.9 g. (0.1 mole) of 2-methylbenzothiazole, 13.6 g. (0.1 mole) of *p*-anisaldehyde, and 10.2 g. (0.1 mole) of acetic anhydride was refluxed for 24 hours under a nitrogen atmosphere. On cooling, the mixture formed a crystalline mass; this was triturated with 50% ethanol, filtered, and washed with 80% ethanol. The product was recrystallized from ethanol to give a solid melting at 142–144°. The yield was 15.0 g. (58%).

2,3-Di-(*p*-methoxystyryl)quinoxaline (VI, Table I) was prepared in 71% yield as compared to the 10% yield obtained by Bennett and Willis.[7] In the latter preparation, perhaps an excessive amount of acetic anhydride (which lowers the reflux temperature of the reaction mixture) was used and the mixture was not heated long enough.

2-(p-Hydroxystyryl)benzothiazole. In 200 ml. of a 1:1 mixture of 47% hydriodic acid and glacial acetic acid was dissolved 7.5 g. of 2-(*p*-methoxystyryl)benzothiazole; the resulting solution was refluxed for 24 hours. On cooling, the mixture was diluted with water and made basic with ammonium hydroxide. Crystals separated (m.p. 211–212°) which were filtered off and washed with water. This product was dissolved in 5% sodium hydroxide, treated with Norit A, and filtered. Acidification of the filtrate with acetic acid caused precipitation. Following filtration and recrystallization from ethanol, 6.0 g. (84.5%) of 2-(*p*-hydroxystyryl)-benzothiazole, m.p. 212–213°, was obtained.

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[3] Tipson, *J. Am. Chem. Soc.*, **67**, 507 (1945).

[4] Gilman and Karmas, *J. Am. Chem. Soc.*, **67**, 342 (1945).

[5] Chiang and Hartung, *J. Org. Chem.*, **10**, 21 (1945).

[6] All melting points are uncorrected.

[7] Bennett and Willis, *J. Chem. Soc.*, 1960 (1928).

A Synthesis of Optically Active Styrene Oxide and Other Epoxides[1]

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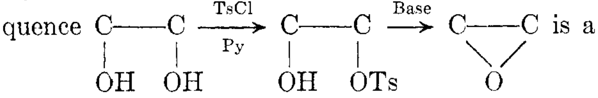
The synthesis of simple alicyclic epoxides,[3] sugar epoxides[4] and epoxides in the cyclitol series[5] by ring closure of glycol monotosylates is well known. However, the only application of this reaction to simple aliphatic epoxides seems to be the synthesis of *l*-glycidol from *l*-glycerol-1-tosylate[6] obtained from a sugar derivative *via* 2,3-isopropylidene-*l*-glycerol. We have now found that the reaction sequence



$\underset{OH}{C}-\underset{OH}{C} \xrightarrow[Py]{TsCl} \underset{OH}{C}-\underset{OTs}{C} \xrightarrow{Base} \underset{\diagdown\ \diagup \atop O}{C-C}$

is a

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(1) Contribution from the Radiation Project of the University of Notre Dame supported in part under Atomic Energy Commission contract AT(11-1)-38 and Navy equipment loan contract Nonr-06900.

(2) Shell Research Fellow, 1955–1956.

(3) L. N. Owen, *et al.*, *J. Chem. Soc.*, 315 (1949); 4026 (1952); 2582 (1953).

(4) *Cf.* S. Peat, *Advances in Carbohydrate Chemistry*, **2**, 41 (1946); R. S. Tipson, *Advances in Carbohydrate Chemistry*, **8**, 166 (1953).

(5) S. J. Angyal and N. K. Matheson, *J. Am. Chem. Soc.*, **77**, 4343 (1955).

(6) J. C. Sowden and H. O. L. Fischer, *J. Am. Chem. Soc.*, **64**, 1291 (1942).

convenient one for the synthesis of *trans*-2-epoxybutane, 1,1-diphenylethylene oxide, and optically active styrene oxide. Since the intermediate monotosylate is not isolated, this is essentially a one-step synthesis.

trans-2-Epoxybutane was obtained from the abundant *meso*-butanediol-2,3 in 28% yield. Heretofore its synthesis has involved a two-step preparation, either starting with the expensive and inconveniently handled *trans*-2-butene, or starting with mixed 2-butene and involving an exacting fractional distillation to separate the diastereoisomers.[7] 1,1-Diphenylethylene oxide was formed in 65% yield from 1,1-diphenylethanediol which is readily available by reduction of benzilic acid[8] or its ethyl ester.[9] A previous synthesis of this epoxide[10] entails a three-step process involving 1,1-diphenylethylene as an intermediate.

Optically active styrene oxide, not until now reported in the literature,[11] was obtained in 46% yield from active styrene glycol, prepared, in turn, by lithium aluminum hydride reduction of active mandelic acid. The optical purity of the epoxide was ascertained by lithium aluminum hydride reduction to phenyl methyl carbinol. From the signs and magnitudes of the rotations reported in the Experimental, together with data in the literature on the maximum rotation of mandelic acid[12] and of phenyl methyl carbinol[13] and on the configurational correlation of mandelic acid with phenyl methyl carbinol[14] it can be calculated that the reaction sequence *via* the monotosylate involves at least 85% retention of configuration and at most 15% racemization (or 92.5% retention and 7.5% inversion). It was not ascertained whether racemization of the epoxide (or one of the reaction intermediates) occurs in the reaction medium, or whether the loss of optical activity is due to formation of a small proportion of the secondary tosylate $PhCH(OTs)CH_2OH$ followed by ring closure with Walden inversion. It is possible that part or all of the observed racemization is only apparent, *i.e.*, actually due to chemical impurities in the phenyl methyl carbinol whose rotation was measured. Mass spectrometry indicated the presence of small amounts of β-phenethyl alcohol and pyridine in this carbinol.

We plan to study extensions of the above method to other epoxides as well as possible improvements in experimental conditions.

EXPERIMENTAL

trans-2,3-Epoxybutane. meso-Butanediol (Eastman, 22.5 g., $^1/_4$ mole) and 47.7 g. ($^1/_4$ mole) of *p*-toluenesulfonyl chloride in 150 ml. of pyridine were allowed to stand 20 hours at 3° and two hours at room temperature.[15] A solution of 42.1 g. of potassium hydroxide in 150 ml. of ethylene glycol was added and the crude oxide was distilled out of this mixture. Redistillation gave 5.1 g. (28%) of *trans*-2-epoxybutane, b.p. 52–55°, n^{20}_{D} 1.3752 (lit.[16] b.p. 56.5° n^{20}_{D} 1.3739); infrared spectrum as published.[17]

Optically active styrene oxide. Mandelic acid[18] of $[\alpha]^{25}_{D}$ $-129.3°$ (in water, *ca.* 82% optical purity[12]) was reduced to phenylethanediol, $[\alpha]^{25}_{D}$ $-47.1°$ (ether) by means of lithium aluminum hydride. The diol (12.60 g., diluted with 8.13 g. of *dl*-material) and 28.6 g. of *p*-toluenesulfonyl chloride in 100 ml. of pyridine were allowed to stand at 3° for 18 hours.[15] After one hour at room temperature, potassium hydroxide (25.26 g.) in 150 ml. of methanol was added, followed by 200 ml. of water. Extraction with ether followed by washing with cold 10% sulfuric acid, 5% aqueous sodium hydroxide and water, drying over potassium carbonate, and concentration gave 8.30 g. (46%) of styrene oxide, b.p. 62–63°/4.5 mm., n^{20}_{D} 1.5354 (lit. b.p. 91°/25 mm., n^{20}_{D} 1.5350) $[\alpha]^{25}_{D}$ $+16.51°$ (neat), identified by infrared spectrum.[17] Reduction of the oxide (diluted 4:1 with *dl*-material) with lithium aluminum hydride[19] gave phenyl methyl carbinol, $[\alpha]^{25}_{D}$ $-3.70°$ (neat), optical purity 8.5%[13] indicating over-all retention of configuration[14] in the reaction sequence with *ca.* 85% preservation of optical purity. The mass spectrum of the carbinol showed residuals at m/e 79 and 91 probably due to the presence of a few percent of pyridine and β-phenethyl alcohol respectively.

1,1-Diphenylethylene oxide. A solution 10.71 g. (0.05 mole) of 1,1-diphenylethanediol[8] and 9.53 g. (0.05 mole) of *p*-toluenesulfonyl chloride in 100 ml. of dry pyridine prepared at −5° was allowed to stand for 19 hours at 3°. A solution of 8.4 g. (0.15 mole) of potassium hydroxide in 50 ml. of methanol then was added followed by 100 ml. of water, and extraction of the oxide was effected by means of ether. The ether extract was washed, successively, with 10% aqueous sulfuric acid, 5% aqueous potassium hydroxide, and water, dried over potassium carbonate, and concentrated. The residue was taken up in boiling petroleum ether (b.p. 30–60°), which was filtered to remove unchanged glycol and chilled to yield 5.43 g. (55.3% or 65.7% taking into account recovered glycol) of 1,1-diphenylethylene oxide, m.p. 49–54°. One recrystallization raised the melting point to 53–56° (lit.[10] 55–56°), undepressed by admixture of an authentic sample.[10]

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