Michael Additions of Oxygen and Sulfur Nucleophiles to 3,4-Di-*t*-butyl-1-[(*p*-tolyl)sulfonylimino]-1,1-dihydrothiophene. A Comparison Study with 3,4-Di-*t*-butylthiophene 1-Oxide and 1,1-Dioxide

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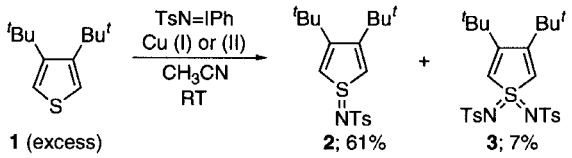
The reactions of 3,4-di-*t*-butyl-1-[(*p*-tolyl)sulfonylimino]-1,1-dihydrothiophene with RONa and RSNa furnished 2-alkoxy- and 2-alkylthio-substituted thiophenes, respectively, through Michael adduct formation. The reaction of 3,4-di-*t*-butylthiophene 1-oxide with RSNa gave 1,6-Michael adducts, whereas the corresponding reaction of 3,4-di-*t*-butylthiophene 1,1-dioxide produced a mixture of 1,4- and 1,6-adducts.

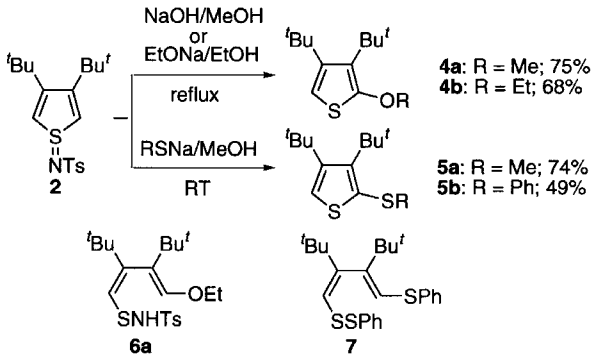
The chemistry of thiophene 1-oxides is a matter of recent keen interest,[1] whereas that of thiophene 1,1-dioxides has been documented in full detail.[2] On the other hand, the chemistry of 1-imino and 1,1-diimino derivatives of thiophenes has been scarcely studied. Thus, the 1-imino derivatives of tetrachlorothiophene had been the sole example of monocyclic thiophene derivatives,[3] until, quite recently, we have reported the preparation of 3,4-di-*t*-butyl-1-[(*p*-tolyl)sulfonylimino]-1,1-dihydrothiophene (**2**) and 3,4-di-*t*-butyl-1,1-bis[(*p*-tolyl)sulfonylimino]-1,1-dihydrothiophene (**3**) by reaction of sterically congested 3,4-di-*t*-butylthiophene (**1**) with *N*-(*p*-tolylsulfonylimino)phenyliodinane (TsN=IPh).[4] As the extension of this study, we have examined detosylation of **2** to obtain the corresponding parent 1-imino derivative. Interestingly, however, the attempted alkaline hydrolysis of **2** in refluxing aqueous MeOH[5] provided 3,4-di-*t*-butyl-2-methoxythiophene (**4a**) as the major product, which corresponds formally to the Pummerer reaction product. Attempted detosylation of **2** by a conventional method, treatment with concentrated H_2SO_4,[6] produced a complex mixture containing **1** and some other products. The above unexpected results, which have never been observed in the chemistry of thiophene 1-oxides and thiophene 1,1-dioxides, have led us to a comparison study of nucleophilic reactivities of **2**, 3,4-di-*t*-butylthiophene 1-oxide (**8**)[7] and 1,1-dioxide (**9**).[8]



Thus, the reaction of **2** with NaOH in refluxing aqueous MeOH for 48 h gave **4a**[9,10] (75%) and *p*-toluenesulfonamide ($TsNH_2$) (79%), whereas **2** was inert to heating with NaOH in aqueous dioxane at 80 °C for 24 h. Heating **2** with EtONa in EtOH at 70 °C for 2 h also gave the 2-ethoxythiophene (**4b**) (68%) and $TsNH_2$ (69%), in addition to the further unexpected product, configurationally pure 1,3-diene (**6a**), in 17% yield.[9,10]

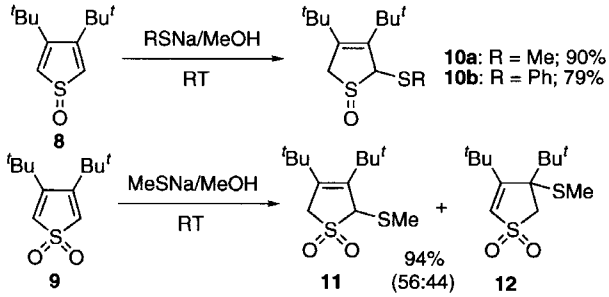
Sulfur nucleophiles, MeSNa and PhSNa, reacted with **2** much more easily at room temperature in MeOH for 48 h to give thiophenes (**5a**) (74%) and (**5b**) (49%), respectively. In the case of the latter nucleophile, the configurationally pure 1,3-diene (**7**), containing two phenylthio groups, was also isolated in 20% yield.[9,10] Assignment of the stereochemistry of the dienes **6a** and **7** is based on the mechanistic grounds as discussed later.

Although it is known that alkaline treatment of sulfilimines produces the corresponding sulfoxides,[11] such hydrolysis of **2**, which leads to the 1-oxide **8**, was never observed throughout this study.

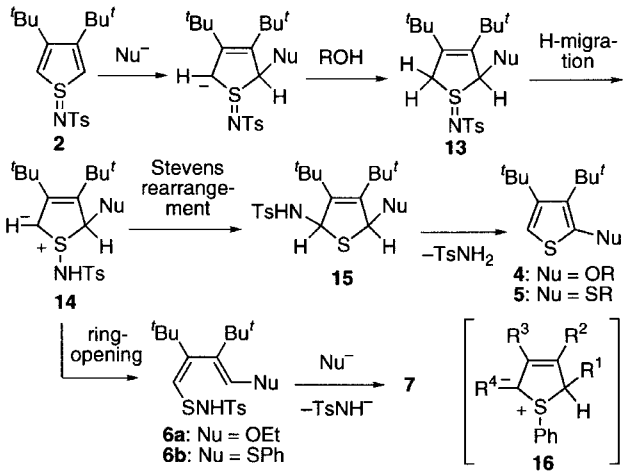


Next, reactions of the 1-oxide **8** and 1,1-dioxide **9** with nucleophiles were investigated for comparison. Either **8** or **9** failed to react with MeONa; both **8** and **9** were recovered quantitatively when heated with MeONa in refluxing MeOH for 48 h. Meanwhile, sulfur nucleophiles, MeSNa and PhSNa, reacted with **8** in MeOH at room temperature to give the 1,6-Michael adducts (**10a**) (90%) and (**10b**) (79%), respectively.[9,12] It is noteworthy that these reactions provides a facile synthesis of cyclic alkenes **10** in which two bulky *t*-butyl groups are placed in *cis*-orientation. When the reaction of **8** with MeSNa was carried out under the forcing conditions (reflux, MeOH, 72 h), **5a** was formed at the sacrifice of **10a** though in a low yield (11%), thus suggesting that 1,6-adducts are the probable intermediates for the formation of **4** and **5** from **2**.

Finally, the reaction of **9** with MeSNa produced a mixture of 1,6- and 1,4-adducts (**11** and **12**) in the ratio 56:44 in 94% combined yield.[9,12,13]



Although the reactivities of *N*-*p*-tolylsulfonylsulfilimines toward nucleophiles have been examined extensively,[11,14] the aforementioned reactions on **2** are unprecedented. Reportedly, the alkaline hydrolysis of cyclic *N*-*p*-tolylsulfonylsulfilimines in MeOH gave Pummerer reaction products, α-methoxy-substituted sulfides, as main products,[14a] but the mechanism proposed therein[14a–b] would not be true of the present case. Thus, the reaction would be best explained as follows. The Michael addition of Nu^- to the less hindered 2-position of **2** produces 2,5-dihydrothiophenes (**13**) initially, which is followed by hydrogen migration that leads to ylide intermediates (**14**). The Stevens-like [1,2]-rearrangement of **14** then affords 2,5-dihydrothiophenes (**15**). Finally, base-catalyzed elimination of $TsNH_2$ from **15** results in the formation of 2-substituted thiophenes **4** and **5**. Meanwhile, the ring-opening of ylides **14** would provide dienes **6**. This type of ring-opening was reported on a series of the sulfur ylides (**16**);[15] the ring-opening process can be presumed as an electrocyclic process of 6π-electron system, which takes place in a concerted disrotatory manner.[16] Finally, the substitution reaction of **6b** by excessive PhSNa explains the formation of **7**. In addition, the formation of **6** (**7**) provides supporting evidences for the intermediacy of the Michael adducts **13**.



In conclusion, **2**, **8**, and **9** all serve as Michael acceptors toward thiolates, whereas only **2** is reactive to alkoxides. In addition, the Michael adducts of **2** undergo a Stevens-like [1.2]-rearrangement to furnish the formal Pummerer reaction products.

References and Notes

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9 Satisfactory elemental analyses were obtained for all new compounds.

10 **4a**: colorless crystals; mp 50–51 °C, ^{1}H NMR (400 MHz, $CDCl_3$) δ = 1.43 (s, 9H), 1.50 (s, 9H), 3.86 (s, 3H), 6.46 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 33.0, 33.3, 35.4, 35.7, 61.0, 106.8, 129.6, 149.3, 162.1. **4b**: colorless crystals; mp 46 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ = 1.42 (t, *J* = 7.1 Hz, 3H), 1.43 (s, 9H), 1.51 (s, 9H), 4.05 (q, *J* = 7.1 Hz, 2H), 6.43 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 15.1, 33.1, 33.3, 35.3, 35.6, 70.0, 106.0, 129.5, 149.2, 161.0. **5a**: colorless crystals; mp 29–30 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ = 1.46 (s, 9H), 1.66 (s, 9H), 2.49 (s, 3H), 7.13 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 23.3, 33.8, 33.9, 35.7, 36.8, 122.5, 133.3, 150.3, 152.0. **5b**: colorless crystals; mp 58–59 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ = 1.51 (s, 9H), 1.64 (s, 9H), 7.02–7.05 (m, 2H), 7.08–7.12 (m, 1H), 7.21–7.25 (m, 2H) 7.33 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 33.9, 34.0, 36.0, 37.2, 125.1, 125.9, 126.5, 128.8, 140.8, 152.3, 154.8. **6a**: colorless crystals; mp 88–89 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ = 0.97 (s, 9H), 1.12 (s, 9H), 1.21 (t, *J* = 7.0 Hz, 3H), 2.43 (s, 3H), 3.65–3.75 (m, 2H, OCH_2), 5.70 (bs, 1H, NH), 5.75 (s, 1H), 6.00 (s, 1H), 7.31 (d, *J* = 8.2 Hz, 2H), 7.82 (d, *J* = 8.2 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 15.4 (CH_3), 21.5 (CH_3), 30.9 (CH_3), 32.3 (CH_3), 33.0 (C), 36.3 (C), 67.6 (CH_2), 124.0 (C), 125.9 (CH), 128.0 (CH), 129.6 (CH), 136.5 (C), 144.0 (C), 144.2 (CH), 146.8 (C). **7**: colorless crystals; mp 60–60.5 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ = 1.23 (s, 9H), 1.24 (s, 9H), 6.25 (s, 1H), 6.37 (s, 1H), 7.17–7.35 (m, 8H), 7.51–7.54 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 31.6, 31.8, 37.0, 37.1, 124.2, 126.2, 126.9, 128.2, 128.8, 128.9, 128.9, 129.0, 137.3, 137.7, 149.3, 149.6.

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12 **10a**: colorless crystals; mp 118–119 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ = 1.31 (s, 9H), 1.41 (s, 9H), 2.25 (s, 3H), 3.50 (d, *J* = 17.4 Hz, 1H), 4.20 (d, *J* = 17.4 Hz, 1H), 4.71 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 16.7 (CH_3), 31.5 (CH_3), 32.4 (CH_3), 34.0 (C), 35.3 (C), 61.4 (CH_2), 79.5 (CH), 138.4, (C), 140.1 (C); IR (KBr) 1038 cm^{-1}. **10b**: colorless crystals; mp 105–109 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ = 1.34 (s, 9H), 1.48 (s, 9H), 3.50 (dd, *J* = 1.1, 17.7 Hz, 1H), 4.21 (d, *J* = 17.7 Hz, 1H), 5.12 (s, 1H), 7.32–7.37 (m, 3H), 7.49–7.53 (s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 31.5, 32.6, 34.2, 35.5, 61.0, 80.1, 128.3, 129.4, 132.0, 133.2, 137.7, 141.7. **11**: ^{1}H NMR (400 MHz, $CDCl_3$) δ = 1.28 (s, 9H), 1.40 (s, 9H), 2.33 (s, 3H), 3.63 (dd, *J* = 0.8, 16.4 Hz, 1H), 4.12 (d, *J* = 16.4 Hz, 1H), 4.43 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 15.1, 31.1, 32.4, 35.0, 36.4, 56.0, 71.4, 140.5, 142.1. **12**: ^{1}H NMR (400 MHz, $CDCl_3$) δ = 1.28 (s, 9H), 1.46 (s, 9H), 2.02 (s, 3H), 3.49 (d, *J* = 15.5 Hz, 1H), 3.96 (d, *J* = 15.5 Hz, 1H), 6.66 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 13.1, 28.9, 33.4, 37.9, 40.9, 61.2, 69.9, 133.0, 164.5.

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