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Chromium(VI) Oxide Catalyzed Oxidation of Sulfides to Sulfones with Periodic Acid

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Abstract: A highly efficient and selective oxidation of sulfides to sulfones with periodic acid catalyzed by CrO_3 is described. A variety of electron-rich and electron-deficient sulfides were oxidized to sulfones with 2 mol % CrO_3 in acetonitrile at room temperature in excellent yields. Sulfides with other readily oxidized functional groups were selectively oxidized to sulfones in high yields with 10 mol % CrO_3 in ethyl acetate/acetonitrile at −35 °C.

Sulfone moieties are useful synthetic intermediates in the preparation and functionalization of chemically and biologically significant compounds.[1−4] Among the different procedures to prepare sulfones, the direct oxidation of sulfides to sulfones is the most straightforward method in organic synthesis.[5] Although various oxidizing reagents have been developed for this oxidation, efficient reagents that can also be used for the oxidation of electron-deficient sulfides and that are tolerant of other easily oxidized groups are rare.[6]

Oxidations with H_5IO_6 alone or with catalysts have been well documented.[7,8] In recent years, H_5IO_6 has been employed to oxidize a variety of substrates with catalysts, such as CrO_3,[9] TEMPO,[10] Mn^{IV} complex,[11] $CrO_2(OAc)_2$,[12] and $FeCl_3$.[13] We recently reported a mild and efficient oxidation of alcohols to aldehydes and ketones with H_5IO_6 catalyzed by $Cr(acac)_3$.[14] Only a few methods are available for the oxidation of electron-deficient sulfides to sulfones. Typical reagents include $HOF{\cdot}CH_3CN$ complex,[6,15] H_2O_2 in $(CF_3CO)_2O$ [16] or HOAc,[17] RuO_4,[18] $KMnO_4$[19] and CrO_3 in HOAc,[20] or HNO_3.[21] However, most of these methods either give low yields of products or use sophisticated reagents that are difficult to handle. Therefore, convenient and efficient reagents are still desired for this transformation. The strong oxidative power of the H_5IO_6/CrO_3 system[9b] prompted an investigation of this reagent with electron-deficient sulfides. Herein, we describe the successful use of the H_5IO_6/CrO_3 system as a method to efficiently oxidize electron-deficient sulfides to sulfones and selectively oxidize sulfides containing other easily oxidized groups.

Initially, we examined the influence of catalyst loading, oxidant concentration, reaction time, and solvent on the oxidation of methyl phenyl sulfide (**1a**) to the corresponding methyl phenyl sulfone (**2a**) (Table 1).

The reactions were performed by addition of sulfide **1a** into a stirred solution of H_5IO_6 and CrO_3 in acetonitrile at room temperature. Acetonitrile was determined to be the most appropriate solvent due to poor solubility of CrO_3 in most other organic solvents (CH_2Cl_2, EtOAc). Relatively low catalyst loading (1−5 mol %) resulted in low yields of the sulfone **2a** with only 2.1 equiv of H_5IO_6. In those cases (Table 1, entries 1−3), the intermediate sulfoxide could not be converted completely into sulfone. Longer reaction times did not improve the conversion. The reaction mixture turned green quickly indicating the generation of Cr^{III} species. It is believed that the catalyst was converted into an inactive low oxidation state chromium species and that the concentration of H_5IO_6 (2.1 equiv) was not sufficient to effectively regenerate the catalyst and drive the reaction to completion. Alternatively, the oxidation proceeded quickly (12 min) and cleanly with 2.1 equiv of H_5IO_6 and 10 mol % CrO_3 at room temperature and gave the optimal yield of **2a** (Table 1, entry 5). It is noteworthy that the oxidation also readily occurred at −60 °C using EtOAc as a cosolvent with acetonitrile (Table 1, entry 6). The reaction rate was

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(1) (a) Nakayama, J.; Sugihara, Y. *Top. Curr. Chem.* **1999**, *205*, 131. (b) De Lucchi, O.; Fabbri, D.; Lucchini, V. *Tetrahedron* **1992**, *48*, 1485. (c) Gronowitz, S.; Nikitidis, G.; Hallberg, A.; Servin, R. *J. Org. Chem.* **1988**, *53*, 3351.

(2) Paquette. L. A. *Synlett* **2001**, 1.

(3) Najera, C.; Sansano, J. M. *Recent Res. Dev. Org. Chem.* **1998**, *2*, 637.

(4) Chinchilla, R.; Najera, C. *Recent Res. Dev. Org. Chem.* **1997**, *1*, 437.

(5) (a) Hollingworth, G. J. In *Comprehensive Organic Functional Group Transformations*; Katrizky, A. R., Meth-Cohn, O., Rees, C. W., Pattenden, G., Eds.; Elsevier: Oxford, 1995. (b) Patai, S., Rappoport, Z., Eds. *The Synthesis of Sulphones, Sulphoxides, and Cyclic Sulphides*; Wiley: New York, 1994. (c) Simpkins, N. S. *Sulphones in Organic Synthesis*; Pergamon Press: Oxford, 1993.

(6) Rozen, S.; Bareket, Y. *J. Org. Chem.* **1997**, *62*, 1457.

(7) For reviews, see: (a) Fatiadi, A. J. *Synthesis* **1974**, 229. (b) Chaudhuri, B. K.; Mukherjee, H. G. *J. Indian Chem. Soc.* **1979**, *56*, 1098.

(8) (a) Haines, A. H. *Methods for the Oxidation of Organic Compounds, Alcohols, Alcohol Derivatives, Alkyl Halides, Nitroalkanes, Alkyl Azides, Carbonyl Compounds, Hydroxyarenes and Aminoarenes*; Academic Press: London, 1988. (b) Rodriguez, C. M.; Ode, J. M.; Palazon, J. M.; Martin, V. S. *Tetrahedron* **1992**, *48*, 3571. (c) Nunez, M. T.; Martin, V. S. *J. Org. Chem.* **1990**, *55*, 1928. (d) Wrobel, J.; Dietrich, A.; Gorham, B. J.; Sestanj, K. *J. Org. Chem.* **1990**, *55*, 2694. (e) Carlsen, P. H. J.; Katsuki, T.; Martin, V. S.; Sharpless, K. B. *J. Org. Chem.* **1981**, *46*, 3936.

(9) (a) Yamazaki, S. *Tetrahedron Lett.* **2001**, *42*, 3355. (b) Yamazaki, S. *Org. Lett.* **1999**, *1*, 2129. (c) Zhao, M.; Li, J.; Song, Z.; Desmond, R.; Tschaen, D. M.; Grabowski, E. J. J.; Reider, P. J. *Tetrahedron Lett.* **1998**, *39*, 5323.

(10) Kim, S. S.; Nehru, K. *Synlett* **2002**, 616.

(11) Barton, D. H. R.; Li, W.; Smith, J. A. *Tetrahedron Lett.* **1998**, *39*, 7055.

(12) Lee, S.; Fuchs, P. L. *J. Am. Chem. Soc.* **2002**, *124*, 13978.

(13) Kim, S. S.; Nehru, K.; Kim, S. S.; Kim, D. W.; Jung, H. C. *Synthesis* **2002**, 2484.

(14) Xu, L.; Trudell, M. L. *Tetrahedron Lett.* **2003**, *44*, 2553.

(15) Beckerbauer, R.; Smart, B. E. *J. Org. Chem.* **1995**, *60*, 6186.

(16) Nenajdenko, V. G.; Gavryushin, A. E.; Balenkova, E. S. *Tetrahedron Lett.* **2001**, *42*, 4397.

(17) (a) Chen, Q.; Duan, J. *J. Chem. Soc., Chem. Commun.* **1993**, 918. (b) Nodiff, E. A.; Lipschutz, S.; Craig, P. N.; Gordon, M. *J. Org. Chem.* **1960**, *25*, 60.

(18) Su, W. *Tetrahedron Lett.* **1994**, *35*, 4955.

(19) Rizzi, J. P.; Schnur, R. C.; Hutson, N. J.; Kraus, K. G.; Kelbaugh, P. R. *J. Med. Chem.* **1989**, *32*, 1208.

(20) (a) Sharma, N.; Gupta, R.; Kumar, M.; Gupta, R. R. *J. Fluorine Chem.* **1999**, *98*, 153. (b) Boiko, V. N.; Gogoman, I. V.; Shchupak, G. M.; Yagupolskii, L. M. *Zh. Org. Khim.* **1987**, *23*, 601. (c) Kondratenko, N. V.; Kolomeitsev. A. A.; Mogilevskaya, V. O.; Varlamova, N. M.; Yagupolskii, L. M. *Zh. Org. Khim.* **1986**, *22*, 1721.

(21) Sharnin, G. P.; Nurgatin, V. V. *Zh. Org. Khim.* **1972**, *8*, 1493.

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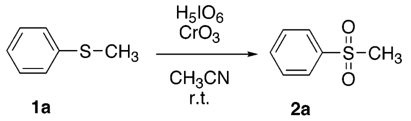
TABLE 1. Oxidation of Methyl Phenyl Sulfide to Methyl Phenyl Sulfone with H_5IO_6/CrO_3



entry	H_5IO_6 (equiv)	CrO_3 (mol %)	time (h)	yield[a] (%)
1	2.1	0	48	13
2	2.1	1.0	48	60
3	2.1	5.0	24	71
4	2.1	7.5	3	90
5	2.1	10	0.2	96
6	2.1	10	2	96[b]
7	3.0	1.0	15	96
8	3.0	2.0	7	96
9	4.0	1.0	6	96
10	4.0	2.0	2	96

[a] Isolated yield. [b] Reaction performed at −60 °C in EtOAc/CH_3CN (2:1).

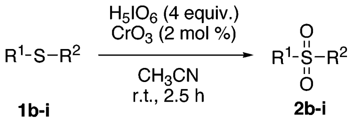
slower at −60 °C and formation of the intermediate sulfoxide could be monitored by TLC. However, the overall oxidation to the sulfone was complete after 2 h and gave the same yield as the room-temperature reaction (Table 1, entry 5).

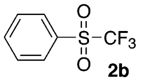
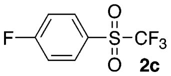
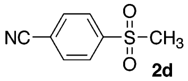
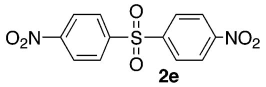
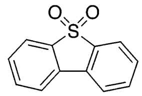
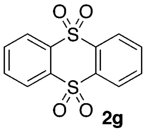
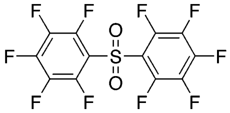
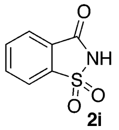
Further investigation of the H_5IO_6/CrO_3 stoichiometry revealed that the oxidation proceeded equally well with less CrO_3 (1−2 mol %) provided the concentration of H_5IO_6 (3 or 4 equiv) was increased (Table 1, entries 7−10). These catalytic systems gave equivalent yields to systems with 10 mol % CrO_3 but required longer reaction times. It was determined that the H_5IO_6/CrO_3 system that employed 4 equiv of H_5IO_5 with 2 mol % CrO_3 (Table 1, entry 10) would be further explored since this system afforded an optimum yield of **2a** as well as offered the advantages of both low catalyst loading (2 mol %) and relatively short reaction times (2 h). The low catalyst loading was particularly attractive since the disposal of toxic chromium waste was minimized.

Other solvents were also investigated as cosolvents in an effort to improve catalytic efficiency. When used as a cosolvent, dichloromethane and chloroform gave similar yields while acetone, ether, and THF gave very poor yields of the desired sulfones. The effect of moisture on catalyst loading and activity was also investigated. In all cases, independent of H_5IO_6/CrO_3 concentration, reactions performed with wet acetonitrile (5−10 vol %) required much longer reaction times.

The results of the oxidation of electron-deficient sulfides (**1b**−**i**) to the corresponding sulfones (**2b**−**i**) with H_5IO_6/CrO_3 are summarized in Table 2. The reactions were performed in a fashion similar to the above oxidation of **1a** employing 2 mol % CrO_3 and 4 equiv of H_5IO_6. The oxidations were generally completed within 2.5 h. A simple workup then furnished the sulfones cleanly and in high yields. In addition, the oxidations were performed with 10 mol % and 2.1 equiv of H_5IO_6. The yields of these reactions were equivalent to the 2 mol % CrO_3 system; however, the oxidations were typically completed within minutes. There are several noteworthy examples in Table 2 that demonstrate the oxidative strength of the H_5IO_6/CrO_3 system. The 4-fluorophenyltrifluoromethyl sulfone (**2c**)[22,23] was readily prepared from commercial 4-fluorophenyl trifluoromethyl sulfide (**1c**) at room temperature within 1−2.5 h and in 96% yield. The binuclear manganese complex $[Mn^{IV}-Mn^{IV}(\mu\text{-}O)_3L_2](PF_6)_2$ has been reported to be a catalyst for the oxidation of sulfides to sulfones by using H_5IO_6 as oxidant but it required 3 days to convert dibenzothiophene (**1f**) into dibenzothiophene-5,5-dioxide (**2f**).[11] The oxidation of **1f** with H_5IO_6/CrO_3 was completed within 1−2 h in 96% yield. In addition, thianthrene 5,5,10,10-tetraoxide (**2g**) was obtained by oxidation of thianthrene (**1g**) with 8 equiv of H_5IO_6 and 2 mol % of CrO_3. The extremely electron-deficient sulfide, pentafluorophenyl sulfide (**1h**), was oxidized to the corresponding sulfone **2h** with 10 equiv of H_5IO_6 and 80 mol % CrO_3 in refluxing acetonitrile for 1 h. To our knowledge, there is only one other report of this transformation in the literature and it employed the $HOF{\cdot}CH_3CN$ complex.[6] It has been reported that 1,2-benzothiazole-3-

TABLE 2. H_5IO_6/CrO_3 Oxidation of Electron-Deficient Sulfides to Sulfones



entry	sulfone	yield (%)[a]
1	 **2b**	96 (96)[b]
2	 **2c**	96 (96)[b]
3	 **2d**	97 (97)[b]
4	 **2e**	97 (97)[b]
5	 **2f**	96 (96)[b]
6	 **2g**	95[c]
7	 **2h**	93[d]
8	 **2i**	90 (91)[b]

[a] Isolated yields. [b] Conditions: H_5IO_6 (2.1 equiv), CrO_3 (10 mol %), rt, 1 h. [c] Conditions: H_5IO_6 (8 equiv), CrO_3 (2 mol %), rt, 3.5 h. [d] Conditions: H_5IO_6 (10 equiv), CrO_3 (80 mol %),CH_3CN, reflux, 1 h.

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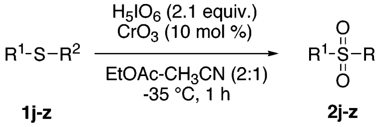
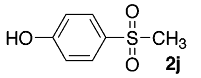
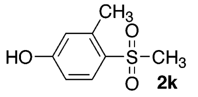
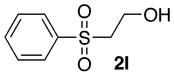
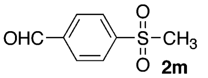
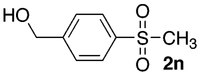
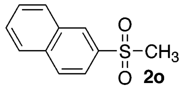
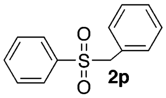
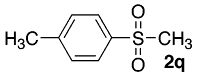
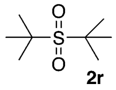
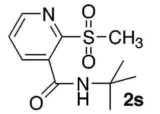
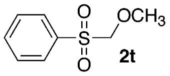
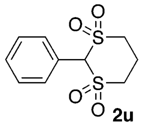
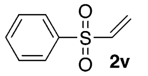
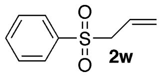
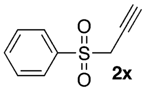
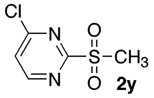
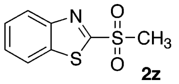
[22] Jones, T. R.; Varney, M. D.; Webber, S. E.; Lewis, K. K.; Marzoni, G. P.; Palmer, C. L.; Kathardekar, V.; Welsh, K. M.; Webber, S.; Matthews, D. A.; Appelt, K.; Smith, W. W.; Janson, C. A.; Villafranca, J. E.; Bacquet, R. J.; Howland, E. F.; Booth, C. L. J.; Herrmann, S. M.; Ward, R. W.; White, J.; Moomaw, E. W.; Bartlett, C. A.; Morse, C. A. *J. Med. Chem.* **1996**, *39*, 904.

[23] Beaumont, A. J.; Clark, J. H. *J. Fluorine Chem.* **1991**, *52*, 295.

TABLE 3. H_5IO_6/CrO_3 Chemoselective Oxidation of Sulfides to Sulfones



1j-z → **2j-z**

entry	sulfone	yield (%)[a]
1	 **2j**	94
2	 **2k**	92
3	 **2l**	90
4	 **2m**	91
5	 **2n**	41
6	 **2o**	92
7	 **2p**	97
8	 **2q**	96
9	 **2r**	91
10	 **2s**	90
11	 **2t**	91
12	 **2u**	91[b,c]
13	 **2v**	93
14	 **2w**	96
15	 **2x**	96
16	 **2y**	94[b]
17	 **2z**	94[b]

[a] Isolated yields. [b] Conditions: 0 °C. [c] Conditions: H_5IO_6 (4.5 equiv).

one (**1i**) is resistant to oxidation and that there are no effective reagents for the transformation of **1i** into saccharin (**2i**).[24] However, oxidation of **1i** with H_5IO_6/CrO_3 afforded **2i** in 91% yield. These results demonstrate that the H_5IO_6/CrO_3 catalyst system is very effective for the oxidation of electron-deficient sulfur atoms.

Chemoselective oxidation of a variety of sulfides (**1j**–**z**) to sulfones (**2j**–**z**) in the presence of a variety of other easily oxidized functional groups was examined, and the results are summarized in Table 3. The reactions were performed by the addition of a solution of H_5IO_6/CrO_3 in acetonitrile to a stirred solution of sulfide in ethyl acetate at −35 °C. Ethyl acetate was employed as the solvent in order to access lower reaction temperatures. The chemoselectivity of the oxidation is due in part to control of both temperature and stoichiometry. In most cases, if higher reaction temperatures or excess oxidant (>2.1 equiv) was employed the chemoselectivity was lost and the additional oxidation of ancillary functional groups became evident. To this end, reaction conditions that employed H_5IO_6 (2.1 equiv)/10 mol % CrO_3 were found to be superior to conditions that employed more H_5IO_6 with less CrO_3. Under these conditions of the H_5IO_6/CrO_3 oxidation a variety ancillary readily oxidized functional groups were unaffected.

Many reagents have been developed for the selective oxidation of sulfides to sulfones [e.g., H_2O_2/catalyst,[25] *m*-chloroperbenzoic acid (*m*-CPBA),[26] dimethyldioxirane (DMD),[27] *tert*-butyl hydroperoxide (TBHP),[28] and potassium hydrogen persulfate (OXONE)[29]]. However, there have been no previous reports that describe the clean oxidation of phenolic sulfides to the corresponding phenolic sulfones. The oxidations of both 4-(methylthio)-phenol (**1j**) and 4-methylthio-3-methylphenol (**1k**) were achieved with H_5IO_6/CrO_3 to furnish the corresponding sulfones **2j** and **2k** in exceptionally pure form and in excellent yields (≥92%).

In addition to phenolic sulfides, sulfides containing a primary alcohol or a formyl group were selectively oxidized to the corresponding sulfones **2l** and **2m**, re-

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[24] Zlotin, S. G.; Kislitsin, P. G.; Podgursky, A. I.; Samet, A. V.; Semenov, V. V.; Buchanan, A. C., III; Gakh, A. A. *J. Org. Chem.* **2000**, *65*, 8439.

[25] (a) Yamada, Y. M. A.; Tabata, H.; Takahashi, H.; Ikegami, S. *Synlett.* **2002**, 2031. (b) Alonso, D. A.; Najera, C.; Varea, M. *Tetrahedron Lett.* **2002**, *43*, 3459. (c) Choi, S.; Yang, J. D.; Ji, M.; Choi, H.; Kee, M.; Ahn, K. H.; Byeon, S. H.; Baik, W.; Koo, S. *J. Org. Chem.* **2001**, *66*, 8192. (d) Sato, K.; Hyodo, M.; Aoki, M.; Zheng, X.; Noyori, R. *Tetrahedron* **2001**, *57*, 2469. (e) Van Dort, P. C.; Fuchs, P. L. *J. Am. Chem. Soc.* **1994**, *116*, 5657.

[26] (a) Loughlin, W. A.; Rowen, C. C.; Healy, P. C. *J. Chem. Soc., Perkin Trans. 2* **2002**, 296. (b) Kurtner, A.; Chodynski, M.; Halkes, S. J. *Synth. Commun.* **1996**, *26*, 1175. (c) Davis, F.; Zhou, P. *Tetrahedron Lett.* **1994**, *35*, 7525.

spectively, in high yields. However, benzylic alcohol and secondary alcohol moieties were not tolerated under these conditions and gave poor yields of the desired sulfone due to competing oxidation of the hydroxyl group. Even at lower reaction temperatures (−60 °C), competing oxidation was problematic. The oxidation of 4-methylthio benzyl alcohol (**1n**) with the H_5IO_6/CrO_3 afforded 4-methylsulfonyl benzyl alcohol (**2n**) in only 41% yield, with a 28% yield of 4-methylsulfonyl benzaldehyde.

It is known that aromatic rings can be oxidized to quinones,[9a] but the oxidation of the sulfur atom is much faster. The 2-methylthionaphthalene (**1o**) was selectively oxidized to the sulfone **2o** in excellent yield leaving the aromatic ring unaffected. In addition, benzyl phenyl sulfide (**1p**) and methyl *p*-tolylsulfide (**1q**) were selectively oxidized to the corresponding sulfones **2p** and **2q** without formation of benzylic oxidation products.

Periodic acid is a weak acid ($pK_1 = 3.29$, $pK_2 = 8.3$, $pK_3 = 11.6$),[7b] and it has recently been reported that H_5IO_6 can selectively oxidize sulfur acetals to aldehydes in the presence of acid sensitive groups.[30] Sulfides containing a *tert*-butyl group (**1r** and entry **1s**) and a methoxymethyl (MOM) group (**1t**) were selectively oxidized to sulfones **2r**−**t** in yields greater than 90%. Moreover, 2-phenyl-1,3-dithiane (**1u**) was oxidized to the 1,3-dithiane-2-phenyl-1,1,3,3-tetraoxide (**2u**) in 91% yield by using 4.5 equiv of H_5IO_6 and 10 mol % of CrO_3 at 0 °C.

Both carbon−carbon double bonds and triple bonds were unaffected by the H_5IO_6/CrO_3 oxidation conditions. Phenyl vinyl sulfide (**1v**), allyl phenyl sulfide (**1w**), and phenyl propargyl sulfide (**1x**) were converted into the corresponding sulfones **2v**−**x** in excellent yields. Similar selectivity was observed for the heterocyclic sulfides **1y** and **1z**. The sulfide moieties were oxidized selectively to the corresponding sulfones without formation of any other oxidation products. It is noteworthy that the thiazole ring sulfur atom of 2-methylthiobenzothiazole (**1z**) was not oxidized, and only the 2-methylsulfonylbenzothiazole (**2z**) was obtained. Although amide and heterocyclic nitrogen atoms (entries 10, 16, and 17) were not affected by the conditions of this oxidation giving high yields of the corresponding sulfones, the amino sulfide derivatives (e.g., 2-methylthioaniline) gave dark intractable mixtures.

In conclusion, we have found H_5IO_6/CrO_3 to be an excellent catalytic system for promoting the efficient oxidation of sulfides to sulfones. Low catalyst loading (2 mol %) afforded the advantage of reduced chromium waste while providing high yields of a variety of electron-deficient sulfones. Alternatively, higher catalyst loading (10 mol %) led to shorter reaction times and the highly chemoselective oxidation of sulfides to sulfones in the presence of other easily oxidized functional groups. This new protocol is superior to other methods by furnishing sulfones in high yield and high purity as well as requiring lower reaction temperatures and shorter reaction times.

Experimental Section

All starting materials unless otherwise noted were commercially available. All products unless otherwise noted were identified by comparison of NMR spectral and physical data with the data reported in the literature and with authentic samples when available. ^1H and ^{13}C NMR spectra were recorded on a Varian-400 MHz spectrometer at ambient temperature in $CDCl_3$ or DMSO-d_6 (Cambridge Isotope Laboratories, Inc.). C, H, N analyses were determined by Atlantic Microlabs, Inc., Norcross, GA. Melting points were recorded on a Hoover Mel-Temp apparatus and are uncorrected.

General Procedure for Oxidation of Simple Sulfides and Electron-Deficient Sulfides to Sulfones. H_5IO_6 (4.6 g, 20 mmol) was dissolved in acetonitrile (80 mL) by vigorous stirring at room temperature for 30 min, and then CrO_3 (10 mg, 0.1 mmol, 2 mol %) was added to the solution. The mixture was stirred at room temperature for 5 min to give a clear orange solution. To this solution was added a solution of sulfide (5 mmol) in CH_3CN (10 mL) at room temperature. The exothermic reaction formed a precipitate immediately. The reaction mixture was stirred at room temperature until the oxidation was completed (monitored by TLC), the mixture was then filtered, and the filter cake was washed with CH_3CN (35 mL). The filtrate was concentrated under reduced pressure at room temperature, and the residue was extracted with ethyl acetate or chloroform. The combined extracts were washed, respectively, with saturated aqueous Na_2SO_3 solution and brine and then dried over $MgSO_4$. Removal of the solvent under reduced pressure afforded the crude sulfones. Most of the crude sulfones were of sufficient purity (>95%) for further use on the basis of ^1H NMR spectra and melting points.

General Procedure for Selective Oxidation of Functionalized Sulfides to Sulfones. H_5IO_6 (2.40 g, 10.5 mmol) was dissolved in CH_3CN (30 mL) by vigorous stirring at room temperature for 1 h. Then CrO_3 (50 mg, 0.5 mmol, 10 mol %) was added to the solution. The mixture was stirred at room temperature for 5 min to give a clear orange solution. The H_5IO_6/CrO_3 solution was then added dropwise over a period of 45 min to a solution of sulfide (5 mmol) in ethyl acetate (60 mL) at −35 °C. After the addition was completed, the reaction mixture was stirred at −35 °C for 1 h. The reaction was quenched by addition of saturated Na_2SO_3 solution (5 mL) and filtered, and the solids were washed with ethyl acetate (60 mL). The filtrate was washed, respectively, with saturated aqueous Na_2SO_3 solution and brine and then dried over $MgSO_4$. Removal of the solvent under reduced pressure afforded the crude sulfones. Most of the crude sulfones were of sufficient purity (>95%) for further use on the basis of ^1H NMR spectra and melting points.

2-(Methylsulfonyl) *tert*-Butyl Nicotinamide (2s). 2-(Methylsulfonyl) *tert*-butyl nicotinamide was prepared from 2-(methylthio) *tert*-butyl nicotinamide (**1s**)[31] using the general procedure for funtionalized sulfides described above: mp 163−5 °C; ^1H NMR (400 MHz, DMSO-d_6) δ 8.74−8.75 (d, 1H, $J = 4.4$ Hz), 8.14 (s, 1H, NH), 7.92−7.94 (d, 1H, $J = 7.2$ Hz), 7.73−7.76 (m, 1H), 3.27 (s, 3H, $MeSO_2$), 1.34 (s, 9H); ^{13}C NMR (75 MHz, DMSO-d_6) δ 164.5, 153, 149.0, 138.1, 133.6, 127.4, 50.9, 41.5, 28.1; IR (liquid film) 2923, 1656, 1556, 1464 cm^{-1}; MS(CI, NH_3) m/z 257 (24, M + 1), 242 (45), 185 (100). Anal. Calcd for $C_{11}H_{16}N_2O_3S$: C, 51.56; H, 6.25; N, 10.93. Found: C, 51.47; H, 6.30; N, 10.80.

Supporting Information Available: References to known compounds. This material is available free of charge via the Internet at http://pubs.acs.org.

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(27) (a) Patonay, T.; Adam, W.; Levai, A.; Kover, P.; Nemeth, M.; Peters, E. M.; Peters, K. *J. Org. Chem.* **2001**, *66*, 2275. (b) Marchan, V.; Gibert, M.; Messeguer, A.; Pedroso, E.; Grandas, A. *Synthesis* **1999**, 43.

(28) Fringuelli, F.; Pellegrino, R.; Piermatti, O.; Pizzo, F. *Synth. Commun.* **1994**, *24*, 2665.

(29) (a) Webb, K. S. *Tetrahedron Lett.* **1994**, *35*, 3457. (b) Trost, B. M.; Curran, D. P. *Tetrahedron Lett.* **1981**, *22*, 1287.

(30) Khanapure, S. P.; Powell, W. S.; Rokach, J. *J. Org. Chem.* **1998**, *63*, 8976.

(31) Arnauld, T.; Barrett, A. G. M.; Cramp, S. M.; Roberts, R. S.; Zecri, F. J. *Org. Lett.* **2000**, *2*, 2663.