

# Rapid, Efficient and Chemoselective Deoxygenation of Sulfoxides to Thioethers Using $\text{NaBH}_4/\text{I}_2$

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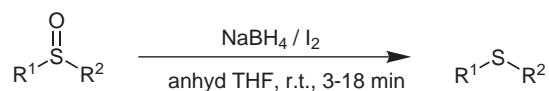
**Abstract:** Sodium borohydride in the presence of iodine in anhydrous THF converts a range of structurally different sulfoxides to their thioethers in excellent yields. It has been found that chemoselective deoxygenation of sulfoxides can be achieved in the presence of other reducible functional groups such as esters, nitriles and double bonds.

**Key words:** sulfoxides, deoxygenation, reduction,  $\text{NaBH}_4$ , iodine, sulfides

Sulfoxides are important intermediates in a variety of synthetic transformation, especially they are used as chiral auxiliary in asymmetric synthesis.<sup>1</sup> This accordingly demands techniques for removal of the residual sulfoxide moiety to generate the corresponding sulfide,<sup>2</sup> which could be further desulfurized by treatment with Raney nickel or a reducing low valent metal system such as lithium in liquid ammonia.<sup>1,3</sup> Therefore, much effort has been devoted, of late, to the development of milder conditions where the presence of various sensitive and/or reducible functional groups can be tolerated.

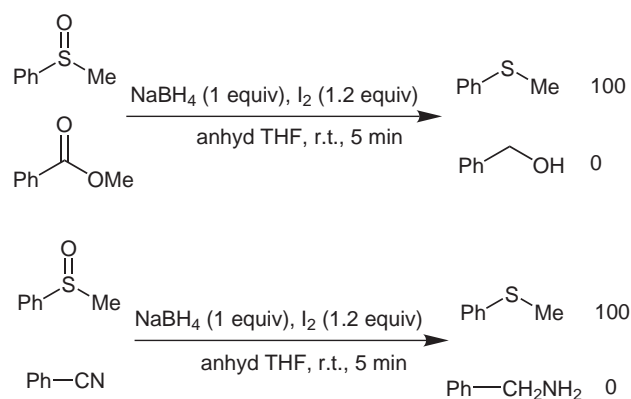
Although there are a good number of methods available for the deoxygenation of sulfoxide to thioethers, there still remain the important problems of reaction, i.e. many of them need rather drastic conditions and/or long reaction time.

Therefore, a search for new improved methods based on readily available reagents is still pursued. Recently, several publications describing the reduction of various types of functional groups such as carboxylic acids,<sup>4</sup> carboxylic esters, amides and nitriles, and hydroboration of alkenes,<sup>5</sup> and amino acids<sup>6</sup> using  $\text{NaBH}_4/\text{I}_2$  systems have appeared. However, to the best of our knowledge there is no report on the use of this reagent for deoxygenation of sulfoxide. We now report that  $\text{NaBH}_4/\text{I}_2$  system is an efficient and powerful reagent for rapid conversion of sulfoxide to their thioethers (Scheme 1).



**Scheme 1**

Inspection of the data in Table 1 clearly shows that the method is equally applicable for a variety of structurally different sulfoxides. Highly chemoselective deoxygenation of sulfoxide can be achieved when it is present along with an olefin moiety without the formation of any detectable hydroboration products (Table 1, entry 3). Moreover, efficient deoxygenation of dibenzyl and benzyl phenyl sulfoxides to their thioethers without cleavage of C–S bond shows the usefulness of the presented protocol. (Table 1, entries 14, 15). The method can be selectively applied for the chemoselective reduction of sulfoxide in the presence of nitriles and esters which was previously reported to be effectively reduced using  $\text{NaBH}_4/\text{I}_2$  system (Scheme 2).<sup>5</sup>



**Scheme 2**

This observation clearly suggests that the method can be applied for the chemoselective reduction of sulfoxides in the presence of other reducible functional groups such as esters and amides in multifunctional molecules.

On the other hand substitution with one nitro group as in the case of 4-nitrophenyl phenyl sulfoxide gave somewhat lower yield of the corresponding sulfide together with unidentified side product (Table 1, entry 16). This is due to the reduction of nitro group leading to a complex mixture of the corresponding amine and azo compounds.<sup>2i</sup>

In summary, we have demonstrated that  $\text{NaBH}_4/\text{I}_2$  system is an inexpensive and excellent reagent for rapid deoxygenation of a variety of structurally diverse sulfoxides to the corresponding sulfides. The present procedure shows good chemoselectivity, and the reaction conditions are quite mild. Further application of this reagent is currently in progress in our laboratory.

**Table 1** Deoxygenation of Sulfoxide to Thioethers Using NaBH<sub>4</sub>/I<sub>2</sub> System

Entry	R <sup>1</sup>	R <sup>2</sup>	I <sub>2</sub> (equiv)	Time (min)	Yield (%) <sup>a</sup>
1	Ph	Me	1.2	4	95
2	Ph	Et	1.2	4	91
3	Ph	CH <sub>2</sub> =CHCH <sub>2</sub>	1.2	5	94
4	Ph	<i>n</i> -Bu	1.2	4	93
5	Ph	PhCH <sub>2</sub> CH <sub>2</sub>	1.2	9	92
6	Ph	<i>i</i> -Pr	2	10	93
7	Ph	<i>s</i> -Bu	1.2	10	93
8	Ph	<i>c</i> -C <sub>5</sub> H <sub>9</sub>	1.2	6	88
9	Ph	<i>c</i> -C <sub>6</sub> H <sub>11</sub>	1.2	6	92
10	3-MeC <sub>6</sub> H <sub>4</sub>	<i>i</i> -Pr	1.2	10	90
11	Ph	Ph	2	18	93
12	4-MeC <sub>6</sub> H <sub>4</sub>	4-MeC <sub>6</sub> H <sub>4</sub>	2	15	95
13	<i>n</i> -Bu	<i>n</i> -Bu	1.2	3	95
14	Ph	PhCH <sub>2</sub>	2	12	93
15	PhCH <sub>2</sub>	PhCH <sub>2</sub>	1.2	5	98
16	4-NO <sub>2</sub> C <sub>6</sub> H <sub>4</sub>	Ph	2	15	57

<sup>a</sup> Yields of isolated pure products.

<sup>1</sup>H NMR and <sup>13</sup>C NMR spectra were recorded on a Bruker 250 or 500 MHz spectrometer in CDCl<sub>3</sub> as the solvent and TMS as internal standard. All of the products are known and the isolated products gave IR spectra in agreement with their structures.

### Deoxygenation of Sulfoxides to Sulfides; General Procedure

To a solution of the appropriate sulfoxide (2 mmol) and I<sub>2</sub> (2.4–4 mmol) in THF (25 mL) was slowly added NaBH<sub>4</sub> (2 mmol). The mixture was stirred at r.t. and the progress of the reaction was followed by TLC. After stirring for the indicated time in Table 1, the reaction was quenched with a 10% aq solution of NaOH (25 mL). The aqueous layer was extracted with Et<sub>2</sub>O (3 × 20 mL), and the combined organic extracts were washed successively with 5% aq Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> (15 mL) and H<sub>2</sub>O (2 × 25 mL). The resulting organic layer was dried (Na<sub>2</sub>SO<sub>4</sub>) and concentrated under reduced pressure. Further purification of the product was achieved by column chromatography on a short column of silica gel using *n*-hexane as eluent.

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