

Regioselective Reduction of Epoxides by Electron Transfer—a Photochemical Approach

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





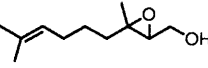
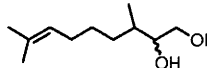
Irradiation of epoxides in the presence of amines and sodium borohydride leads cleanly to a regioselective opening of the epoxide, giving the lesser substituted alcohol as a product.

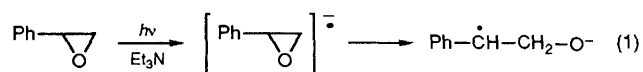
Epoxides are an important class of compounds which are widely used in organic synthesis.¹ Regioselective epoxidation followed by regioselective epoxide cleavage provides a powerful entry into specifically functionalized molecules. Considerable effort has focused on the development of methods for regioselective epoxide cleavage.² Borane,³ acids, bases, hydrides,⁴ boron trifluoride,⁵ electrochemistry⁶ and recently, magnesium iodide–tri-*n*-butyl tin hydride⁷ are methods which have been explored. In many cases low yields or poor regioselectivities have been observed. Reagents often predominantly yield the more highly substituted alcohol.^{2,4}

We report an effective new method for the cleavage of epoxides which takes place under mild conditions, gives near quantitative yields, and very high regioselectivities. Our method is based upon the assumption that photolysis would lead to excited state electron transfer between epoxides and good electron donors such as amines. Accordingly, we have irradiated epoxides (typically 2 to 5 g as a solution in 1:1 acetonitrile: water in the presence of 10 mmol triethylamine and 1 mmol sodium borohydride) under nitrogen using a Rayonet photoreactor equipped with 254 nm lamps. Within 1–5 h of photolysis the epoxide was cleanly cleaved to the lesser substituted corresponding alcohol. Examples of isolated yields from several compounds are shown in Table 1. In all

cases the observed regioselectivity was seen to be excellent by GC and NMR spectroscopy. In most cases the preference for the products shown in Table 1 was >99:1. Only with

Table 1 Yields of alcohols from electron-transfer reactions of epoxides

Starting material	Product	Isolated yield (%)
	PhCH ₂ CH ₂ OH	95
	Ph ₂ CHCH ₂ OH	91
	Ph(Me)CHCH ₂ OH	94
	PhCH ₂ CH(OH)Ph	96
		94
		90



methylcyclohexene oxide was the other regioisomer formed in appreciable amounts; a 93:7 ratio was observed with that compound.

We envisage the key step in the photoreaction to be excited state electron transfer to give the epoxide radical anion. Cleavage of the carbon–oxygen bond occurs in a manner that would lead to the more stable radical, which directly provides the alcohols after hydrogen-atom transfer and protonation (reaction (1)). The reaction proceeds in the absence of sodium borohydride, but the yields were lower. For example, irradiation of 5 g of styrene oxide with only triethylamine present gave a 73% isolated yield of $\text{PhCH}_2\text{CH}_2\text{OH}$. Apparently, radical reactions leading to byproducts are suppressed by the presence of sodium borohydride. The cleavage of methylcyclohexene oxide gave a mixture of stereoisomers, showing that the ring cleavage is not stereospecific. This is consistent with opening to give a radical as shown in reaction (1).

The epoxide cleavage did not occur when the mixture of reagents was kept in the dark. Thus, the highly regioselective ring opening is clearly a photochemically induced process. The high regioselectivity, excellent isolated yields, and mild

conditions of reaction appear to make this reaction a valuable alternative to existing methods for reductive cleavage of epoxides. By combining selective epoxidation⁸ with our method of regioselective opening, one can accomplish selective anti-Markovnikov hydration of a specific double bond in the presence of other double bonds.

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