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

Selective and Efficient Transformation of Thioethers to Their Sulfoxides and Catalytic Conversions of Thiols to The Disulfides with Hydrated Iron(III) and Copper(II) Nitrates in Aprotic Organic Solvents or Under Solvent Free Conditions.

H. Firouzabadi [a] , N. Iranpoor [a] & M. A. Zolfigol [a]

[a] Chemistry Department , Shiraz University , Shiraz, 71454, Iran

To cite this article: H. Firouzabadi , N. Iranpoor & M. A. Zolfigol (1998) Selective and Efficient Transformation of Thioethers to Their Sulfoxides and Catalytic Conversions of Thiols to The Disulfides with Hydrated Iron(III) and Copper(II) Nitrates in Aprotic Organic Solvents or Under Solvent Free Conditions., Synthetic Communications: An International Journal for Rapid Communication of Synthetic Organic Chemistry, 28:7, 1179-1187, DOI: 10.1080/00397919808005959

To link to this article: http://dx.doi.org/10.1080/00397919808005959

Taylor & Francis makes every effort to ensure the accuracy of all the information (the “Content”) contained in the publications on our platform. However, Taylor & Francis, our agents, and our licensors make no representations or warranties whatsoever as to the accuracy, completeness, or suitability for any purpose of the Content. Any opinions and views expressed in this publication are the opinions and views of the authors, and are not the views of or endorsed by Taylor & Francis. The accuracy of the Content should not be relied upon and should be independently verified with primary sources of information. Taylor and Francis shall not be liable for any losses, actions, claims, proceedings, demands, costs, expenses, damages, and other liabilities whatsoever or howsoever caused arising directly or indirectly in connection with, in relation to or arising out of the use of the Content.

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden. Terms & Conditions of access and use can be found at http://www.tandfonline.com/page/terms-and-conditions

Downloaded by [UOV University of Oviedo] at 02:48 17 October 2014

SYNTHETIC COMMUNICATIONS, 28(7), 1179-1187 (1998)

SELECTIVE AND EFFICIENT TRANSFORMATION OF THIOETHERS TO THEIR SULFOXIDES AND CATALYTIC CONVERSIONS OF THIOLS TO THE DISULFIDES WITH HYDRATED IRON(III) AND COPPER(II) NITRATES IN APROTIC ORGANIC SOLVENTS OR UNDER SOLVENT FREE CONDITIONS.

H. Firouzabadi*, N. Iranpoor*, M.A. Zolfigol

Chemistry Department, Shiraz University, Shiraz 71454, Iran

Abstract: *$Fe(NO_3)_3.9H_2O$ and $Cu(NO_3)_2.3H_2O$ are efficient reagents for the conversion of thioethers to their sulfoxides in refluxing EtOAc in high yields. $Fe(NO_3)_3.9H_2O$ is also able to proceed the transformations under solvent free conditions at room temperature with excellent yields. $Cu(NO_3)_2.3H_2O$ is highly selective for the oxidation of aryl thioethers to the corresponding sulfoxides. $Cu(NO_3)_2.3H_2O$ also oxidizes catalytically thiols to their corresponding disulfides in excellent yields.*

Preparation of sulfoxides, as important precursors in organic synthesis, by oxidation of their respective sulfides is important.[1-3] This type of transformation by various methods has been extensively reviewed.[4]

---

* To whom correspondence should be addressed.

$$R_1-S-R_2 \xrightarrow{\text{I or II}} R_1-\overset{\overset{\displaystyle O}{\|}}{S}-R_2$$

Table 1. Oxidation of Thioethers to Their Corresponding Sulfoxides with I and II.

Entry	R_1	R_2	Time (h)		Yield%[a]	
			I	II	I	II
1	C_6H_5	CH_3	1	1.25	80	92
2	C_6H_5	C_2H_5	1.25	1.33	84	97
3	C_6H_5	C_4H_9	1.4	1.5	84	96
4	C_6H_5	$C_6H_5CH_2$	2	24	86	-[b]
5	C_3H_7	C_3H_7	2	1	93	95
6	C_4H_9	C_4H_9	2	1.5	92	94
7		$(CH_3)_2CH$	3	2	93	95

a) Isolated yields after column chromatography. b) Reaction was not occurred.
I) $Fe(NO_3)_3$.9H2O/EtOAc/Δ/Oxid/Subst=2
II) $Fe(NO_3)_3$.9H2O/without solvent/rt/Oxid/Subst=2

Clayfen and claycop are the two clay supported Iron(III) and copper(II) nitrates which are extensively studied for different purposes in organic synthesis.[5] To the best of our knowledge no report is available for the conversion of thioethers to their sulfoxides with clayfen, claycop, hydrated iron(III) and copper(II) nitrates. This prompted us to investigate this type of oxidation with cheap and most available compounds in any laboratories; $Fe(NO_3)_3.9H_2O$ and $Cu(NO_3)_2.3H_2O$.

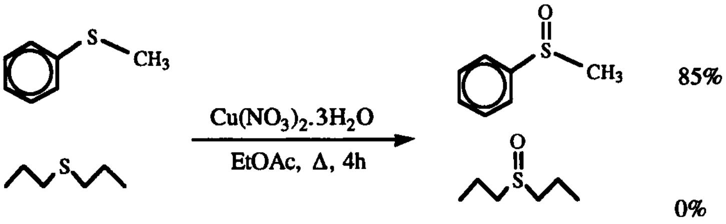
$Fe(NO_3)_3.9H_2O$, in refluxing EtOAc, oxidizes aryl and alkyl sulfides efficiently to their corresponding sulfoxides (1-3 h) in high yields (80-93%, Table 1). Solvent free reactions are important from different views.[6,7] $Fe(NO_3)_3.9H_2O$ is able to oxidize aryl and alkyl sulfides efficiently (1-1.5 h) at room temperature in the absence of solvent with excellent yields (92-97%) to their sulfoxides (Table 1). Phenylbenzyl sulfide does not undergo oxidation under solvent free condition with this reagent (Entry 4, Table 1).

$Cu(NO_3)_2.3H_2O$ is more selective than its iron(III) analogue and could be used for the oxidation of thioethers that in their structures sulfur atom is directly attached to an

Table 2. Oxidation of Thioethers to Their Corresponding Sulfoxides with Two Equimolar Amounts of $Cu(NO_3)_2.3H_2O$ in Refluxing EtOAc.

Entry	R_1	R_2	Time (h)	Yield%[a]
1	C_6H_5	CH_3	3.5	85
2	C_6H_5	C_2H_5	3.75	80
3	C_6H_5	C_4H_9	4	82
4	C_6H_5	$C_6H_5CH_2$	4	84
5	C_3H_7	C_3H_7	no reaction	no reaction
6	C_4H_9	C_4H_9	no reaction	no reaction
7		$(CH_3)_2CH$	no reaction	no reaction

a) Isolated yields.



Scheme 1

aryl group (Table 2). This selectivity is demonstrated by a competitive reaction between phenylmethyl and dipropyl sulfides (Scheme 1).

This reagent oxidizes diaryl and arylalkyl sulfides efficiently (3.5-4 h) with high yields (80-85%) in refluxing EtOAc to sulfoxides (Table 2). $Cu(NO_3)_2.3H_2O$ is not able to perform the transformations under solvent free conditions at room temperature.

Sulfides with carbon-carbon double bonds form complexes with the nitrates under our studies and the reaction does not proceed further.

Table 3. Comparison of the Results Obtained by Our Mthods with Those Reported by Other Reagents.

		Yield% Times (h)					
R_1	R_2	Our Methods			Reported Methods		
		I	II	III	IV[3]	V[1]	VI[2]
C_6H_5	CH_3	80(1)	92(1.25)	85(3.5)	98(1.5)	89(0.25)	82(2)
C_6H_5	C_2H_5	84(1.25)	97(1.3)	80(5)	98.5(1.5)	84(0.25)	-
C_6H_5	C_4H_9	84(1.4)	96(1.5)	82(5.3)	-	84(0.33)	-
C_6H_5	$C_6H_5CH_2$	86(2)	-[a]	84(5.3)	99(1.5)	-	-
C_3H_7	C_3H_7	93(2)	95(1)	-[a]	-	85(0.33)	-
C_4H_9	C_4H_9	92(2)	94(1.5)	-[a]	-	87(0.4)	84(0.5)
	$(CH_3)_2CH$	93(3)	95(2)	-[a]	-	-	-

a) Reaction was not occured.
I) $Fe(NO_3)_3.9H_2O/EtOAc/\Delta$
II) $Fe(NO_3)_3.9H_2O/Neat/\Delta$
III) $Cu(NO_3)_2.3H_2O/EtOAc/\Delta$
IV) $(n\text{-}Bu)_4NS_2O_8/\ CH_2Cl_2/rt$
V) $NaClO_2/Al_2O_3/Mn^{3+}/\ CH_2Cl_2/rt$
VI) $H_2O_2/MeCN/K_2CO_3/CH_3OH$

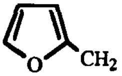
In order to show the strong points and drawbacks of these reagents, the results are compared with other methods in (Table 3).

Coupling of thiols with Cu(II) salts and CuO as reagents (not as catalysts) are reported in the literature.[8] Except in the presence of equimolar amounts of clay supported iron(III) and copper(II) nitrates in which the coupling reaction is fast,[9-12] in the presence of other copper salts eg. Cu(II) octanoate the reaction, times are too long (18-22.5 h).[8b] Cu(II) has also been reported to be used catalytically for this purpose in the presence of oxygen with low reaction rates (5 days). Rate enhancement has been observed in the presence of hydrogen peroxide and tert-butylhydroperoxide.[13]

During our investigations, we have found that $Cu(NO_3)_2.3H_2O$ is an efficient catalyst for the conversion of thiols to their corresponding disulfides. Most of the

$$RSH \longrightarrow RSSR$$

Table 4. Coupling of Thiols with 0.2 Equimolar Amounts of $Cu(NO_3)_2.3H_2O$ in Acetone at Room Temperature.

Entry	R	Time (min)	Yield[a]
1	n-C_3H_7	10	90
2	iso-C_3H_7	140	87
3	-$(CH_2)_3$-SH	15	-[b]
4	n-C_4H_9	10	92
5	Cyclohexyl	130	95
6	Ph	10	98
7	$PhCH_2$	5	96
8	3-$CH_3C_6H_4$	7	98
9	4-$CH_3OC_6H_4$	-[c]	99
10		3	93

a) Isolated yields.
b) Polymerization was occurred.
c) Reaction was compeleted immediately.

reactions, under our studies, were proceeded smoothly at 35-40°C with excellent yields (Table 4).

The thionitrite intermediacy is detected by UV spectral analysis in the reactions under our studies.[14] The catalytic effects of Cu(II) and Cu(I) on the decomposition of the thionitrite is quite stablished.[13,15] Therefore, we have suggested a mechanism in which the catalytic effect of $Cu(NO_3)_2.3H_2O$ is explained (Scheme 2).

In conclusion, the cheapness and the availability of the compounds, easy work-up, high yields and selectivity make these methods attractive for the large-scale operations.

1) $RSH + Cu(NO_3)_2 \longrightarrow RSSR + Cu(I) + HNO_3$

2) $Cu(I) + HNO_3 \longrightarrow Cu(II) + NO + H_2O$

3) $Cu(II) + NO \longrightarrow Cu(I) + NO^+$

4) $RSH + NO^+ \longrightarrow RSNO + H^+$

5) $RSNO + Cu(I) \longrightarrow RS^- + NO + Cu(II)$

6) $RS^- + Cu(II) \longrightarrow RSSR + Cu(I)$

Scheme 2

$Fe(NO_3)_3.9H_2O$ is not toxic and is an environmentally benign compound and $Cu(NO_3)_2.3H_2O$ conducts the thiol dimerization catalytically.

EXPERIMENTAL:

General: Chemicals were either prepared in our laboratories or were purchased from Fluka, Merck and Aldrich Chemical Companies. Products were characterized by comparison of their physical data with those of authentic samples. All yields refer to isolated products. IR and UV spectra were recorded on a Perkin Elmer 781 and Pye Unicam 8725 Spectrometers. NMR spectra were recorded on a Bruker DPX 250. Mass spectra were recorded on a Shimadzu GCMS-QP 1000EX instrument. The purity determination of the substrates and reaction monitoring were accomplished by TLC on Silica gel polygram SILG/UV 254 plates or GLC by a Shimadzu GC-14A instrument.

Oxidation of Benzylphenyl Sulfide to Its Corresponding Sulfoxide with $Cu(NO_3)_2.3H_2O$, A Typical Procedure.

To a solution of benzylphenyl sulfide (0.4 g, 2 mmol) in EtOAc (4 ml), $Cu(NO_3)_2.3H_2O$ (0.96 g, 4 mmol) was added. The reaction mixture was stirred vigorously under reflux condition for 4 h. To the reaction mixture, saturated NaCl solution (20 ml) was added and was extracted with CH_2Cl_2 (3x40 ml). The organic layers were separated and combined together and was dried over anhydrous $MgSO_4$. The solvent was evaporated and the resulting crude material was presorbed on Silica gel (2g) and was applied on a short column of Silica gel and eluted with petroleum ether: acetone (3:1). Evaporation of the solvent afforded pure benzylphenyl sulfoxide 363 mg, 84%, mp 123-124 °C, [lit.[3] mp 122-125 °C] (Entry 4, Table 2).

Solvent Free Oxidation of Methylphenyl Sulfide to Methylphenyl Sulfoxide with $Fe(NO_3)_3.9H_2O$. A Typical Procedure.

A mixture of methylphenyl sulfide (248 mg, 2 mmol) and $Fe(NO_3)_3.9H_2O$ (1.6 g, 4 mmol) was prepared. The mixture was agitated magnetically at room temperature for 1.25 h. To the reaction mixture, saturated NaCl solution (20 ml) was added and the resulting mixture was extracted with CH_2Cl_2 (3x40 ml). The organic layers were separated and combined together and was dried over anhydrous $MgSO_4$. The solvent was evaporated and the resulting crude material was presorbed on Silica gel (2 g). The resulting solid mixture was applied on a short column of Silica gel and eluted with petroleum ether: acetone (3:1). Evaporation of the solvent afforded pure methylphenyl sulfoxide, 257 mg, 92%, mp 30 °C, [lit[3]. mp 29-30 °C] (Entry 1, Table 1).

Reaction of n-Butyl Thiol with $Cu(NO_3)_2.3H_2O$. A Typical Procedure.

To a solution of n-butyl thiol (0.18 g, 2 mmol) in acetone (4 ml), $Cu(NO_3)_2.3H_2O$ (0.096 g, 0.4 mmol) was added. The resulting mixture was stirred at 35-40°C for 10 min. To the resulting mixture, CCl_4 (20 ml) was added and the precipitate was filtered. The resulting filtrate was evaporated and chromatographed on a short column of Silica gel. Pure n-butyl disulfide was obtained as colourless liquid, 0.165 g, 92%, bp 114-116°C/18 torr, [lit.[16] bp 114-115°C/18 torr](Entry 4, Table 4).

Acknowledgements: The authors are thankful to Shiraz University Research Council for partial support of this work and also Z. Pakniyat for her patience for typing the manuscripts.

References:

1. Hirano, M., Yakabe, S., Clark, J.H., Kudo, H., Morimoto, T., *Synth. Commun.*, **1996**, 26, 1875 and the references cited therein.
2. Page, P.C.B., Graham, A.E., Bethell, D., Park, B., K. *Synth. Commun.*, **1993**, 23, 1507. and the references cited therein.
3. Chen, F., Wan, I., Guan, C., Yang, J. , Zhang, H., *Syhnth. Commun.* **1996**, 26, 253. and the references cited therein.
4. Madesclaire, M., *Tetrahedron*, **1986**, 42, 5459.
5. a) Cornelis, A., Laszlo, P., *Synthesis* **1985**, 909. b) Laszlo, P., *Acc. Chem. Res.* **1986**, 19, 121. c) Laszlo, P., Cornelis, A., *Aldrichim. Acta* **1988**, 21,97. d) Delaude, L., Laszlo, P. Smith, K., *Acc. Chem. Res.* **1993**, 26, 607. e) Cornelis, A., Laszlo, P., *Synlett* **1994**, 155.
6. Toda, F., *Acc. Chem. Res.* **1995**, 28, 480.
7. *Chem. & Engin. News* **1996**, April 8, pp 39-44.
8. a) Wallace, T.J. *J., Org. Chem.* **1966**, 31, 1217. b) ibid, **1966**, 31, 3071.
9. Cornelis, A., Laszlo, P., *Synthesis* **1985**, 909.
10. Cornelis, A., Depaye, N., Gerstmans, A., Laszlo, P., *Tetrahedron Lett.* **1983**, 24, 3103.
11. Laszlo, P., Cornelis, A., *Aldrichim. Acta.* **1988**, 21, 97.
12. Cornelis, A., Laszlo, P., *Synlett* **1994**, 155.
13. Scrivens, G., Gilbert, B.C., Lee, T.C.P., *J. Chem. Soc. Perkin Trans 2*, **1995**, 955.
14. Oae, S., Fukushima, D., Kim, Y.H., *J. Chem. Soc. Chem. Commun.* **1977**, 407.
15. a) Askew, S.C., Barnett, D.J., McAninly, J., Williams, D.L.H., *J. Chem. Soc. Perkin. Trans 2* , **1995**, 741. b) Barnett, D.J., Rios, A., Williams, D.L.H., *J. Chem. Soc. Perkin Trans 2*, **1995**, 1279. c) Dicks, P., Swift, H.R., Williams,

D.L.H., Butler, A.R., Al-Sadoni, H.H., Cox, B.G., *J. Chem. Soc. Perkin Trans 2* **1996**, 481.

16. Drabowicz, J., Mikolajczyk, M., *Synthesis* **1980**, 32.

(Received in The Netherlands 03 November 1997)