

An Efficient Method for the Oxidation of Organic Sulfides to Sulfones

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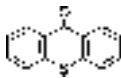

Keywords: Oxygenations, Reagents, Sulfur, Synthetic methods, Sulfones**Abstract.** Mild and safe oxidation of dialkyl-, diaryl- and alkyl-aryl sulfides (**1a–m**) to the corresponding sulfones (**2a–****m**) by using urea-hydrogen peroxide/formic acid system is reported.

Sulfones are useful intermediates which play an important role in organic chemistry [1]. These compounds are almost invariably prepared by oxidation of the corresponding organic sulfides [2–7]. The conventional methods of carrying out this transformation include oxidation of the sulfide with peracids (*i.e.* *m*-CPBA or H₂O₂/acetic acid), or oxone [8]. Hydrogen peroxide with a variety of metal catalyst [9] as well as KMnO₄ [10] and Zn(MnO₄)₂ [11] have been used for this purpose. However, most of the existing methods are deficient in some respect such as: low yields, use expensive, toxic or rare oxidizing reagents, severe reaction conditions or difficulties with isolation of the product. Oxidation of sulfides bearing bulky groups or electron withdrawing substituents is also often not satisfactory. Therefore, there is a need for simple, less expensive and safer methods for conversion of sulfides to sulfones.

A survey of the literature revealed that the adduct between hydrogen peroxide and urea (UHP) [12] is a cheap, safe and stable source of pure H₂O₂. Several systems containing UHP with some acid anhydrides were used as efficient oxidizing agents [13, 14]. Recently, we reported that performic acid obtained by the combination of UHP and 85% formic acid appeared to be an effective reagent for mild and selective *N*-oxidation of *N*-heteroaromatics and tertiary amines [15]. These results prompted us to extend the investigation of oxidizing abilities of this novel reagent.

In this paper we wish to report on the facile and efficient oxidation of organic sulfides **1** to the respective sulfones **2** by use 85% HCOOH/UHP system. The reaction is very easy and proceeds within 1–4 hrs upon addition of the substrate **1** to a suspension of UHP in formic acid at room temperature to afford the corresponding sulfone **2**, which precipitates during

Table 1 Oxidation of sulfides to sulfones

$\text{R}^1 \text{--} \text{S} \text{--} \text{R}^2 \xrightarrow{\text{HCOOH/UHP}} \text{R}^1 \text{--} \text{SO}_2 \text{--} \text{R}^2$					
Substrate 1	R ¹	R ²	Time (h)	Yield of 2 ^{a, b)} (%)	<i>m.p.</i> (°C) ^{c)}
a	<i>n</i> -Pr	<i>n</i> -Pr	1.0	96	28–29 (29–30) [16]
b	<i>n</i> -Bu	<i>n</i> -Bu	1.5	95	44 (44) [17]
c	<i>t</i> -Bu	<i>t</i> -Bu	2.5	92	126–127 (128) [18]
d	<i>i</i> -Pr	<i>i</i> -Pr	1.5	94	oil [19]
e	Me	Ph	2.0	95	86–87 (88) [20]
f	Bn	Bn	2.0	97	150–151 (151) [21]
g	Bn	Ph	2.0	94	145 (146–147) [22]
h	Ph	Ph	2.5	95	122–123 (123) [23]
i	<i>o</i> -NO ₂ -Ph	Ph	3.5	90	141–142 (143) [24]
k	<i>p</i> -NO ₂ -Ph	<i>p</i> -NO ₂ -Ph	4.0	91	279 (280–281) [18]
l			3.0	98	226–227 (230) [25]
m			4.0	88	216–217 (218) [18]
n			2.0	96	>235 dec. (>230 dec) ^{d)}

^{a)} The identity of the products was confirmed by comparison of their TLC and NMR spectra with those of authentic samples, *e.g.* for **2a** – ¹H NMR (CDCl₃): δ/ppm = 0.98 (t, 6H, CH₃), 1.64 (m, 4H, -CH₂), 3.12 (t, 4H, -CH₂) – ¹³C NMR (CDCl₃): δ/ppm = 54.4 (C–1), 24.4 (C–2), 13.5 (C–3)

^{b)} Yields of isolated products ^{c)} Literature *m.p.*'s given in parentheses ^{d)} 1,3,5-Trithian-1,1,3,3,5-pentaoxide [26]

the reaction. Thin-layer chromatography of the crude solid and reaction mixture indicated that oxidation of sulfide **1** is quantitative, and intermediate sulfoxides were not observed. On the other hand, if UHP was replaced by 30% H₂O₂, the yield of the reaction product was markedly lower and in some cases no reaction occurs.

The optimum ratio substrate **1** to UHP in the case of oxidation of dialkyl sulfides was found to be 1:4, and in the case of oxidation of alkyl-aryl- and diaryl sulfides 1:8.

Several examples illustrating this novel and efficient procedure for the oxidation of organic sulfides **1** to the corresponding sulfones **2** are presented in Table 1.

In conclusion, this new method for converting sulfides to the corresponding sulfones offers the following advantage: (a) safe and cheap oxidizing reagent is used; (b) the oxidation is mild and fast giving exclusively sulfones in quantitative yields; (c) the method is efficient also for the oxidation of sulfides containing bulky groups (entry **1c**) and electron withdrawing substituents (entries **1i**, **1k**); (d) the procedure is very facile, and sulfones precipitate from the reaction mixture.

Experimental

All reagents are commercially available and were used without purification. TLC analyses were run on plates covered with silica gel, eluted with benzene-methanol (8:1, v/v).

Oxidation of Organic Sulfides (General Procedure)

The corresponding substrate **1** (3 mmol for dialkyl- and 1.5 mmol for alkyl-aryl- or diaryl sulfides) is introduced to the solution of UHP (12 mmol) in formic acid (10 ml) at room temperature with stirring. A white precipitate is formed during reaction. After 1–4 h, the reaction is complete (TLC analysis). Water (20 ml) and ether (20 ml) are added. After separation, the ether layer is washed successively with saturated sodium bicarbonate and sodium chloride solutions. Drying over magnesium sulfate, filtration through a pad of silica gel and concentration give chromatographically pure sulfone **2**.

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