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Silica–PSCl₃: A Mild and Efficient Reagent for Deoxygenation of Sulfoxides

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Abstract: A new solid supported reagent, silica–PSCl₃, has been developed for deoxygenation of sulfoxides. With this reagent, conversion of sulfoxides to sulfides occurred cleanly and efficiently at room temperature. Facile isolation of the product was achieved by simple filtration of the by-products without any extensive workup.

Keywords: deoxygenation, heterogenization, silica-PSCl₃, sulfides, sulfoxides

Sulfides are important in organic chemistry because of their versatile utility.^[1] The deoxygenation of sulfoxides is one of the most commonly used routes to sulfides. Various reagents/methods are available for this transformation,^[2–5] including the recently introduced Silphos^[6] and PhSiH₃/MoO₂Cl₂.^[7] Although these reagents are useful, many of them suffer from drawbacks such as prolonged reaction time, difficult to prepare and expensive reagents, elevated temperature, and complex experimental procedure, which make isolation of the desired product tedious. Therefore, the search for a better reagent/method had continued with an aim to develop a mild and clean procedure, where various sensitive functional groups can be tolerated. For the conversion of sulfoxide to sulfide, phosphorus compounds^[8] have made a major contribution, which is mainly due to the strong affinity between phosphorus and oxygen. Because, the oxo-transfer reaction from sulfoxide to

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phosphorus compounds is a thermodynamically favorable process,^[9] this reaction is expected to occur under mild condition. But, the use of these reagents is limited by their high volatility, corrosive nature, and extremely difficult isolation of the desired product from the malodorous by-products formed during the reaction. Heterogenized reagents are being widely accepted in organic synthesis.^[10,11] Through heterogenization, easier handling and lower toxicity can be achieved for toxic, explosive, or malodorous reagents, as supported reagents are safer and more convenient than their solution-phase equivalents. Another important motive for heterogenization is the facile isolation of the pure product. Hence, a solid-supported deoxygenating agent was particularly desirable. Herein, we report a new reagent, silica–PSCl₃, for a very simple, mild, clean conversion of sulfoxide into sulfide. Silica-PSCl₃ can be prepared conveniently from silica and PSCl₃, which is available commercially.

This is an easily handled, low-odor reagent and can be stored for months without any appreciable loss in activity. Clean deoxygenation can be achieved by simple stirring of the reagent with sulfoxides at room temperature. The interesting features of this protocol are the mild reaction condition and facile isolation of the pure product without any extensive workup. The phosphorous oxide by-products remained bound to the silica, and there is no need for any further purification. No undesirable side product formation was observed under the reaction condition.

In a typical experimental procedure, sulfoxide 1 was stirred with silica– PSCl₃ 2 in dry acetonitrile at room temperature (Scheme 1). Progress of the reaction was monitored by thin-layer chromatography (TLC) and gas chromatography (GC). After completion of the reaction, silica was filtered off, and removal of the solvent afforded pure compound 3 (Table 1). Reaction with alkyl sulfoxides occurred more rapidly than with aryl sulfoxides. Functional group tolerance with this method is evident from entries 7 and 10 (Table 1). Various solvents were screened for the reaction, and acetonitrile was found to be most suitable. The reaction was studied with different molar ratios of the reagent (Table 2). For alkyl and aryl/alkyl sulfoxide, best results were obtained with sulfoxide and silica–PSCl₃ in 1:2 molar ratios, whereas complete deoxygenation of aryl sulfoxides at room temperature required 2.5 mol.

Furthermore, effect of temperature on the progress of the reaction was also investigated. With an increase in temperature, a marked acceleration in



Scheme 1. Deoxygenation of sulfoxides.

Table 1. Deoxygenation of sulfoxides by 2

Entry	R_1	R ₂	Time ^a	Time ^b	Yield $(\%)^c$
1	C ₄ H ₉	C ₄ H ₉	2 h	0.5 h	94
2	C_6H_5	C ₆ H ₅	6 h	2 h	91 ^d
3	C ₆ H ₅	CH ₃	4.5 h	1 h	93
4	p-CH ₃ C ₆ H ₄	CH ₃	2.5 h	0.7 h	92
5	C ₆ H ₅ CH ₂	$C_6H_5CH_2$	2.5 h	0.6 h	93
6	C ₁₀ H ₇	p-NO ₂ C ₆ H ₅	5.5 h	1.7 h	88^d
7	C ₆ H ₅	Vinyl	4 h	0.9 h	92
8	$C_{10}H_{7}$	CH ₃	3 h	0.7 h	91
9	$p-ClC_6H_4$	$p-ClC_6H_4$	8 h	2.5 h	90^d
10	$HO(CH_2)_2$	CH ₃	2 h	0.5 h	88
11	Benzothio- phene 5-oxide		4.5 h	0.8 h	92 ^d

Note: All the products gave satisfactory NMR, IR and MS data.

^aReactions carried out at room temperature.

^bReactions carried out at 70°C.

^cIsolated yield.

^dMolar ratio of sulfoxide and silica–PSCl₃ is 1:2.5.

Entry	Molar ratio of substrate (mmol)/ reagent (mmol) ^{b}	Reaction time (h)	Conversion $(\%)^a$
1	1:1	2.0	30
2	1:1	4.0	66
3	1:1	6.0	70
4	1:2	3.0	59
5	1:2	6.0	84
6	1:2.5	4.0	83
7	1:2.5	6.0	100
8	1:1	1.0	71
9	1:1.5	2.0	74
10	1:2.0	1.0	86
11	1:2.0	2.0	100

Table 2. Optimization of reagent for conversion of sulfoxides to sulfides

Note: Entries 1-7 for diphenyl sulfoxide and 8-11 for n-butyl sulfoxide.

^aConversion was determined by GC analysis.

^{*b*}1 mmol ≈ 0.77 g of silica–PSCl₃.

the reaction rate was observed. At 70° C, optimum conversion was obtained. Further increase in temperature no doubt increased the reaction rate, but some side product formation was also observed. To see the importance of silica–PSCl₃, similar reactions with PSCl₃ were also carried out. No significant conversion could be obtained, and the reaction mixture gradually turned brown with excessive side product formation.

In conclusion, silica–PSCl₃ has been found to be a very mild and efficient reagent for deoxygenation of sulfoxides to sulfides. Because, the reaction occurred at room temperature, the method is of considerable interest for heat-sensitive compounds. Additional important features of this protocol are clean conversion with no undesired side product formation and facile purification of the product without any extensive workup. Other potential applications of this newly developed reagent are being explored and will be reported in due course.

EXPERIMENTAL

General Procedure for Deoxygenation of Sulfoxide

Methyl *p*-tolyl sulfoxide (0.15 g, 1 mmol) was taken in 10 mL of dry acetonitrile. To this, 1.54 g (2.0 mmol) of silica–PSCl₃ was added. The reaction mixture was stirred slowly, and progress of the reaction was monitored by TLC and GC. After completion of the reaction, which took ca. 2.5 h, 2.0 g of dry silica was added to the reaction mixture to absorb the traces of leached by-products, and the product was filtered and washed with hexane. Removal of the solvent afforded the pure compound. The phosphorous oxide by-products remained bound to the silica; there is no need for any further purification. When the same reaction was carried at 70°C, the reaction was complete within 40–45 min. The compound was found to pure by GC. MS: m/z; 138 [M⁺], 123, 91, 79, 65, 51. ¹H NMR (CDCl₃, 400 MHz): $\delta = 2.32$ (s, 3H), 2.47 (s, 3H), 7.09–7.2 (m, 4H).

Preparation of Silica-PSCl₃

PSCl₃ (41.6 mL, 0.4 mol) was added to dry silica-gel (54.0 g, 0.9 mol) and constantly stirred for 60 min. The mixture was then heated to 70°C for 3 h to remove all the HCl under nitrogen while stirring was continued. Silica-PSCl₃ (59.4 g) was obtained as white free-flowing solid and was stored in a capped bottle in a refrigerator. This can be used for months without appreciable loss in activity. IR spectra of both silica and silica–PSCl₃ were found to be similar, and both showed strong adsorption at 1100 cm⁻¹ and 800 cm⁻¹. Sulfur content was found to be 4.5% by elemental analysis, corresponding to the 1.3 mmol of sulfur per g of silica–PSCl₃. IR (KBr disk), v (cm⁻¹): 3420, 1100, 804.

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REFERENCES

- (a) Bernardi, F.; Csizmadia, I. G.; Mangini, A., Eds.; Organic Sulfur Chemistry; Elsevier: Amsterdam, 1985; (b) Damani, L. A. ed. Sulfur-containing drugs and related organic compounds: Chemistry, Biochemistry and Toxicology; Harwood, E. Ed.; Chichester, England, 1989; (c) Pathak, U.; Raza, S.; Kulkarni, A. S.; Vijayaraghavan, R.; Kumar, P.; Jaiswal, D. K. Novel S-substituted aminoalkylamino ethanethiols as potential antidotes against sulfur mustard toxicity. J. Med. Chem. 2004, 47, 3817.
- Solladie, G. Synthesis of sulfides, sulphoxide, and sulfones. In *Comprehensive* Organic Synthesis; Trost, B. M. and Fleming, I. Eds.; Pergamon Press: Oxford, U. K., 1991, Vol. 6, pp. 130–170.
- (a) Page, B. P. C.; Wilkes, R. D.; Reynolds, D. In *Comprehensive Organic Functional Group Transformations*, 1st Edn.; Katritzky, A. R., Cohn, O. M. and Rees, C. W. Eds.; Elsevier: Oxford, 1995, Vol. 2 Section 2.03; (b) Procter, D. J. The synthesis of thiols, selenols, sulfoxides, selenides, sulfoxides, selenoxides, sulfones and selenones. J. Chem. Soc. Perkin Trans. 1 1999, 641–667; (c) Procter, D. J. The synthesis of thiols, selenols, sulfoxides, selenides, sulfoxides, selenoxides, sulfones and selenones. J. Chem. Soc. Perkin Trans. 1 2001, 335–354.
- Miller, S. J.; Collier, T. R.; Weiming, W. Efficient reduction of sulfoxides with 2, 6-dihydroxypyridine. *Tetrahedron Lett.* 2000, 41, 3781–3783.
- Nakayama, J.; Tai, A.; Iwasa, S.; Furuya, T.; Sugihara, Y. Tetracyanoethylene oxide not only oxidizes sulfides to sulfoxides but also reduces sulfoxides to sulfide. *Tetrahedron Lett.* 2005, 461, 1395–1397.
- Iranpoor, N.; Firouzabadi, H.; Jamalian, A. Deoxygenation of sulfoxides and reductive coupling of sulfonyl chlorides, sulfinates and thiosulfonates using [PCl_{3-n}(SiO₂)_n] as a heterogeneous phosphine reagent. *Synlett* **2005**, *9*, 1447–1449.
- Fernandes, A. C.; Romao, C. C. A novel method for the reduction of sulfoxides and pyridine *N*-oxides with the system silane/MoO₂Cl₂. *Tetrahedron* 2006, 62, 9650–9654.
- (a) Olah, G. C.; Gupta, B. G. B.; Narang, S. C. Synthetic methods and reactions; 54: ¹Deoxygenation of sulfoxides and azoxides with tris(dimethylamino)phosphine/Iodine/sodium iodide reagent. *J. Org. Chem.* **1978**, *43*, 4503–4505; (b) Denis, J. N.; Krief, A. Phosphorus tri-iodide (PI₃), a powerful deoxygenating agent. *J. Chem. Soc. Chem. Com.* **1980**, 544–545; (c) Vozza, J. F. Deoxygenation and chlorination of azoxybenzene by acidic halides. *J. Org. Chem.* **1969**, *34*, 3219–3220; (d) Castrillon, J. P. A.; Szmani, H. H. J. Reduction of sulfoxides by triphenylphosphine and carbon tetrachloride. *J. Org. Chem.* **1965**, *30*, 1338.
- Sanz, R.; Escribano, J.; Aguado, R.; Pedrosa, M. R.; Arnaiz, F. J. Selective deoxygenation of sulfoxides to sulfides with phosphate catalysed by dichlorooxomolbdenum (VI). *Synthesis* 2004, 1629.
- Smith, K., ed. Solid Supports and Catalysts in Organic Synthesis; Harwood, E. and PTR Prentice Hall: New York and London, 1992.
- Clark, J. H.; Kybett, A. P.; Macquarrie, D. J. Suported Reagents: Preparation, Analysis and Applications; VCH: New York, 1992.