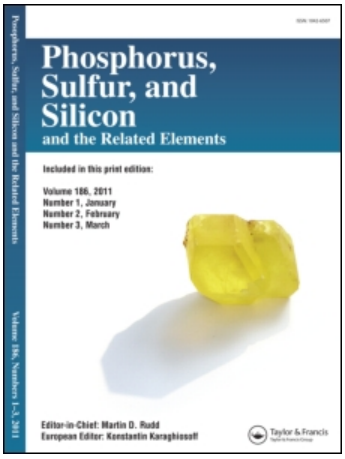

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Synthesis of β -Dihydroxysulfides by Cleavage of Epoxides Using Quaternized Amino-Functionalized Cross-Linked Polyacrylamide as a New Polymeric Phase Transfer Catalyst

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Synthesis of β-Dihydroxysulfides by Cleavage of Epoxides Using Quaternized Amino-Functionalized Cross-Linked Polyacrylamide as a New Polymeric Phase Transfer Catalyst

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*Poly[*N*-(2-aminoethyl)acrylamido]trimethyl ammonium halide resin was developed as a new solid-liquid phase transfer catalyst. This quaternized polyacrylamide catalyzed regioselective ring opening of epoxide by Na_2S to obtain bis[β-hydroxyalkyl]sulfide in high yield under mild conditions.*

Keywords β-Dihydroxysulfides; epoxides; phase transfer catalyst; polyacrylamide

INTRODUCTION

Phase Transfer Catalysis (PTC) is now established as a versatile and important synthetic technique in organic chemistry. Many reviews on synthetic methods using PTC have been written.[1] One of the major concerns in using PTC in soluble form is its separation from the reaction mixture. For efficient use of the catalyst and to meet product purity requirements, synthesis techniques using PTCs involve an additional separation step for catalyst isolation and product purification. Polymer-supported phase transfer catalysts,[2] also known as triphase catalysts, provide an attractive means of recycling the catalyst after the reaction.

The 1,2-epoxide functionality is largely present in nature, is biologically important, and is a powerful building block in organic synthesis.[3] Recently, Sharpless,[4] following the chemical lead of mother nature, proposed the term "click chemistry," the synthetic approach that generates substances "by joining small units together with heteroatom links

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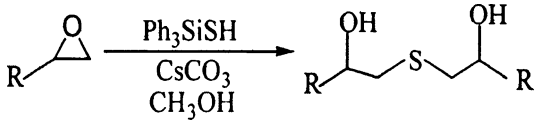
(C-X-C)" and defined the criteria that a process must meet to be useful in this context. A "click reaction" that uses this strategy is the nucleophilic ring-opening of 1,2-epoxides.

Generally, β-hydroxysulfides are prepared by a ring-opening reaction of epoxides with thiols.[5] The most common protocol to achieve the ring-opening process by thiols is by the direct displacement reaction of epoxides with thiols in the presence of a base (NaOH or Et_3N) in a protic solvent (i-PrOH or MeOH).[5,6] Similar results are obtained, for example, when the oxiranes opening reactions with thiols are performed in the presence of lanthanide trichloride[7,8] and metal salts such as $LiClO_4$, $KClO_4$, and $Mg(ClO_4)_2$.[9] On the other hand, as far as we know, there is only one report in the literature on the preparation of symmetrical β-dihydroxysulfide from the reaction of sulfur nucleophile with epoxide rings in the presence of triphenylsilanethiol/$CsCO_3$ (as a solid H_2S equivalent) (Scheme 1).[10]



SCHEME 1

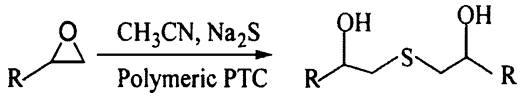
Recently, we have reported the use of a quaternized amino–functionalized cross-linked polyacrylamide as an efficient polymeric phase-transfer catalyst in the synthesis of halohydrins,[11] azidohydrins,[12] thiocyanohydrins,[13] chemoselective reduction of aldehydes and ketones by sodium borohydride,[14] and also synthesis of nitroalcohols.[15] This report describes the results that successfully led to the development of an efficient and simple method for the transformation of epoxides to β-hydroxysulfides using quaternized amino–functionalized cross-linked polyacrylamide as an efficient heterogeneous polymeric PTC in presence of no other catalyst.

RESULT AND DISCUSSION

Polyacrylamide cross-linked with divinylbenzene (2%) was prepared by free radical solution polymerization of the monomer mixture in ethanol by using benzoyl peroxide as an initiator. Poly[*N*-(2-aminoethyl)acrylamide] was obtained by the transamidation reaction of cross-linked polyacrylamide with excess ethylene-diamine. Poly[*N*-(2-aminoethyl)acrylamido]trimethylammonium chloride was prepared by the reaction of poly[*N*-(2-aminoethyl)acrylamide] with an excess of

methyl iodide in DMF at room temperature and subsequent exchange of the iodide anion with chloride.[11]

In view of our results in previous works, and to develop the synthetic utility of poly[*N*-(2-aminoethyl)acrylamido]trimethylammonium chloride, as a phase transfer catalyst the reaction of epoxides with Na_2S to obtain bis[β-hydroxy-alkyl]sulfide under phase-transfer condition was studied (Scheme 2).

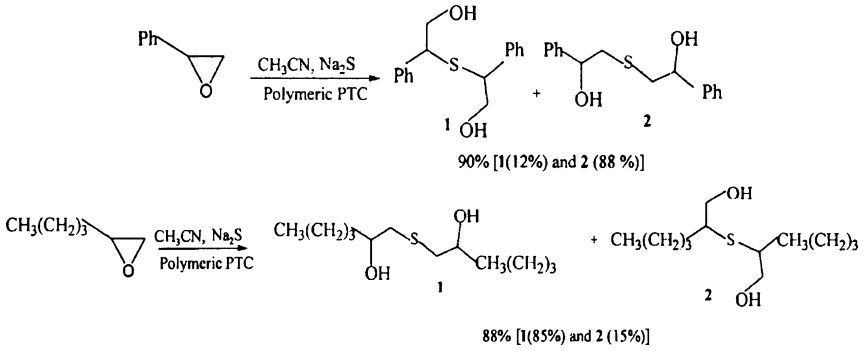


SCHEME 2

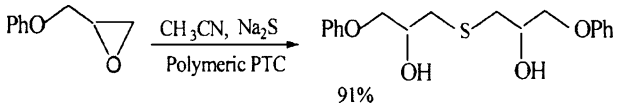
To determine the optimum conditions, the conversion of styrene oxide to the corresponding β-dihydroxysulfide was investigated. The optimum molar ratio of the polymeric catalyst to epoxide was found to be 0.25:1 (Table I). The effects of solvents were also investigated by carrying out the reactions in wet tetrahydroforan, chloroform, dichloromethane, ethyl acetate, acetonitrile, and water (Table II). The best solvent was found to be acetonitrile.

The reactions of different epoxides carrying electron-donating or withdrawing groups with Na_2S were performed in acetonitrile at room temperature in the presence of 0.25 molar equivalents of the polymeric phase-transfer catalyst. The corresponding β-dihydroxysulfides were obtained in high yields (Table III).

Except for the reactions of styrene oxide (Table 3, entry 1; Scheme 3) and 1,2-hexene oxide (Table 3, entry 6) which produce a small percentage of both regioisomers, the reactions of other epoxides were found to be highly regioselective and only one isomer was obtained (e.g., Scheme 4).

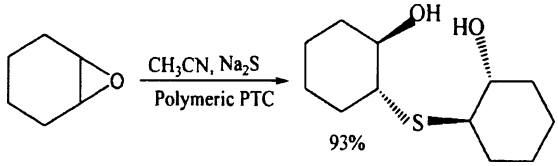


SCHEME 3



SCHEME 4

Also in the case of cyclic epoxides (Table 3, entries 7-8), *trans*-products were obtained (e.g. Scheme 5).



SCHEME 5

The observed regio- and stereochemistry clearly indicate that the reaction proceeds through an S_N2 type mechanism, where the nucleophilic attack by the sulfide (S^{2-}) ion at the less-substituted carbon atom of the epoxide ring, a fact which is reasonably well established.[16]

Table IV shows a comparison between our results and those reported by Gareau.[10] As seen, when epoxides were allowed to react in the presence of our catalyst, the yields and regioselectivity were higher than those reported by the other methods.

As shown in our previous articles, poly[*N*-(2-aminoethyl)acrylamido]trimethylammonium chloride resin in this transformation presumably acts both as a catalyst for nucleophilic ring opening reactions as well as being a phase-transfer agent.

In conclusion, poly[*N*-(2-aminoethyl)acrylamido]trimethyl ammonium chloride resin has proven to be a highly efficient polymeric

TABLE I The Effect of the Molar Ratio of the Polymeric PTC on the Reaction of Styrene Oxide with Na_2S in Acetonitrile

Entry	Molar ratio of PTC	Time (h)	Conversion %
1	0.05	12	100
2	0.1	5	100
3	0.15	3.5	100
4	0.2	1.45	100
5	0.25	1	100
6	0.25	1	100

TABLE II The Effect of the Solvent on the Reaction of Styrene Oxide with Na_2S Using the Polymeric PTC[a]

Entry	Solvent	Time (h)	Conversion %[b]
1	THF	8	6
2	$CHCl_3$	8	0
3	CH_2Cl_2	8	12
4	$CH_3COOC_2H_5$	8	27
5	H_2O	8	43
6	CH_3CN	1	100

[a]The molar ratio of the polymeric catalyst to styrene oxide 0.25:1.
[b]By GC.

phase-transfer catalyst for the regioselective ring opening of epoxides to β-dihydroxysulfides by the S^{2-} ion. The resin has the inherent advantages of being a solid phase-transfer catalyst, including operational simplicity, filterability, regenerability, and reuse. In particular, the workup of the reaction mixture was very easy and the pure products could be isolated without further purification.

EXPERIMENTAL

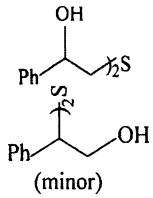
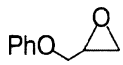
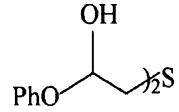
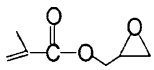
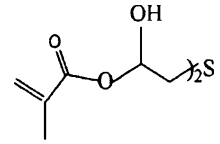
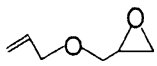
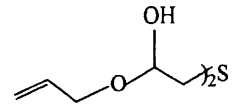
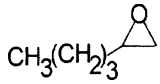
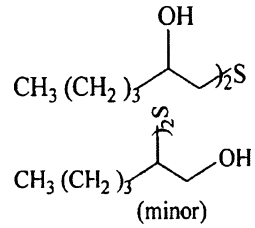
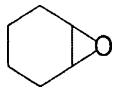
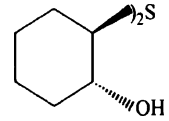
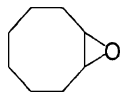
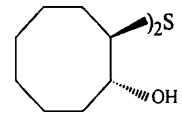
(A) Preparation of Poly[*N*-(2-aminoethyl)acrylamido]trimethyl Ammonium Iodide

The resin was prepared as described in the our previous papers.[16–19]

(B) Preparation of bis[β-hydroxy-alkyl]sulfide (General)

To a mixture of epoxide (1.0 mmol) and sodium sulfide (0.85 g, 10 mmol) in CH_3CN (10 mL) was added to poly[*N*-(2-aminoethyl)acrylamido]trimethylammonium chloride (0.1 g, ~0.3 mmol Cl^-). The suspension was stirred at room temperature for the lengths of time shown in Table 3. Progress of each reaction was monitored by TLC, using CCl_4-Et_2O (5:1) as an eluent and GC. Polymer and salt were removed by filtration. The organic solvent was dried with anhydrous Na_2SO_4. The corresponding pure product was obtained by evaporation of the solvent. The characterization of the product was performed by ^1H, ^{13}C NMR, and IR spectroscopy.

TABLE III Reaction of Epoxides with Na_2S in the Presence of the 0.2 Molar Equivalent of Poly[N-(2-aminoethyl)acrylamido]trimethyl Ammonium Chloride Resin as PTC[a]

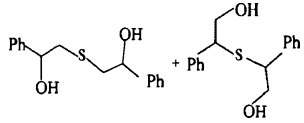
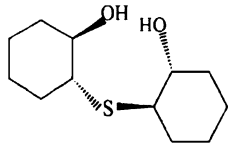
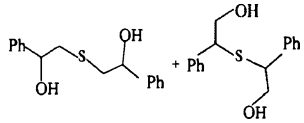
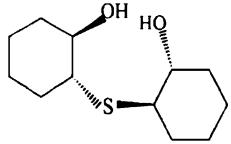
Entry	Epoxide	Solvent	Time (h)	Product[b]	Yield%[c]
1		CH_3CN	1	 (minor)	90(88, 12)
2		CH_3CN	1.1		91
3		CH_3CN	1		92
4		CH_3CN	1		93
5		CH_3CN	1	 (minor)	88 (85, 15)
6		CH_3CN	1		93
7		CH_3CN	1		77

[a] All of the reactions were carried out at room temperature.

[b] Products were identified by comparison of their IR and NMR spectra and/or physical data with those reported in the literature.[10]

[c] Yield refers to the isolated product.

TABLE IV Reaction of Epoxides with Sulfide Reagents in the Presence of the Representative Catalysts

Entry	Epoxide	Catalyst	Reaction condition	Product(s)	Time (h)	%[a] Yield
1		PhSiSH/ $CSCO_3$	MeOH Reflux		1	64(50, 50)
3		PhSiSH/ $CSCO_3$	MeOH Reflux		1	59
4		Na_2S/QPA	CH_3CN/r·t		1	90(88, 12)
6		Na_2S/QPA	CH_3CN/r·t		1	93

QPA: Poly[*N*-(2-aminoethyl)acrylamido]trimethylammonium chloride.

2. Conversion of Cyclohexene Oxide to Bis[β-Hydrocyclohexyl]sulfide under PTC: A Typical Procedure

To a mixture of cyclohexene oxide (0.098 g, 1.0 mmol) and Na_2S (0.85 g, 10 mmol) in acetonitrile (20 mL) was added to poly[*N*-(2-aminoethyl)acrylamido]trimethylammonium chloride (0.1 ng). The mixture was stirred at room temperature for 1 h. The polymer and salt were removed by filtration. The organic solvent was dried with anhydrous Na_2SO_4 and evaporated. The product was bis[β-hydroxycyclohexyl]sulfide in 90% yield. The corresponding data related to product are shown below:

IR (neat) ν 3550, 2930, 2853, 1450, 1207, 1275; ^{1}H NMR δ 1.2 (m., 4H, C$\underline{H}_2$), 1.6 (m., 2H, C$\underline{H}_2$), 2.0 (m., 2H, C$\underline{H}_2$), 2.6 (dd , 1H, —C$\underline{H}$S—), 3.6 (m , 1H, C$\underline{H}$OH); ^{13}C NMR δ 25.4, 26.3, 37.9, 38.44, 40.15.

REFERENCES

[1] a) E. V. Dehmlow and S. S. Dehmlow, *Phase transfer catalysis* (3rd ed.), Weinheim: VCH Publishers (1993); b) W. P. Weber and G. W. Gokel, Phase transfer catalysis in organic synthesis. In *Reactivity and Structure Concepts in Organic Chemistry,* Vol. 4., Berlin Heidelberg: Springer (1977); c) C. M. Starks, *Phase Transfer Catalysis*. New York: Chapman & Hall (1994); d) H. H. Freedman, *Pure and Applied Chemistry*, **58,** 857 (1986).

[2] a) A. Akelah and A. Moet, *Functionalized Polymers and Their Applications*, New York: Chapman and Hall (1990); b) P. Hodge and D. C. Sherington, Eds. *Synthesis and Separations Using Functionalized Polymers*, New York: Wiley (1988).

[3] F. Fringuelli, O. Piermatti, and F. Pizzo, *Trends in Organic Chemistry*, vol. 6 (1997).

[4] H. C. Kolb, M. G. Finn, and K. B. Sharpless, *Angew. Chem. Int. Ed.*, **40,** 2005 (2001).

[5] E. J. Corey, D. A. Clark, G. Goto, A. Marfat, C. Mioskowski, B. Samuelsson, et al. *J. Am. Chem. Soc*., **102,** 1436 and 3663 (1980).

[6] M. E. Peach and S. Patai (eds.). The *Chemistry of the Thiol Group*, New york: John Wiley (1974).

[7] Y. Guidon, R. N. Young, and R. Frenette, *Synthetic Commun*., **11,** 391 (1981).

[8] A. E. Vougioukas and H. B. Kagam, *Tetrahedron Lett*., **28,** 6065 (1987).

[9] M. Chini, P. Crotti, E. Giovani, F. Macchina, and M. Pinechi, *Synlett.*, 303 (1992).

[10] J. Brittain and Y. Gareau, *Tetrahedron Lett.*, **34,** 3363 (1993).

[11] B. Tamami and H. Mahdavi, *Tetrahedron Lett.*, **42,** 8721 (2001).

[12] B. Tamami and H. Mahdavi, *Reactive & Funct. Polym*., **51,** 7 (2002).

[13] B. Tamami and H. Mahdavi, *Tetrahedron Lett.*, **43,** 6225 (2002).

[14] B. Tamami and H. Mahdavi, *Tetrahedron*, **56,** 621 (2003).

[15] H. Mahdavi and B. Tamami, *Reactive & Funct. Polym*., accepted.

[16] (a) M. Chini, P. Crotti, and F. Macchia, *Tetrahedron Lett*., **31,** 5641 (1990); (b) M. Meguro, N. Asao, and Y. Yamamoto, *J. Chem. Soc., Chem. Commun*., 1021 (1995); (c) M. Caron and K. B. Sharpless, *J. Org. Chem.*, **50,** 1557 (1985); (d) D. Sinou and M. Emziane, *Tetrahedron Lett*., **27,** 4423 (1986); (e) C. Blandy, R. Choukroun, and D. Gervais, *Tetrahedron Lett*., **24,** 4189 (1983); (f) S. Saito, S. Yamashita, T. Nishikawa, Y. Yokoyama, M. Inaba, and T. Moriwake, *Tetrahedron Lett*., **30,** 4153 (1989); (g) C. Sarangi, N. B. Das, B. Nanda, A. Nayak, and R. P. Sharma, *J. Chem. Res., (S)*., 378 (1997).