Extended Pummerer Reaction of Arylketene Dithioacetal Monoxides with Aromatic Compounds by Means of Trifluoromethanesulfonic Anhydride

Suguru Yoshida, Hideki Yorimitsu,* and Koichiro Oshima*
Department of Material Chemistry, Graduate School of Engineering, Kyoto University,
Kyoto-daigaku Katsura, Nishikyo-ku, Kyoto 615-8510

(Received May 8, 2008; CL-080474;
E-mail: yori@orgrxn.mbox.media.kyoto-u.ac.jp, oshima@orgrxn.mbox.media.kyoto-u.ac.jp)

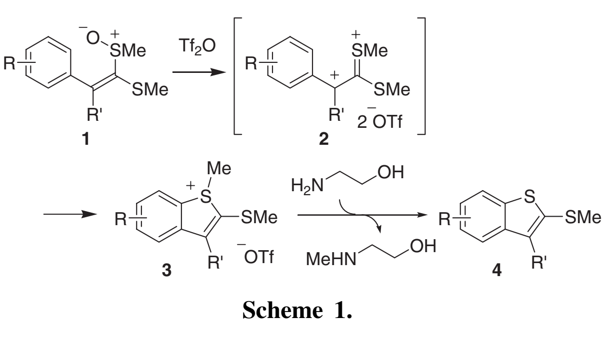
Extended Pummerer reaction of arylketene dithioacetal monoxides with aromatic compounds by means of trifluoromethanesulfonic anhydride proceeded in moderate to good yields. In the case of intramolecular cyclization of (2-arylphenyl)ketene dithioacetal monoxides, phenanthrenes were obtained via ring-closure and skeletal rearrangement.

The Pummerer reaction is regarded as an important synthetic method for preparation of α-substituted sulfides.[1] Particularly, the Pummerer rearrangement has been utilized widely as a transformation from alkyl sulfoxides to aldehydes or ketones for synthesis of many natural products.[2] However, extended Pummerer reactions using alkenyl or aryl sulfoxides are still limited.[3] Especially, there are few reports on nucleophilic attack to cationic species generated from alkenyl sulfoxides via cleavage of the S–O bond.

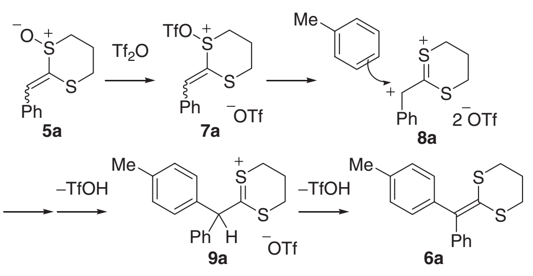
Recently, we have reported the synthesis of benzo[*b*]thiophenes **4** by cyclization of arylketene dithioacetal monoxides **1** under Pummerer-like conditions (Scheme 1).[4] The reaction should involve stabilized cationic intermediate **2** generated from arylketene dithioacetal monoxides with trifluoromethanesulfonic anhydride.[5] Here, we report intermolecular nucleophilic attack to a similar cationic intermediate by aromatic compounds.

First, 2-phenylmethylene-1,3-dithiane 1-oxide (**5a**) was treated with trifluoromethanesulfonic anhydride in toluene, as a nucleophile as well as solvent, at −78 °C (Scheme 2). The mixture was warmed to 25 °C, and stirred for 12 h. Extractive work up followed by silica-gel column purification afforded 2-[phenyl(4-tolyl)methylene]-1,3-dithiane (**6a**) in 80% yield. A plausible reaction mechanism is as follows. At first, sulfoxide **5a** gave intermediate **7a** upon treatment with trifluoromethanesulfonic anhydride. Then, dicationic intermediate **8a** could be generated after cleavage of the S–O bond.[6] Friedel–Crafts-type nucleophilic attack to dicationic intermediate **8a** followed by deprotonation would afford desired product **6a**.

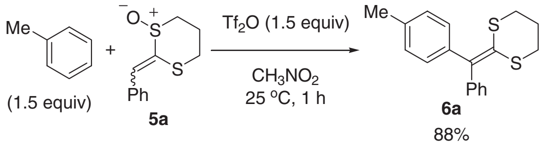
Then, we have examined reactions of sulfoxide **5a** with 1.5 equiv of toluene and 1.5 equiv of trifluoromethanesulfonic anhydride in several solvents. Although reactions in CH_2Cl_2, CH_3CN, THF, or diethyl ether gave complex mixtures, the use of CH_3NO_2 provided a good result due to the high polarity of the solvent (eq 1). Stabilization of cationic intermediates by CH_3NO_2 could allow toluene to attack intermediate **8a** intermolecularly. When acetic anhydride, trifluoroacetic anhydride, or trifluoromethanesulfonic acid was used instead of trifluoromethanesulfonic anhydride, no desired product was obtained.



Scheme 1.



Scheme 2.

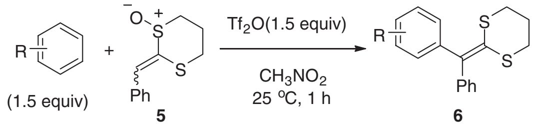


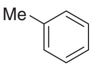
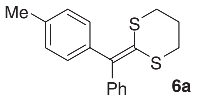
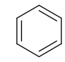
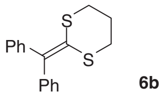
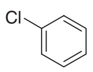
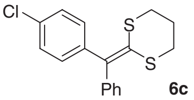
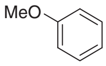
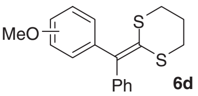
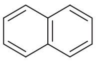
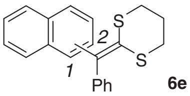
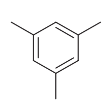
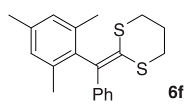
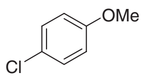
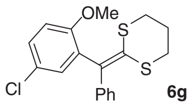
(1)

We examined the scope of the extended Pummerer reaction (Table 1). Nucleophilic attack of benzene or chlorobenzene to sulfoxide **5a** with the aid of trifluoromethanesulfonic anhydride proceeded in moderate yields, although the nucleophiles were used as solvent (Entries 2 and 3). In the case of anisole or naphthalene, the reaction proceeded in high yields and the products were obtained as mixtures of regioisomers (Entries 4 and 5). Treatment of mesitylene or *p*-chloroanisole gave desired multisubstituted benzene derivatives in good yields (Entries 6 and 7).

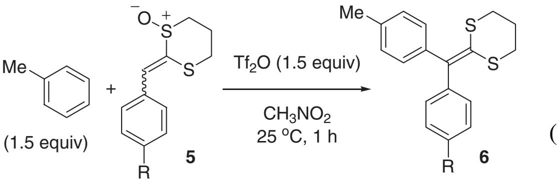
Substituents on olefins affected the reaction significantly. Treatment of a mixture of 2-methylene- or 2-propylidene-1,3-dithiane 1-oxide and toluene with trifluoromethanesulfonic anhydride in CH_3NO_2 gave a complex mixture. In the case of 2-arylmethylene-1,3-dithiane 1-oxide, yields of **6** were lowered by the substituents on the aromatic rings (eq 2). Although the reaction of 2-(4-chlorophenyl)methylene-1,3-dithiane 1-oxide (**5b**) afforded desired product **6h** in good yield, 2-(4-trifluoromethylphenyl)methylene-1,3-dithiane 1-oxide (**5c**), a more electron-deficient substrate, afforded a complex mixture which did not contain **6i**. 2-(4-Methoxyphenyl)methylene-1,3-dithiane 1-oxide (**5d**) gave desired product **6j** in low yield due to some unidentified side reactions.

Table 1. Reaction of sulfoxide **5** with aromatic compounds by means of Tf_2O



Entry	Nucleophile	Product	Yield/%[a]
1		 **6a**	88
2		 **6b**	50[b]
3		 **6c**	55[b]
4		 **6d**	92 (o/p = 1/2)[c]
5		 **6e**	76 (*1*/*2* = 4/1)
6		 **6f**	85
7		 **6g**	61

[a]Isolated yields. [b]Nucleophile was used as solvent instead of CH_3NO_2. [c]Tf_2O (2.5 equiv), K_2CO_3 (5.0 equiv), CH_3NO_2, 25 °C, 1 h.

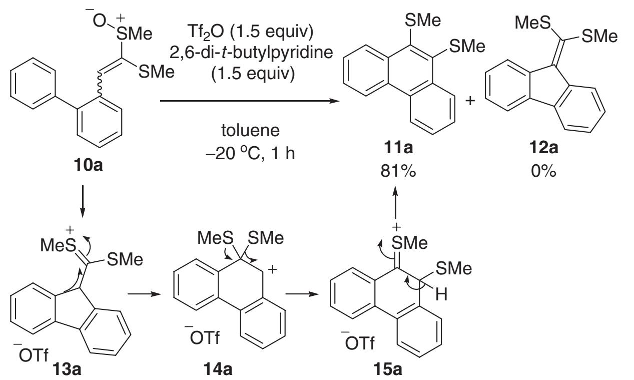


(2)

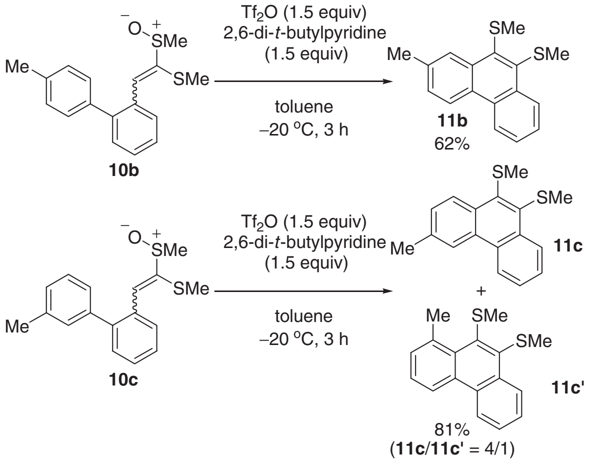
R = Cl (**5b**)
R = CF_3 (**5c**)
R = OMe (**5d**)

R = Cl (**6h**)	83%
R = CF_3 (**6i**)	0%
R = OMe (**6j**)	38%

Then, we tried intramolecular extended Pummerer reactions. Trifluoromethanesulfonic anhydride was added to biphenylketene dithioacetal monoxide **10a** in the presence of 2,6-di-*tert*-butylpyridine in toluene at −20 °C.[7] The reaction did not give fluorene **12a**, but afforded phenanthrene **11a** in good yield (Scheme 3). Phenanthrene **11a** should be formed via the intramolecular extended Pummerer reaction and the Wagner–Meerwein-type skeletal rearrangement[8] of cationic intermediate **13a** before deprotonation.[9] Methyl-substituted biphenylketene dithioacetal monoxides **10b** and **10c** also gave the corresponding phenanthrenes **11b** and **11c** in good yields (Scheme 4).



Scheme 3.



Scheme 4.

In conclusion, we have developed an extended Pummerer reaction of arylketene dithioacetal monoxides and aromatic compounds. Nitromethane is the choice of solvent and allows for intermolecular Friedel–Crafts-type nucleophilic attack to cationic intermediates. In the intramolecular extended Pummerer reaction of arylphenylketene dithioacetal monoxides, phenanthrenes were obtained via cyclization and skeletal rearrangement.

References and Notes

1 S. K. Bur, A. Padwa, *Chem. Rev.* **2004**, *104*, 2401.

2 Application of the Pummerer reaction to synthesis of complex carbocycles and heterocycles has been shown: A. Padwa, D. E. Gunn, Jr., M. H. Osterhout, *Synthesis* **1997**, 1353.

3 Selected examples: a) D. Craig, K. Daniels, *Tetrahedron* **1993**, *49*, 11263. b) Y. Kita, Y. Takeda, M. Matsugi, K. Iio, K. Gotanda, K. Murata, S. Akai, *Angew. Chem., Int. Ed. Engl.* **1997**, *36*, 1529. c) A. Padwa, J. T. Kuethe, *J. Org. Chem.* **1998**, *63*, 4256. d) S. Akai, N. Morita, K. Iio, Y. Nakamura, Y. Kita, *Org. Lett.* **2000**, *2*, 2279. e) K. S. Feldman, D. B. Vidulova, *Org. Lett.* **2004**, *6*, 1869. f) S. Akai, N. Kawashita, H. Satoh, Y. Wada, K. Kakiguchi, I. Kuriwaki, Y. Kita, *Org. Lett.* **2004**, *6*, 3793. g) A. Padwa, S. Nara, Q. Wang, *Tetrahedron Lett.* **2006**, *47*, 595.

4 S. Yoshida, H. Yorimitsu, K. Oshima, *Org. Lett.* **2007**, *9*, 5573.

5 High oxophilicity of Tf_2O and its applications have been summarized: I. L. Baraznenok, V. G. Nenajdenko, E. S. Balenkova, *Tetrahedron* **2000**, *56*, 3077.

6 According to our previous report (Ref. 4), the generation of dicationic intermediate **8a** is possible. However, the possibility of attack of toluene to intermediate **7a** in an S_N2' mode cannot be excluded.

7 Treatment of **10a** with trifluoromethanesulfonic anhydride in CH_3NO_2 gave a complex mixture. After extensive screening of the reaction conditions for the cyclization, we have found the conditions.

8 For review on the Wagner–Meerwein rearrangement see: A. J. Floyd, S. F. Dyke, S. E. Ward, *Chem. Rev.* **1976**, *76*, 509.

9 Skeletal rearrangement to phenanthrenes from fluorenes by the Wagner–Meerwein rearrangement has been reported: W. G. Brown, B. J. Bluestein, *J. Am. Chem. Soc.* **1940**, *62*, 3256.

Published on the web (Advance View) June 21, 2008; doi:10.1246/cl.2008.786