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EPOXIDATION OF OLEFINS BY OXAZIRIDINES

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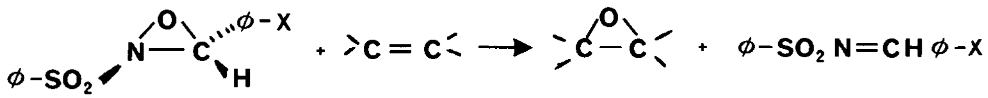
Abstract: The first examples of the epoxidation of olefins by oxaziridines, 2-benzenesulfonyl-3-aryloxaziridines (1a-b) is described.

Studies of model systems that mimic the behavior of the oxygenases have contributed much to our fundamental understanding of these complex oxygen-transfer reactions.[1] For the flavin dependent mono-oxygenases it is generally agreed that the active site is a reduced flavin cofactor.[2] The structure of the active site, however remains controversial, with flavin hydroperoxides,[3] flavin carbonyl oxides[4] and flavin oxaziridines[5] being proposed.

Oxidation of sulfides to sulfoxides, olefin epoxidation and the hydroxylation of aromatic hydrocarbons results on photolysis of heteroaromatic N-oxides.[6] The similarity in oxygen-transfer selectivities for this reagent system and for enzyme catalyzed oxidations has made the photolysis of heteroaromatic N-oxides a useful model system (bio-mimetic) for studying enzyme oxygen-transfer reactions. Oxaziridines are believed to be formed by photolysis of heteroaromatic N-oxides.[7] A transition state involving an oxaziridine was proposed by Boyd and co-workers for the oxidation of sulfides to sulfoxides by this system.[8] This datum was based, in part on the similarities in oxygen-transfer stereoselectivities between their system and stable oxaziridines such as 2-benzenesulfonyl-3-phenyloxaziridine (1a).[9] Since precedents were lacking for the epoxidation of olefins by oxaziridines, no conclusions could be reached on the possible involvement of these species in the epoxidation of olefins by heteroaromatic N-oxides.[8]



1

2

a X = H
b X = p-NO₂

2-Arenesulfonyl-3-aryloxaziridines (**1**) are a new class of selective, aprotic, oxygen-transfer reagents capable of oxidizing sulfides to sulfoxides,[10] amines to amine oxides[11] and organometallic reagents to alcohols and phenols.[12] We report here the epoxidation of olefins by these oxaziridines, **1a-b**, in good yield. Olefin epoxidation by **1** is carried out by heating a two-fold excess of the olefin with the oxaziridine at 60° C in CHCl$_3$. Products were identified by comparision with authentic samples of the reaction mixtures (Table). These epoxides can be separated from the sulfonimine, **2**, by extraction into n-pentane and further purified by preparative TLC or by distillation.

The oxidation of sulfides by **1** is complete in less than a minute at ambient temperature.[10] Olefin epoxidation by **1a-b** is considerably slower. For example, trans-stilbene was epoxidized by **1b**, 25 percent at 25° C after 7 days and 95 percent at 60° C for 12 hr. (entry 14). Electron rich olefins are epoxidized faster than electron-poor olefins by **1a-b**. Compare, for example, the epoxidization of 1-octene with 2-methyl-1-hexene (entries 4 and 5).

The fact that cis-stilbene gives a 72 percent yield of cis-stilbene oxide (entry 16) with **1b** suggests that the epoxidation of olefins by **1a-b** involves a stereospecific syn-addition of oxygen to the C-C double bond. Oxaziridine **1a**, which is thermally less stable than **1b**, gave both cis and trans-stilbene oxides with cis-stilbene (entry 15). One of the products of the thermal ring-opening of oxaziridines, which competes with olefin epoxidation in the case of **1a**, is benzenesulfonic acid.[13] Under the reaction conditions benzenesulfonic acid isomerizes cis-stilbene to trans-stilbene.[14] The latter is also detected (GLC, TLC, NMR) in the epoxidation of cis-stilbene by **1a**. Note that while indene with **1a** gives both indene oxide and 2-indanone (entry 9) with **1b** only indene oxide is obtained (entry 10).[15] In general yields are also better with the more thermally stable oxaziridine **1b** (Table).

Boyd et. al. proposed a non-concerted transition state for the epoxidation of olefins in the photolysis of pyridine N-oxide because both cis and trans epoxides were obtained.[8] Thus the stereospecificity of the epoxidation of olefins by **1** may be interpreted to mean that oxaziridine intermediates are not involved in the epoxidation of olefins by photolysis of heteroaromatic N-oxides. Nevertheless our results demonstrate that a suitably activated oxaziridine can transfer its oxygen atom to the same substrates as do enzyme systems. Studies of the oxygen-transfer reactions of oxaziridines should prove useful in evaluating their involvement in enzyme catalysed oxidations.

Currently we are exploring the scope of the epoxidation of olefins by 2-arenesulfonyl-3-aryloxaziridines (**1**).

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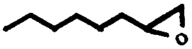
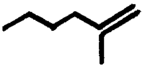
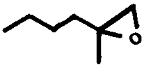
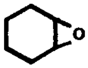
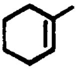
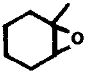
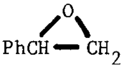
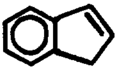
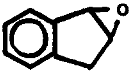
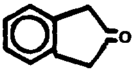
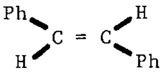
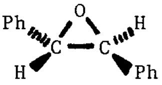
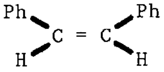
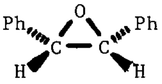
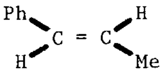
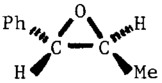
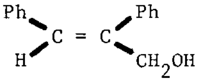
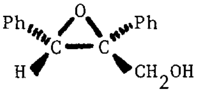
Table : Epoxidation of Olefins by 2-Arenesulfonyl-3-aryloxaziridines (1a-d) in $CHCl_3$ (at $60^{\circ}C$ / 3 hr).

Entry	Oxaziridine[a]	Olefin	Products	(% yield)	Unreacted oxaziridine(%)
1	1a			N.R.	85
2	1b			N.R.	100
3	1b (72 hr)			(42)[c]	
4	1a			(50)	8
5	1b			(77)	
6	1a			(81)	
7	1b			(95)	
8	1b	$PhCH=CH_2$	 $PhCH-CH_2$ (O bridging)	(74) (50)[d]	
9	1a		 (40) 	(10)[c]	20
10	1b		(63)	(--)	
11	1a			(36) (30)[d]	
12	1b			(23)[e]	60
13	1b			(47)	42
14	1b (12 hr)			(95) (70)[d]	
15	1a			(27) (36)[f]	
16	1b			(72) (1)[f]	
17	1a			(41)	30
18	1b (12 hr)			(80) (70)[d]	
19	1b			(63) (30)[c]	

a) Ratio of oxaziridine to olefin was 1:2 unless otherwise noted. b) NMR yields using the internal standard method unless otherwise noted and based upon the oxaziridine. c) GLC analysis using a 6 ft. 3 % OV-17 on Anakrom Q 90/100 mesh column. The analyses were determined by comparison of peak areas with standard solutions of the reaction products. d) Isolated yields. e) Ratio of 1b to trans-stilbene was 1:1. f) Yield of trans-stilbene oxide.

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    A 13% yield of 2-indanone was obtained on heating indene oxide with a trace of benzenesulfonic acid for 3 hr. at 60°C in $CHCl_3$.

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