Arene sulfenylation by arenesulfenamides and arenesulfenylacetates

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Two systems for arene sulfenylation were investigated: arenesulfenamides in the presence of SO_3 and sulfenylacetate complexes with $AlBr_3$. A preference for the second reagent was demonstrated for sulfenylation of substrates bearing donor substituitents.

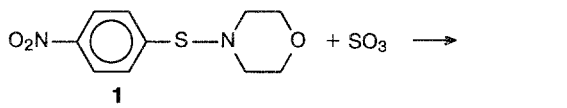
Key words: arenesulfenamides, arenesulfenyl acetates, diarenesulfides.

One of the challenging problems in organic synthesis is the preparation of organic sulfides, which are commonly used as antioxidants and stabilizers as well as drugs, dyes, and detergents.[1,2] When using electrophilic substitution in the aromatic ring for this purpose, arenesulfenylchlorides activated with Lewis acids ($AlCl_3$,[3] as a rule) can be used as the electrophilic agents. However, the low electrophilicity of the arenesulfenylchlorides restricts the choice of the substrates to electron-excessive arenes.

The objective of this research is to find alternative highly electrophilic reagents for arene sulfenylation. Two sulfenylation systems were studied: one based on arenesulfenamides and one based on arenesulfenylacetates.

Arenesulfenamides are very weak electrophilic agents which can, however, be activated with Lewis acids, *e.g.*, trifluoroboron etherate. Effective strong electrophilic reagents are thereby formed.[4] It is also possible to modify the amides of arenesulfenyl acids by insertion of free SO_3 at the sulfenamide S—N-bond (in CH_2Cl_2 at −70 °C). The mixed anhydrides of sulfenic and sulfamic acids formed thereby are highly reactive electrophilic reagents.[5] These compounds have been previously studied in reactions with alkenes.[6,7]

We studied the reactions between p-nitrobenzenesulfenmorpholide and aromatic compounds in the presence of SO_3. As the reagent formed decomposes at 20 °C, it was not isolated and the arene was added to the reaction mixture which was then gradually heated to 20 °C. The electrophilic substitution reaction then occured (for 1 h in the temperature range −30—0 °C depending on electron saturation of the substrate).



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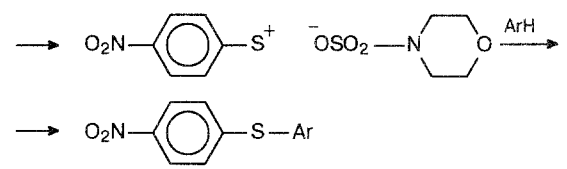
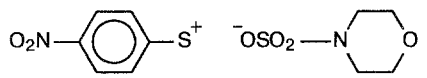
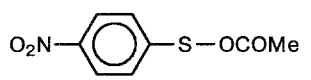


2—5

A number of model arenes with different electron densities at the aromatic ring were used. The results are given in Table 1. The reaction with anisole is complicated by interaction between SO_3 and the methoxy

Table 1. Sulfenylation reactions of model arenes

Reagent	Arene	Product	Yield (%)
	Anisole	**2**	20
	p-Xylene	**3**	30
	Toluene	**4a**, **4b** (4 : 1)	25
	Anthracene	**5**	55
	*p*-Xylene	**3**	70
	Toluene	**4a**, **4b** (2 : 1)	30
	Benzene	**7**	20

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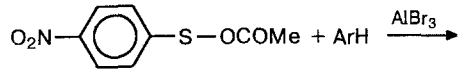
group, resulting in destruction of the substrate and a decrease in the yield. A mixture of isomers is formed in the reaction with toluene. Their ratio attests to a rather great steric volume of the reagent.

The low yield of the reactions studied is due to the degradation of arenesulfenylsulfamate, which proceeds in parallel to diaryldisulfide formation. An attempt to accelerate the rate of electrophilic substitution by additional activation of the reagent by the Lewis acid ($AlBr_3$) resulted in further acceleration of the degradation and a sharp drop in the yield of the target product.

In order to enhance the yield of the diarylsulfides we used the complex of p-nitrobenzenesulfenylacetate with $AlBr_3$, which is less electrophilic but more stable towards degradation, as an alternative sulfenylation reagent. The reactions between this reagent and the arenes proceed smoothly for a few hours at 20 °C.



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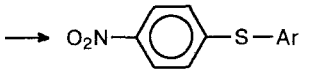

3, 4, 7

4,4'-Dinitrodiphenyldisulfide, isolated in all cases as a by-product, is a result of the radical degradation of the reagent. The yield of the sulfenylation product depends on the ratio of the rates of the radical degradation of the S-electrophilic agent to form disulfide and the electrophilic substitution reaction. The formation of the arene π-complex with the reagent can be assumed to inhibit the degradation of the latter. In the case when the formation of the π-complex (for a highly electrophilic reagent) is the limiting stage of the reaction, the yield of the target product should depend only slightly on the electron donating ability of the substrate. This is the case when using sulfenylsulfamate. However, the second stage, the transformation of the π-complex into a σ-complex, seems to be the limiting stage in the case of a weaker electrophilic agent (sulfenylacetate).

Based on the foregoing speculations, one would expect that sulfenylacetate would be better for the sulfenylation of highly electron-saturated arenes. For reactive substrates, the choice of the reagent (sulfenylsulfamate or sulfenylacetate) should not have much effect on the product yield. The results obtained confirm this supposition.

Experimental

The purity of the reaction products was monitored by TLC. The preparative separation of the reaction products was carried out by TLC with Silufol plates using ethyl acetate—petroleum ether (1 : 3) as the eluent. PMR spectra were recorded on Tesla-BS-467 (60 MHz) and Varian-400 NMR spectrometers (400 MHz). The chemical shifts are given in the δ-scale with HMDS as the internal standard. Mass spectra were obtained on a Varian-MAT-212 instrument (direct injection, electron impact, 70 eV).

Reactions between p-nitrobenzenesulfenmorpholide and arenes. (General procedure). An equivalent amount of sulfenamide in CH_2Cl_2 was slowly added to a solution of SO_3 in absolute CH_2Cl_2 at −70 °C in a stream of dry Ar with stirring, and after 15 min an arene solution was added at the same temperature. The mixture was heated to −30 °C, stirred for 1 h at this temperature, then the temperature was increased gradually to ~20 °C. The reaction mixture was passed through a column-filter with silica gel (h = 5 cm). After evaporation of the solvent the residue was chromatographed.

Reactions between p-nitrobenzenesulfenylacetate and arenes. (Ceneral procedure). Sulfenylacetate was generated *in situ*, for which purpose a solution of p-nitrobenzenesulfenyl chloride in abs. CH_2Cl_2 was added gradually at ~20 °C to a stirred suspension of an equivalent amount of $Hg(OAc)_2$ in CH_2Cl_2. An equimolar amount of $AlBr_3$ and a 3-fold excess of the arene were added to the obtained solution, then the solution was stirred for 5 h. The mixture was passed through a column-filter with Al_2O_3 (h = 5 cm), the solvent was evaporated, and the residue was chromatographed.

4-Methoxy-4'-nitrodiphenylsulfide (2). M.p. 55 °C (CCl_4—heptane). R_f 0.33. PMR spectrum (60 MHz, CCl_4), δ: 2.3 (s, 3 H, Me); 3.8 (s, 3 H, MeO); 6.9 (m, 4 H, C_6H_4O); 7.4 (d, 2 H, arom); 7.9 (d, 2 H, arom). Mass spectrum, m/z (I(%)): 261 [M^+] (100).

2,5-Dimethyl-4'-nitrodiphenylsulfide (3). M.p. 90—92 °C (CCl_4). R_f 0.47. PMR spectrum (60 MHz, CCl_4), δ: 2.2 (d, 6 H, Me); 7.0 (m, 4 H, arom); 7.2 (s, 1 H, arom); 7.9 (d, 2 H, arom, J = 9 Hz). Found (%): C, 65.15; H, 5.06; N, 5.23. $C_{14}H_{13}NO_2S$. Calculated (%): C, 64.86; H, 5.02; N, 5.41.

4-Methyl-4'-nitrodiphenylsulfide (4a). M.p. 70—72 °C (pentane) (*cf.* Ref. 9: m.p. 78 °C). R_f 0.43. PMR spectrum (400 MHz, $(CD_3)_2CO$), δ: 2.4 (s, 3 H, Me); 7.25 (d, 2 H, J = 9.2 Hz); 7.49 (d, 2 H, J = 8.5 Hz); 7.35 (d, 2 H, J = 8.5 Hz); 8.11 (d, 2 H, J = 9.2 Hz).

2-Methyl-4'-nitrodiphenylsulfide (4b) was isolated in the mixture with the isomer **4a**. R_f 0.43. PMR spectrum (400 MHz, $(CD_3)_2CO$), δ: 2.35 (s, 3 H, Me); 7.19 (d, 2 H, J = 9.2 Hz); 7.47 (m, 2 H); 7.36 (d, 1 H, J = 7.5 Hz); 7.59 (d, 1 H, J = 7.5 Hz); 8.11 (d, 2 H, J = 9.2 Hz). For the **4a+4b** mixture found (%): C, 62.97; H, 4.56; N, 5.97. $C_{13}H_{11}NO_2S$. Calculated (%): C, 63.67; H, 4.49; N, 5.71.

(Antryl-9)-4-nitrophenylsulfide (5). M.p. 173 °C ($CHCl_3$). R_f 0.42. PMR spectrum (400 MHz, CD_2Cl_2), δ: 6.96 (d, 2 H, J = 9 Hz); 7.54 (m, 4 H); 7.93 (d, 2 H, J = 9 Hz); 8.11 (d, 2 H, J = 9 Hz); 8.61 (d, 2 H, J = 9 Hz); 8.74 (c, 1 H, HC(10)). Mass spectrum, m/z (I(%)): 331 [M^+] (100); 285 [$M-NO_2$] (48); 284 [$M-NO_2-H$] (36); 252 [284—S 43]; 209 (27).

4-Nitrodiphenylsulfide (7). M.p. 53 °C (*cf.* Ref. 10: m.p. 55 °C). R_f 0.49. PMR spectrum (60 MHz, CCl_4), δ: 7.3 (m, 7 H); 7.9 (d, 2 H, J = 9 Hz). Mass spectrum, m/z (I(%)): 231 [M^+] (99); 230 [M−H] (31); 201 [M−NO] (28); 185 [$M-NO_2$] (35); 184 [dibenzothiophene] (100); 152 (dibenzothiophene−S] (20).

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References

1. *Spravochnik rezinschika* [*Rubber Industry Worker's Handbook*], Chemistry, Moscow, 1971 (in Russian).
2. *Vrednie veschestva v promishlennosti* [*Harmful Substances in Industry*], Chemistry, Leningrad, 1976, **2**, 387 (in Russian).
3. E. Kuhle, *Synthesis* , 1971, 617.
4. V. D. Sorokin, I. G. Plokhikh, and M. Y. Berlin, *Dokl. Acad. Nauk*, 1993, **332**, 730 [*Dokl. Chem.*, 1993, **332** (Engl. Transl.)].
5. N. S. Zefirov, N. V. Zyk, A. G. Kutateladze, and Y. A. Lapin, *Zh. Org. Khim.*, 1987, **23**, 392 [*J. Org. Chem. USSR*, 1987, **23** (Engl. Transl.)].
6. N. V. Zyk, Y. A. Lapin, A. G. Kutateladze, and N. S. Zefirov, *Zh. Org. Khim.*, 1989, **25**, 198 [*J. Org. Chem. USSR*, 1989, **25** (Engl. Transl.)].
7. N. S. Zefirov, N. V. Zyk, A. G. Kutateladze, and E. K. Beloglazkina, *Sulfur Reports*, 1993, **14**, 223.
8. D. H. R. Barton, A. A. L. Gunatilaka, and T. Nakanishi, *J. Chem. Soc., Perkin Trans, 1*, 1976, 821.
9. K. Durkin, R. Landler, and N. Morrison, *Can. J. Chem.*, 1987, **66**, 3070.
10. *Svoystva organicheskikh soyedinenii* (*spravochnik*) [*The Properties of Organic Compounds* (*handbook*)], Chemistry, Leningrad, 1984, 209 (in Russian).

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