Oxidation of Primary Alkyl Triflates to the Corresponding Aldehydes via Alkoxy(*N*-*tert*-butylamino)(methyl)sulfonium Triflates

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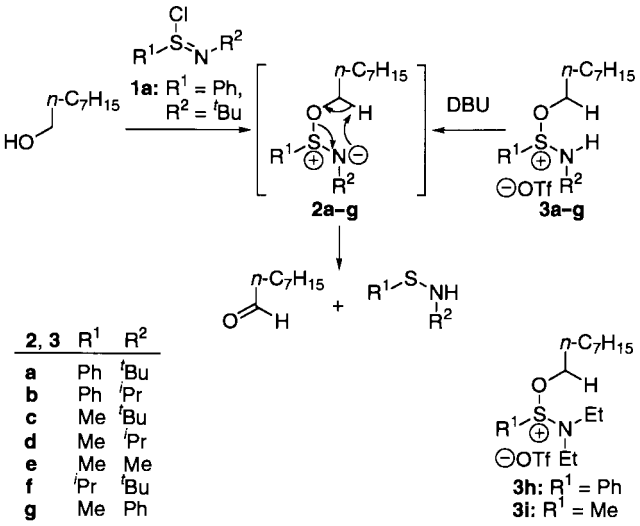
Various alkoxy(*N*-*tert*-butylamino)(methyl)sulfonium triflates are prepared by selective *O*-alkylation of *N*-*tert*-butylmethanesulfinamide (**4c**) with primary alkyl trifluoromethanesulfonates (triflates). Successive treatment of thus formed alkoxyaminosulfonium salts with DBU smoothly affords the corresponding aldehydes in good yields. The sequential combination of the two reactions provides a new method for oxidation of primary alkyl triflates to aldehydes, and the present study suggests the existence of alkoxysulfilimines as intermediates of the previously-reported direct oxidation of alcohols by using *N*-*tert*-butylphenylsulfinimidoyl chloride (**1a**) and DBU.

Recently, a new method for oxidation of primary and secondary alcohols to the corresponding aldehydes and ketones by using *N*-*tert*-butylphenylsulfinimidoyl chloride (**1a**) in the coexistence of DBU or zinc oxide was reported.[1] For example, octanol was smoothly oxidized to octanal in 98% yield by the combined use of **1a** and DBU.[1a] The oxidation was assumed to proceed via octyloxysulfilimine (**2a**) which was formed by the reaction between **1a** and octanol in the presence of DBU and was in turn converted to octanal and *N*-*tert*-butylbenzenesulfenamide by an intramolecular proton transfer through a five-membered transition state (Scheme 1). In order to prove the existence of alkoxysulfilimines in the alcohol-oxidation using **1a** and to investigate further the proton transfer step in the proposed mechanism of the oxidation, two kinds of octyloxyaminosulfonium salts (**3**) were prepared and their structural requirements for the oxidation were studied. Namely, one kind of **3** was octyloxy(*N*-monoalkylamino)sufonium salts (**3a**–**g**) and octyloxy(*N*,*N*-diethylamino)sulfonium salts (**3h**,**i**) were the others. It was considered that **2** would be readily formed and oxidation would take place by treating the former with an appropriate base. In this communication, we would like to present new findings concerning the mechanism of the direct oxidation of alcohols using **1a**, together with a new method for oxidation of primary alkyl triflates to the corresponding aldehydes by using *N*-*tert*-butylmethanesulfinamide (**4c**).

As *N*,*N*-dialkylsulfinamides were already reported to be selectively *O*-alkylated by using hard alkylating agents such as methyl triflate[2a–c,e] or triethyloxonium tetrafluoroborate,[2d] several octyloxyaminosufonium salts[2] were prepared by *O*-alkylation of sulfinamides with octyl triflate (Table 1). In the first place, three types of benzenesulfinamides (**4a**,**b**,**h**)[3] were *O*-alkylated with octyl triflate in refluxing CH_2Cl_2. *N*-*tert*-Butyl- and *N*-isopropylamino(octyloxy)(phenyl)sulfonium triflates (**3a** and **3b**) were obtained only in low yields although *N*,*N*-diethylaminosulfonium salt (**3h**) was formed in 91% yield (Table 1, entries 1, 2, and 8). Therefore, methane- or isopropylsulfinamides[3] were employed in *O*-octylation reaction since they were supposed to be more nucleophilic than benzenesulfinamides. Expectedly, the *O*-octylation reactions proceeded at lower temperatures (room temperature), and **3c** and **3i** were obtained from **4c** and **4i**, respectively, in over 90% yields. It was also found that *N*-*tert*-butylalkylsulfinamides (**4c** and **4f**) and *N*,*N*-diethylsulfinamides (**4h** and **4i**) were more smoothly *O*-octylated than other sulfinamides were. Because all of these octyloxyaminosulfonium triflates (**3**) except **3a** and **3g** were oily substances and were difficult to be purified, yields of **3a**–**i** were estimated by ^{1}H NMR analysis after washing crude sulfonium salts with petroleum ether (*vide infra*).



Scheme 1.

As the second step, the formation of octyloxysulfilimines (**2**) was carried out by treating the above-mentioned **3** with a base. When neutralization of **3** was conducted by using 1.1 equiv of DBU as the base in toluene, it was found that all of octyloxy-*N*-monoalkylaminosulfonium triflates (**3b**–**f**) were converted to octanal, while *N*,*N*-diethylaminosulfonium salts (**3h**,**i**) were not (Table 1). This result implied that octyloxysulfilimines (**2**) were readily formed from **3b**–**f** by treating them with DBU, and oxidation took place to afford octanal immediately after the formation of **2**. Further, the results that oxidation did not take place in the case of *N*,*N*-diethylaminosulfonium salts (**3h**,**i**) suggested that DBU did not take part in α-proton-abstraction at the proton-transfer step of the oxidation reaction and the proton-transfer proceeded via the intramolecular five-membered transition state. In fact, when **3h** was treated with DBU, no desired octanal was detected at all, while added DBU was octylated with **3h** to form a quaternary ammonium salt in 34% yield along with the formation of *N*,*N*-diethyl benzenesulfinamide (41%) and the recovery of **3h** (37%). Instead of oxidation, nucleophilic replacement of **3h** with DBU apparently took place.

Because *N-tert*-butylmethanesulfinamide (**4c**) gave the best results concerning both *O*-alkylation and oxidation among sulfinamides examined, **4c** has been used in the oxidation of alkyl triflates since then. On the other hand, when *O*-alkylation of dimethyl sulfoxide with octyl triflate was tried, the corresponding dimethyl(octyloxy)sulfonium triflate was obtained in a lower yield and a lower purity (70% yield, 73% purity). This result indicated that *O*-alkylation of **4c** proceeded more efficiently than that of dimethyl sulfoxide. It was also advantageous that the present oxidation proceeded smoothly at room temperature, considering the fact that higher temperatures such that ranging from 100 to 150 °C were required in the similar oxidation by Kornblum using dimethyl sulfoxide.[4]

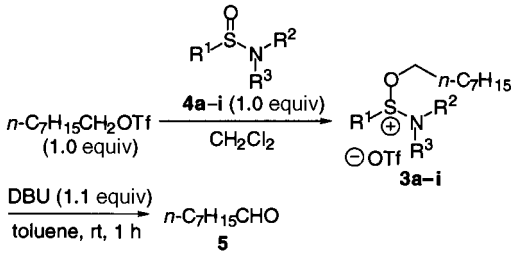


Table 1. Oxidation of octyl triflate to octanal (**5**) via formation of octyloxyaminosulfonium triflates (**3a–i**)

Entry	Sulfinamide (**4**) R[1]	R[2]	R[3]		*O*-Alkylation Conditions	Yield/% **3**[a]	**5**[b]
1	Ph	*t*Bu	H	**4a**	reflux, 12 h	**3a** —[c]	—[d]
2	Ph	*i*Pr	H	**4b**	reflux, 1 h	**3b** 44 (65)	52
3	Me	*t*Bu	H	**4c**	rt, 42 h	**3c** 95 (>99)	88
4	Me	*i*Pr	H	**4d**	rt, 24 h	**3d** 44 (65)	52
5	Me	Me	H	**4e**	rt, 44 h	**3e** 84 (90)	23
6	*i*Pr	*t*Bu	H	**4f**	rt, 40 h	**3f** 87 (93)	93
7	Me	Ph	H	**4g**	rt, 24 h	**3g** —[c]	—[d]
8	Ph	Et	Et	**4h**	reflux, 12 h	**3h** 91 (94)	0
9	Me	Et	Et	**4i**	rt, 44 h	**3i** 95 (96)	1

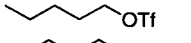
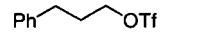
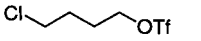
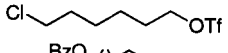
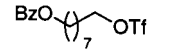
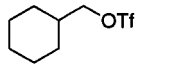
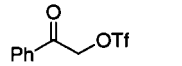
[a]Determined by ^{1}H NMR analysis using Ph_3CH as an internal standard. The number in parenthesis is wt% purity of **3**. [b]Yield based on **3** was determined by GC-analysis using an internal standard. [c]Complex mixture. [d]The experiment was not carried out.

Oxidation of various primary alkyl triflates to the corresponding aldehydes was performed in two reactions, i. e. the initial formation of alkoxy(*N-tert*-butylamino)(methyl)sulfonium salts by the reaction of **4c**, and the successive oxidation step by using DBU (Table 2). In the cases of simple primary alkyl triflates, the above oxidation proceeded very smoothly, and alkyl triflates bearing chloro or ester functionality were also oxidized in good yields by the present method (entries 2–6). Thus, alkoxy(*N-tert*-butylamino)(methyl)sulfonium salts would be regarded as stable precursors of the corresponding aldehydes. In the case of *β*-branched primary alkyl triflate, higher temperature and longer reaction time (reflux, 3 h) were required for the formation of sulfonium salt (entry 7). Also, a complicated mixture resulted when applied to phenacyl triflate (entry 8).

Typical experimental procedure is as follows (Table 1, entry 3): to a stirred solution of *N-tert*-butylmethanesulfinamide (**4c**, 2.99 g, 11.4 mmol) in CH_2Cl_2 (10 mL) was added a solution of octyl triflate (1.54 g, 11.4 mmol) in CH_2Cl_2 (15 mL) at room temperature. After the reaction mixture was stirred for 42 h at room temperature, the solvent was removed, and the residue was washed with petroleum ether (5 mL × 5) and dried *in vacuo* to afford **3c**[5] as a colorless oil (4.31 g). Purity of the obtained **3c** (99.8 wt% purity) was checked by ^{1}H NMR analysis using triphenylmethane as an internal standard and its yield was estimated to be 95%.

To a stirred suspension of **3c** (99.8% purity, 205 mg, 0.51 mmol) in toluene (1.5 mL) was added a solution of DBU (86 mg, 0.57 mmol) in toluene (2 mL) at room temperature and the reaction mixture was stirred for 1 h at the same temperature. Then, it was quenched with 1% aqueous HCl solution and the resulting mixture was extracted with CH_2Cl_2. The yield of octanal (**5**, 0.45 mmol, 88%) was determined by GC analysis using an internal standard.

Table 2. Oxidation of primary alkyl triflates to the corresponding aldehydes using **4c** and DBU via formation of alkoxy(*N-tert*-butylamino)(methyl)sulfonium triflates[a]

Entry	Primary Alkyl Triflate	Alkylation time/h	Yield/% Alkoxyamino-sulfonium salt[b]	Aldehyde[c]
1	MeOTf	16	91 (91)	—
2		36	96 (97)	95
3		41	95 (97)	82
4		38	93 (94)	61
5		40	90 (95)	84
6		39	90 (95)	71[d]
7		3[e]	62 (76)	73
8		37	84 (83)	complex mixture

[a]Reaction conditions: see Table 1. [b]Determined by ^{1}H NMR analysis by using an internal standard. The Number in parenthesis is the caluculated purity (wt%). [c]Yield based on the sulfonium salt was determined by GC-analysis using an internal standard. [d]Isolated yield. [e]The *O*-alkylation was carried out in refluxing CH_2Cl_2.

References and Notes

1 a) T. Mukaiyama, J. Matsuo, and M. Yanagisawa, *Chem. Lett.*, **2000**, 1072. b) J. Matsuo, H. Kitagawa, D. Iida, and T. Mukaiyama, *Chem. Lett.*, **2001**, 150.

2 a) H. Minato, K. Yamaguchi, and M. Kobayashi, *Chem. Lett.*, **1975**, 991. b) H. Minato, K. Yamaguchi, K. Okuma, and M. Kobayashi, *Bull. Chem. Soc. Jpn.*, **49**, 2590 (1976). c) M. Mikolajczyk, B. Bujnicki, and J. Drabowicz, *Bull. Acad. Pol. Sci., Ser. Sci. Chim.*, **25**, 267 (1977). d) H-U. Wagner and A. Judelbaum, *Angew. Chem., Int. Ed. Engl.*, **17**, 460 (1978). e) H. Minato, K. Okuma, and M. Kobayashi, *J. Org. Chem.*, **43**, 652 (1978). f) M. Haake and H. Gebbing, *Synthesis*, **1979**, 98.

3 Sulfinamides (**4a–i**) were prepared from the corresponding sulfinyl chlorides and amines.

4 N. Kornblum, W. J. Jones, and G. J. Anderson, *J. Am. Chem. Soc.*, **81**, 4113 (1959).

5 **3c**: ^{1}H NMR (270 MHz, $CDCl_3$, Me_4Si) δ 0.88 (3H, t, J = 7.1 Hz), 1.27–1.48 (10H, m), 1.42 (9H, s), 1.66–1.76 (2H, m), 3.39 (3H, s), 4.09 (1H, td, J = 6.4, 9.2 Hz), 4.27 (1H, td, J = 6.4, 9.2 Hz), 8.34 (1H, bs). ^{13}C NMR (68 MHz, $CDCl_3$) δ 13.78, 22.33, 25.12, 28.76, 28.90, 29.59, 31.42, 34.06, 34.11, 57.40, 69.08, 120.20 (q, J = 319 Hz). MS (FAB+) *m/z* 248 ([*n*-BuOSMeNH^{t}Bu]$^+$). MS (FAB–) *m/z* 149 (OTf^-).