molecular bromine or by NBS, the possibility exists that further consumption of the ether or acetate may occur by benzylic attack of R·.

### Experimental Section

**Procedure.**—Weighed amounts of the α-substituted toluene and toluene were diluted to a 50-ml volume with methylene chloride, and a 20-ml aliquot was placed in an erlenmeyer flask containing a known weight of NBS. There was a sufficient amount of NBS added to react with about 50% of the total amount of α-substituted toluene and toluene present. The flask was attached to a water condenser under a positive nitrogen pressure. The reaction mixture was stirred using a Teflon-covered magnetic stirring bar and illuminated with a 150-w tungsten filament bulb about 4 in. from the flask. This served to keep the reaction mixture at the reflux temperature of 40°. Reaction was considered complete when the solution gave a negative test for bromine with starch–iodide paper.

After reaction was complete, the mixture was analyzed for unreacted α-substituted toluene and toluene by glpc. Ethylbenzene was used as the internal standard in all the analyses.

Competitive brominations of toluene and α-chlorotoluene were analyzed at 150° with a 2-m polypropylene glycol column utilizing a F and M Scientific Corp. Model 500 chromatograph. The other analyses employed linear temperature programming (50–180°) with a 2-m GE XF-1150 cyanosilicone oil column. The chromatograph peaks were measured with a planimeter. The peak areas were converted to moles by using the known number of moles of the internal standard and the correction factors calculated from the analysis of the standard solutions. The mixture of α-nitrotoluene and toluene was analyzed only for the unreacted reference compound, toluene. In this case the final concentrations of α-nitrotoluene was calculated from the starting quantity of NBS and the amount of toluene reacted.

**Reagents.**—N-Bromosuccinimide, obtained from Matheson Coleman and Bell, was purified by recrystallization from ten times its weight of hot water, followed by filtration. It was allowed to dry in air for 2 days. Reagent grade phenylacetonitrile and toluene were used without further purification. α-Nitrotoluene obtained from K and K Laboratories was distilled under 0.06-mm pressure and had a boiling point of 61–62°. Methyl phenylacetate, which had a boiling point of 54–55° at 1-mm pressure, was prepared by the sulfuric acid catalyzed reaction of phenylacetic acid and methanol. Benzyl acetate, which had a boiling point of 46–47° at 0.06-mm pressure, was prepared by the sulfuric acid catalyzed reaction of benzyl alcohol and acetic acid. Methylene chloride, obtained from Mallinckrodt, was washed with water and sodium carbonate, dried over calcium chloride, and distilled at 39.5–40°.

## The Oxidation of Substituted Aziridines with Peracids[1]

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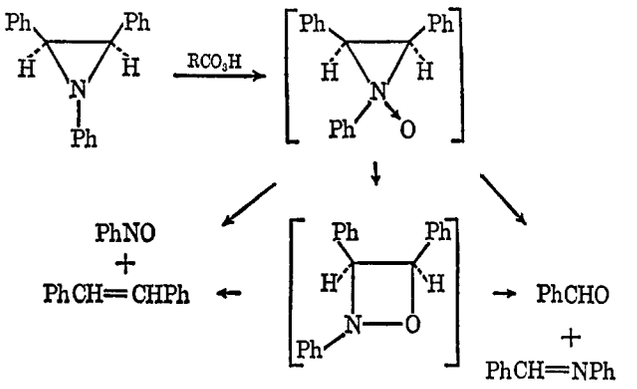
The formation of a four-membered 1,2-oxazetidine ring by the cycloaddition of nitrosobenzene with diethyl methylenemalonate and 1,1-diphenylethylene had been reported by Ingold and Weaver in 1924.[4] A reinvestigation of the structural assignments by Lapworth[5] and more recently by Griffin[6] has shown that the products obtained are in fact N-phenyl-N-(β,β′-dicarboethoxyvinyl)hydroxylamine and α,α-N-triphenylnitrone. With the refutation of the oxazetidine formulation for these products, the only authentic examples of this ring system are the fluorinated[7] and tetramethoxy 1,2-oxazetidines.[8] In an attempt to find a more convenient route to the 1,2-oxazetidine ring, we investigated the reaction of phenyl-substituted aziridines with organic peracids. It was anticipated that the reaction would produce 1,2-oxazetidines through the intermediate formation of aziridine N-oxides. This latter method would be advantageous in that low temperatures could be employed.

It was observed that *cis*-1,2,3-triphenylaziridine[9] reacted smoothly with 1 equiv of *m*-chloroperbenzoic acid in methylene chloride. The reaction was followed by gas–liquid partition chromatography of aliquots withdrawn during the reaction, and product assignments were made by comparison of spectra and glpc retention times with those of known compounds, and were checked by product isolation using preparative glpc. Analysis by gas–liquid partition chromatography of the crude reaction mixture showed that it contained 16% benzaldehyde, 14% nitrosobenzene, 8% benzalaniline, 7% *cis*-stilbene, and 7% *trans*-stilbene. A substantial amount (19%) of a mixture of *cis*- and *trans*-stilbene oxide was obtained as a by-product in the reaction. It appears as though low temperature and equivalent amount of peracid gave the best yield of stilbenes (see Experimental Section). The peracid oxidation was extended also to *cis*-1,2-diphenylaziridine, to give benzaldehyde (44%), and *cis*- and *trans*-stilbene (8%).

The reaction bears a formal resemblance to the peracid oxidation of imines to nitrosoalkane dimers in which a three-membered N-oxide was postulated as an intermediate.[10] Rearrangement of the initially formed aziridine N-oxide to a 1,2-oxazetidine, followed by fragmentation of the four-membered ring readily accounts for the products observed. There still remains the possibility of fragmentation of the initially produced aziridine oxide prior to ring expansion.




Although we are unaware of any close analogy for the expansion of the N-oxide to the 1,2-oxazetidine, the

(1) Epoxidation Studies. IV. For part III, see A. Padwa, *J. Am. Chem. Soc.*, **87**, 4365 (1965).

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TABLE I

THE REACTION OF *cis*-1,2,3-TRIPHENYLAZIRIDINE AND *m*-CHLOROPERBENZOIC ACID

| Product | Solvent | Temp, °C | Moles of peracid | Yield, % |
|---|---|---|---|---|
| PhCHO | $CH_2Cl_2$ | 25 | 1.0 | 16 |
| PhCHO | $ClCH_2CH_2Cl$ | 85 | 1.0 | 34 |
| PhCHO | $ClCH_2CH_2Cl$ | 85 | 4.0 | 23 |
| $PhNO_2$ | $CH_2Cl_2$ | 25 | 1.0 | 14 |
| $PhNO_2$ | $ClCH_2CH_2Cl$ | 85 | 1.0 | 5 |
| $PhNO_2$ | $ClCH_2CH_2Cl$ | 85 | 4.0 | 5 |
| PhCH=NPh | $CH_2Cl_2$ | 25 | 1.0 | 8 |
| PhCH=NPh | $ClCH_2CH_2Cl$ | 85 | 1.0 | 6 |
| PhCH=NPh | $ClCH_2CH_2Cl$ | 85 | 4.0 | .. |
| PhCH=CHPh | $CH_2Cl_2$ | 25 | 1.0 | 7 |
| PhCH=CHPh | $ClCH_2CH_2Cl$ | 85 | 1.0 | 5 |
| PhCH=CHPh | $ClCH_2CH_2Cl$ | 85 | 4.0 | .. |
| PhCH—CHPh (O) | $CH_2Cl_2$ | 25 | 1.0 | 19 |

thermal rearrangement of benzyldialkylamine oxides to trialkylhydroxylamines bears similar characteristics.[11]

The structures of fluorinated oxazetidines have been deduced from the identities of the perfluoro(alkylenealkylamines) and carbonyl halides that are produced in essentially quantitative yields by pyrolysis.[12] An interesting feature of the reaction involving aziridines and peracids is that a significant proportion (14%) of cleavage of the transient oxazetidine occurs in a direction opposite to that involved in the fluorinated case. Thus the isolation of nitrobenzene can be explained by cleavage of the C–N and C–O bond of the oxazetidine ring followed by subsequent oxidation of nitrosobenzene.

The formation of a mixture of *cis*- and *trans*-stilbene suggests either that the transient oxazetidine was present in the reaction as *cis* and *trans* isomers or the fragmentation of the heterocyclic ring does not occur *via* a concerted path. Clearly, no definite conclusion can be reached regarding these possibilities at this time. Further study of the scope, mechanism and utility of oxidation of such aziridines is in progress.

### Experimental Section

***m*-Chloroperbenzoic Acid Oxidation of *cis*-1,2,3-Triphenylaziridine.**—A solution of 0.225 g of *cis*-1,2,3-triphenylaziridine and 0.220 g of *m*-chloroperbenzoic acid in 10 ml of methylene chloride was stirred for 12 hr at room temperature. After this time no more active oxygen content remained as evidenced by the lack of iodine liberation from an acidic potassium iodide solution. The reaction mixture was concentrated under reduced pressure and the residue was analyzed by vapor phase chromatography. The analytical gas chromatography was performed on an Aerograph 350-B instrument with helium as the carrier gas on a column of Ucon LB-1715 (5% on Chromosorb P) at a flow rate of 60 cc/min. Analysis of the crude residue showed that the product was composed of seven components with retention times of 1.5 (16%), 2.6 (14%), 4.2 (6.8%), 10.6 (8%), 11.4 (7%), 14.5 (9%), and 17.1 (10%) min on the Ucon column. Comparison of retention times and infrared spectra with those of known samples of benzaldehyde, nitrobenzene, *cis*-stilbene, benzylidenaniline, *trans*-stilbene, and *cis*- and *trans*-stilbene oxide established the identity of the products.

In an attempt to maximize the formation of products, the reaction between the aziridine and peracid was repeated at various experimental conditions and the yields obtained are described in Table I.

**Reaction of *cis*-1,2-Diphenylaziridine with *m*-Chloroperbenzoic Acid.**—A mixture of 0.25 g of *cis*-1,2-diphenylaziridine and 0.25 g of *m*-chloroperbenzoic acid in 10 ml of 1,2-dichloroethane was heated to reflux for 1 hr. The solution was concentrated under reduced pressure and separated by glpc on a Ucon LB-1715 column at 165°. The materials of retention times 1.5, 10.6, and 11.4 min were collected in a Dry Ice–acetone trap connected to the gas outlet. The colorless liquids had infrared and ultraviolet spectra that were identical to benzaldehyde and *cis*- and *trans*-stilbene.

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## Selective O-Alkylation of Tyrosine

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The synthesis of alkyl ethers of tyrosine has been reported by Weiss and co-workers.[1] Their method requires the protection of the amino group by formylation, and the over-all yield of the three-step method is 30–40% (as the hydrochloride). Earlier, Aberhalden and Guggenheim[2] reported the synthesis of the glycerine monoether, in unspecified yield, through the disodium salt of tyrosine.

In view of the ability of dimethyl sulfoxide to enhance base-catalyzed condensations,[3-5] it seemed worthwhile to investigate the O-alkylation of L-tyrosine in this solvent without protecting the amino group. After our initial investigation had been completed, our findings were confirmed by the publication of Kingsbury's work,[6] in which he reported that dimethyl sulfoxide was particularly effective in promoting O-alkylations.

For this purpose L-tyrosine was dissolved in a mixture of DMSO and aqueous sodium hydroxide and treated with the appropriate alkyl halide (usually bromide) at an elevated temperature. Under these conditions no significant N-alkylation was observed. The major by-product was the ether ester resulting from dialkylation. This by-product could be avoided by carrying out the reaction with a slight excess of the amino acid or eliminated by saponification with dilute base before isolation of the product.

The highest yields of ethers from these reactions were normally obtained by maintaining homogeneous conditions throughout the reaction. This was generally achieved by using 2 equiv of 10–25% sodium hydroxide in about 3–10 vol of DMSO and carrying out the reaction at 70–90°. If the ether ester is the desired product, it may be obtained by using more concentrated

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