Synthetic Communications: An International Journal for Rapid Communication of Synthetic Organic Chemistry
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/lsyc20

Facile and Selective Oxidation of Sulfides to Sulfoxides by t-Butyl Hydroperoxide in Aqueous Medium

F. Fringuelli [a] , R. Pellegrino [a] & F. Pizzo [a]
[a] Dipartimento di Chimica , Università di Perugia , Via Elce di Sotto 8, 06100, Perugia, Italy

To cite this article: F. Fringuelli , R. Pellegrino & F. Pizzo (1993) Facile and Selective Oxidation of Sulfides to Sulfoxides by t-Butyl Hydroperoxide in Aqueous Medium, Synthetic Communications: An International Journal for Rapid Communication of Synthetic Organic Chemistry, 23:22, 3157-3163

To link to this article: http://dx.doi.org/10.1080/00397919308011174

SYNTHETIC COMMUNICATIONS, 23(22), 3157-3163 (1993)

FACILE AND SELECTIVE OXIDATION OF SULFIDES TO SULFOXIDES BY t-BUTYL HYDROPEROXIDE IN AQUEOUS MEDIUM

F. Fringuelli*, R. Pellegrino, F. Pizzo
Dipartimento di Chimica, Università di Perugia,
Via Elce di Sotto 8, 06100 Perugia, Italy

Abstract: The oxidation of sulfides to sulfoxides with TBHP in water only occurs selectively with high yields and permits the sulfoxides to be prepared without using organic solvents. When the reaction is performed in aqueous sulfuric acid with a H_2SO_4/sulfide molar ratio of 20/1, the oxidation rate is greatly increased.

The synthesis of sulfoxides is of continued interest because they are useful reagents in organic chemistry. The oxidation of sulfides to sulfoxides has been widely explored and numerous oxidants have been developed in an effort to achieve a facile, efficient, cheap and selective method[1-11].

t-Butyl hydroperoxide (TBHP) was one of the first oxidizing agents investigated[12,13] but till now, it has not found synthetic applications even though it is one of the best sources of oxygen atom when one considers the combined features of economics,

---

* To whom correspondence should be addressed.

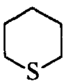
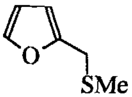
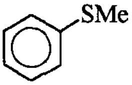
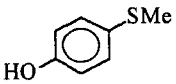
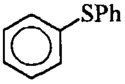
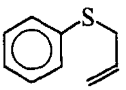
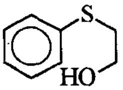
selectivity and safety[14]. Most of the previous investigations have been of kinetic and mechanistic types. In the 1954 Bateman and Hargrave[12] studied the kinetics of the oxidation of cyclohexyl methyl sulfide by TBHP in various solvents and in the 1968 Curci and Edwars[15] reported evidence of the partecipation of "acidic" molecules, such as inorganic acids and protic solvents, in the activated complex of the oxidation reaction of 1-thia-4-oxacyclohexane. In the absence of any protic material, the TBHP itself can serve as a proton donor. Kinetics studies performed by Curci, Di Furia and Modena[16-19] have shown that the oxidations of di-n-buthyl sulfide and p-tolyl-methyl sulfide by TBHP occur smoothly and selectively in organic solvents at 25°C in the presence of catalytic amounts of transition metals.

Recently we showed that the oxidations of alkenes, ketones and allylic alcohols with peracids occur quickly and with high yields in heterogeneous aqueous medium and that the pH plays a fundamental role in the control of the selectivity of the reaction[20-23].

We describe here a synthesis of sulfoxides in water only by oxidation of the parent sulfides with TBHP. Representative examples are reported in the Table.

Oxidations of sulfides with commercial 70% aqueous TBHP in deionized water (pH 7) occurs in heterogeneous phase at 20 - 70°C and affords sulfoxides selectively with very good yields within a reasonable reaction time. The oxidation rate is increased markedly when the reaction is performed in aqueous sulfuric acid with a H_2SO_4/sulfide molar ratio of 20/1. The reaction rate is strongly affected by the concentration of the acid and by the acid/sulfide molar ratio. The oxidation rate is greatly slowed down by reducing the acidity of the medium[32]. Hydrochloric acid and perchloric acid behave similarly[33] and no oxidation was observed in the absence of TBHP.

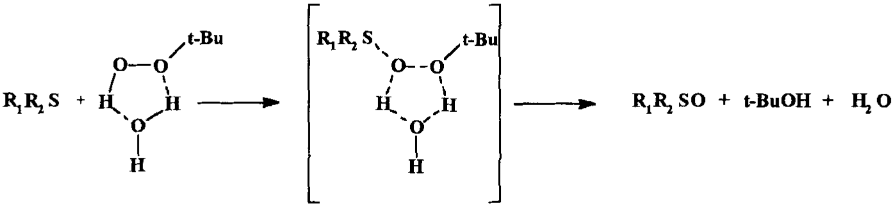
Table. Oxidation of Sulfides to Sulfoxides by TBHP[a]

Entry	Sulfide	Ref[b]	T (°C)	t (min)	medium	yeld (%)[c]
1.	Et_2S	(25)	20	120	DCE	0
			20	120	H_2O	96 [e]
			20	20	H_2O-AH[d]	100
2.	Bu_2S		70	30	DCE	100
			70	30	H_2O	100
			70	5	H_2O-AH[d]	100
3.		(26)	20	180	DCE	20 [e]
			20	180	H_2O	100
			20	10	H_2O-AH[d]	100
4.		(27)	20	600	DCE	5 [e]
			20	600	H_2O	95 [e]
			20	30	H_2O-AH[d]	100
5.			20	1200	DCE	20 [e]
			20	1200	H_2O	100
			20	90	H_2O-AH[d]	100
6.		(28)	20	900	DCE	5 [e]
			20	900	H_2O	100
			20	15	H_2O-AH[d]	100
7.			70	1920	DCE	88 [e]
			70	1920	H_2O	71 [e]
			50	1200	H_2O-AH[d]	95 [e]
8.		(29)	70	120	DCE	53 [f]
			70	120	H_2O	98 [f]
			50	180	H_2O-AH[d]	95 [f]
9.		(30)	70	120	DCE	100
			70	120	H_2O	100
			70	10	H_2O-AH[d]	100

---

[a] A TBHP/Sulfide molar ratio of 6 was used with the exception of entry 7 for which a ratio of 10 was used. [b] References of non-commercial parent sulfoxides. [c] By GC analysis. The yield of isolated and purified sulfoxide is ca. 5% lower. [d] 1.86 M aqueous H_2SO_4 with a H_2SO_4/sulfide molar ratio of 20. [e] The remainder is unreacted material. [f] The remainder is the parent sulfone.

Reactions executed in 1,2-dichloroetane[24] (DCE), under the same conditions, showed that, as previously reported,[13-15] the oxidation of sulfides with TBHP in organic solvent is very slow in the absence of catalyst. The greater reactivity of sulfides in aqueous medium compared to that in organic phase is justified by considering[15] that the water facilitates the O-O bond fission promoting the hydrogen transfer in the transition state of the rate determining step.



In the acid medium, the t-Butyl hydroperoxide protonated like wise to the metal-linked peroxide molecule in the metal catalyzed oxidation[17], is the oxidizing reagent and the reaction rate is related to its concentration.

Of interest is the fact that when the oxidation of sulfides by TBHP in aqueous medium is carried out under neutral conditions or in the presence of HCl, the sulfoxides are prepared without using organic solvents. This makes the present procedure not only easy and efficient but also clean and environment-friendly. Moreover the methodology also seems to be suitable for sulfides which have mineral acid sensitive groups (entries 4 and 8 of Table).

EXPERIMENTAL

The starting sulfides and aqueous 70% TBHP were commercial products. The sulfoxides were identified by comparison (GC, MS, ^{1}H-NMR) with authentic samples which are referred to in the parentheses in the Table with the exception of those that were commercial. GC analyses were performed on a Hewlett-Packard 5890 chromatograph with SPB-5 fused silica capillary column (30m, 0.25mm internal diameter), an "on-column" injector system, a FID detector, and hydrogen as the carrier gas. GC-MS analyses were carried out on and HP 5970 GC-MSD instrument with 70 eV electron energy mass selective detector. ^{1}H-NMR spectra were recordered on FT 80SY and 200 AC Brucher spectrometers.

Oxidation of 4-(methylthio)phenol under neutral conditions; Typical Procedure: Aqueous 70% TBHP (1.5 mL; 12 mmol) was added at 20°C to a stirred heterogeneous mixture of 4-(methylthio)phenol (2 mmol) in deionized water (20mL). The mixture was stirred for 15 h and water and TBHP were eliminated under reduced pressure. The residue was crystallized from ethyl acetate/n-hexane to give 4(methylsulfinyl)phenol (mp 105-106°C; litt.[28] 104°C) in 95% yield.

Oxidation of methyl phenyl sulfide in acid aqueous medium; Typical Procedure: A solution (21.5 mL) prepared with 2M H_2SO_4 (20 ml; 40 mmol) and aqueous 70% TBHP (1,5 mL; 12 mmol) is added at 20°C to a methyl phenyl sulfide (2mmol). The heterogeneous mixture was stirred for 1.5 h, was saturated with NaCl and extracted with diethyl ether. Work up as usual affords methyl phenyl sulfoxide (mp 29-30°C; litt.[34] 29-30°C) in 94% yield.

Acknowledgment: The Consiglio Nazionale delle Ricerche (CNR Rome) and Ministero dell'Università e della Ricerca Scientifica e Tecnologica (MURST) are thanked for financial support.

REFERENCES AND NOTES

1. Madesclaire, M. *Tetrahedron* **1986**, 42, 5459.
2. Greenhalgh, R. P. *Synlett* **1992**, 235.
3. Balicki, R., Kaczmarek, L. and Nantkanamirski, P. *Liebigs Ann. Chem.* **1992**,883.
4. Hirano, M., Kudo, H. and Morimoto, T. *Bull. Chem. Soc. Jpn.* **1992**, 65, 1744.

5. Folson, H. E. and Castrillon, J. *Synth. Commun.* **1992**, 22, 1799.
6. Davis, F.A., Reddy, R. T., Han, W. and Carrol, P.J. *J. Am. Chem. Soc.* **1992**, 114, 1428.
7. Rossi, C., Fauve, A., Madesclaire, M., Roche, D, Davis, F.A. and Reddy, R. T. *Tetrahedron Asymmetry* **1992**, 3, 629.
8. Cordellicchio, C., Fiandanese, V. and Naso, F. *J. Org. Chem.* **1992**, 57, 1718.
9. Chondary, B. M. and Rani, S. S. *J. Mol. Catal.* **1992**, 75, L7
10. Pautet, F. and Daudon, M. *Tetrahedron Lett.* **1991**, 32, 1457.
11. Menger, F. M. and Elrington, A.R. *J. Am. Chem. Soc.* **1991**, 113, 9621.
12. Bateman, L. and Hargrave, K. R. *Proc. R. Soc. A* **1954**, 224, 389,399.
13. Barnard, D. *J. Chem. Soc.* **1956**, 489.
14. Sharpless, K. B. *Aldrichim. Acta* **1979**, 12, 63.
15. Dankleff, M. A. P., Curci, R., Edwards, J. O. and Pyun, H-Y. *J. Am. Chem. Soc.* **1968**, 90, 3209.
16. Di Furia, F., Modena. G. and Curci, R. *Tetrahedron Lett.* **1976**, 50,4637.
17. Curci, R., Di Furia, F. Testi, R. and Modena, G. *J. Chem. Soc. Perkin II* **1974**, 752.
18. Di Furia, F., Modena, G. and Seraglia, R. *Synthesis* **1984**, 325.
19. Campesini, S., Conte, V., Di Furia, F., Licini, G. and Modena, G. *Chim. Ind.* (Milano) **1990** (408).
20. Fringuelli, F., Germani, R., Pizzo, F. and Savelli, G. *Tetrahedron Lett.* **1989**, 30, 1427.
21. Fringuelli, F., Germani, R., Pizzo, F. and Savelli G. *Gazz. Chim Ital.* **1989**, 119, 249.
22. Fringuelli, F., Pizzo, F. and Germani, R. Synlett **1991**, 475.
23. Fringuelli, F., Germani, R., Pizzo, F., Santinelli, F. and Savelli, G. *J. Org. Chem.* **1992**, 57, 1198.

24. A solution of TBHP in DCE ca. 2.35 M prepared as described[14] was used.

25. Barnard, D., Fabian, J. M. and Kock, H. P. *J. Chem. Soc.* **1949**, 2442.

26. Cerani, A., Modena, G. and Todesco, P. E. *Gazz. Chim. Ital*. **1960**, 382.

27. Identified as sulfone[31].

28. Bordwell, F. C. and Boutan, P. J. *J. Am. Chem. Soc.* **1957**, 79, 717.

29. Antonjuk, D.J., Ridley,D.D. and Smal, M. A. *Aust. J. Chem.* **1980**, 33, 2635.

30. Yamamoto, T, Kakimoto, M-A. and Okawara, M. *Bull. Chem. Soc. Jpn.* **1979**, 52, 841.

31. Takeda Chemical Industries, Ltd. Brit. 1,069,379, *C.A.* **1968**, 68, 39472j.

32. When the oxidation of methyl phenyl sulfide is carried out in 0.6 M aqueous H_2SO_4 and with a H_2SO_4/sulfide molar ratio equal to 6, only 15% of the sulfide is oxidized after 3 h.

33. The oxidation of methyl phenyl sulfide in aqueous mixtures of TBHP-HCl and TBHP-$HClO_4$, under the same condition of acidity noted in the Table, is quantitative after 3 h and 4 h, respectively.

34. Johnson, C. R. and Keiser, J. E. *Organic Syntheses*, collective volume V, **1973**,791.

(Received in The Netherlands 18 June 1993)