Remote Oxygen Migration Reaction between Sulfur Atoms in 1,4-Bis(methylthio)benzene Derivatives: Possible Formation of Bis(dithia dication) Dimer as an Intermediate

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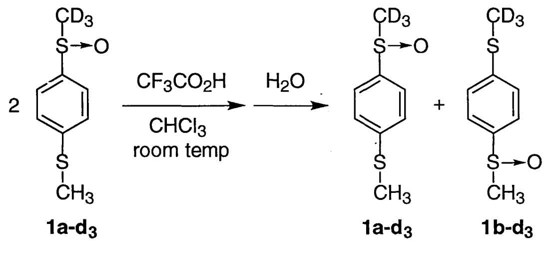
The oxygen migration reaction between sulfur atoms in the monooxide of 1,4-bis(methylthio)benzene proceeds in the presence of CF_3CO_2H. The reaction of 1,4-bis(methylthio)benzene with its bis-sulfoxide also gives the corresponding monooxide at room temperature. A two-point bis(dithia dication) dimer is proposed as an intermediate.

σ-Bonded dithia dications via a transannular (intramolecular) interaction between bifunctional sulfur atoms have attracted considerable attention in heteroatom chemistry.[1] Despite the accumulation of a large body of information about dithia dications, the bond formation by *intermolecular reaction* remains an elusive task,[2,3] because a transannular effect is unavailable.

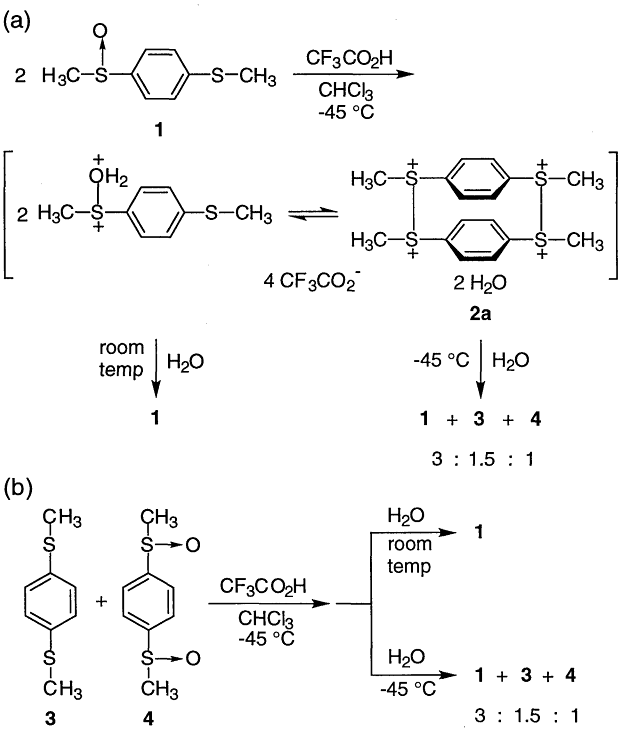
The oxygen exchange and racemization reactions of sulfoxides mediated by strong acids or acid-halide ion combinations have extensively been studied in terms of the mechanistic interest[4] and the selective oxidation of methionine in peptides.[5] The oxygen migration between sulfinyl and sulfenyl groups in close proximity in one molecule proceeds via a dithia dication formed by a transannular interaction.[6] Here we report the *remote* oxygen migration reactions of 1-(methylsulfinyl)-4-(methylthio)benzene (**1**) and the derivatives. The two sulfur atoms in **1**, which are separated intramolecularly not to contact each other, may allow a two-point intermolecular through-space interaction.



Scheme 1.

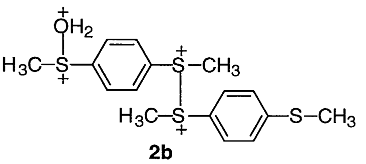
All reactions were carried out in dry $CHCl_3$ or $CDCl_3$. The treatment of 1-(trideuteriomethylsulfinyl)-4-(methylthio)benzene (**1a-d$_3$**) (34 mmol dm^{-3}) with 30 equiv of CF_3CO_2H at room temperature afforded a 1:1 mixture of **1a-d$_3$** and 1-(methylsulfinyl)-4-(trideuteriomethylthio)benzene (**1b-d$_3$**) quantitatively after quenching with H_2O (Scheme 1). In the ^1H NMR spectrum of a mixture of **1** and CF_3CO_2H, the signals due to the methyl protons of sulfinyl and sulfenyl groups (δ 2.71 and 2.52, respectively, for free **1**) are shifted downfield by 0.35 and 0.03 ppm, respectively. This indicates that the oxygen atom of sulfinyl group is protonated. When this reaction was conducted at -45 °C, the ^1H NMR spectrum shows that the protonated **1** almost disappears and instead a new species **2** exhibiting two singlet peaks at δ 3.07 (s, 6H) and 8.02 (s, 4H) appears.[7] The ^{13}C NMR spectrum of **2** shows absorptions at δ 41.4, 125.8, and 144.7. On the basis of the observed NMR data, **2** should have a highly symmetrical structure. There is an equilibrium between **2** and protonated **1**, depending on the reaction temperature. While the concentration of protonated **1** increases with raising the reaction temperature with concomitantly decreasing **2**, that of **2** increases again with decreasing the temperature.

The reaction mixture was quenched with H_2O at room temperature to give only **1**, whereas quenching the reaction mixture containing **2** as the main component at -45 °C quantitatively afforded a mixture of **1**, 1,4-bis(methylthio)benzene (**3**), and 1,4-bis(methylsulfinyl)benzene (**4**) in the ratio of 3:1.5:1 (Scheme 2a). The reaction of ^{18}O-labeled **1-^{18}O** with CF_3CO_2H followed by quenching with H_2O at room temperature gave **1**. This observation implies that an intermolecular reaction takes place and that the oxygen atom of $H_2{}^{18}O$ generated by the cleavage of protonated oxygen-sulfur bond is exchanged with that of CF_3CO_2H. The reaction of **2**, prepared in situ at -45 °C, with 4 equiv of thiophenol gave **3** and diphenyl disulfide via a redox reaction.

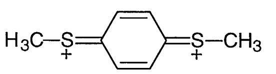


Scheme 2.

As an intermediate **2** in the present remote oxygen migration reaction, a *two-point bis(dithia dication) dimer* **2a**, mono(dithia dication) dimer **2b**, and/or *para*-dithia quinodimethane dication **2c** may be conceivable. Species **2a** and **2b** would be produced by an intermolecular through-space interaction, whereas **2c** would result via a through-bond interaction. The formation of **2b** would be ruled out, because the reaction of **1a-d$_3$** gave a 1:1 mixture of **1a-d$_3$** and **1b-d$_3$** and the NMR spectrum of **2** suggests a highly symmetrical structure (vide supra). In fact, a 1:1 mixture of trideuteriomethyl phenyl sulfoxide and methyl phenyl sulfide under the same conditions did not undergo an oxygen migration at all. The two sulfur atoms in one molecule are undoubtedly essential for the present oxygen migration reactions. The formation of **3** and **4** as well as **1** by the quenching experiment of the reaction mixture at -45 °C also could rule out **2c**. If **2c** occurs at -45 °C, **1** should be the sole product. Thus, a plausible mechanism which could fit all the results described above may involve the formation of bis(dithia dication) dimer **2a**. The double protonations of the oxygen atom of the sulfinyl group followed by the sulfur-oxygen bond breakage due to the nucleophilic attack by the sulfide sulfur atom of the other substrate would produce the intermediate **2a** and two molecules of H_2O. The nucleophilic attack of H_2O on the sulfur atoms of **2a** from the reverse side would give **1**, while the nucleophilic attack from the same side would afford **3** and **4** (Scheme 2a).



2b



2c

Further evidence for the existence of **2a** arises from the reaction of **3** with **4**. In the ^{1}H NMR spectrum of the reaction of a 1:1 mixture of **3** and **4** (17 mmol dm^{-3} each) with 30 equiv of CF_3CO_2H at -45 °C, a similar symmetrical species which shows signals at δ 3.07 (s, 6H) and 8.02 (s, 4H) was observed. Quenching the reaction mixture with H_2O at -45 °C gave a mixture of **1**, **3**, and **4** in the ratio of 3:1.5:1, and quenching at room temperature afforded **1** as the sole product (Scheme 2b). These data are completely consistent with those for the reaction using **1** as a substrate. In the reaction of **3** or **4** alone, the substrate was recovered unchanged, respectively. These results unambiguously indicate that the reaction of **3** with **4** proceeds via the same intermediate as that for the reaction of **1**.

Both 1-(trideuteriomethylsulfinyl)-2-(methylthio)benzene (**5a-d$_3$**) and 1-(trideuteriomethylsulfinyl)-3-(methylthio)benzene (**6a-d$_3$**) also reacted in the presence of CF_3CO_2H to give a 1:1 mixture of the oxygen migration products, respectively.[8] The fact that **6a-d$_3$**, which cannot conjugate via a through-bond interaction, undergoes the oxygen migration reaction supports an intermolecular through-space interaction.

The bis(dithia dication) dimer **2a**, 1,2,9,10-tetramethyl-1,2,9,10-tetrathia[2.2]paracyclophane tetracation, proposed here is very unstable and has not been isolated as yet. The aromatic protons of heteroatom-bridged [2.2]paracyclophanes in the ^{1}H NMR spectra are shifted upfield by 0.18-0.61 ppm relative to the corresponding monomers due to the ring current effect of the benzene ring.[9] On the other hand, those of **2a** are shifted downfield by 0.35 and 0.60 ppm relative to the protonated **1**. It is well known that the aromatic protons linked to dithia dications[1] or sulfonium groups[10] are shifted downfield. Consequently, the cationic character of **2a** would cause a downfield shift of the aromatic protons. The *trans-trans* configuration among the stereoisomers conceivable in **2a** would be most reasonable so as to minimize a steric repulsion between methyl groups.

In summary, we have proposed the two-point bis(dithia dication) dimer **2a** as the intermediate in the remote oxygen migration reaction of 1-(methylsulfinyl)-4-(methylthio)benzene derivatives. The studies for a stabilization of **2a** and an extension of the present reaction to a more remote type of reaction are underway.

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References and Notes

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7 In the ^{1}H NMR spectrum, the singlet peak at δ 3.07 in **2** is overlapping with that of methyl-sulfinyl group in the protonated **1**.

8 The reaction of 1-(ethylsulfinyl)-4-(methylthio)benzene (**7**) gave **7** and 1-(ethylthio)-4-(methylsulfinyl)benzene in the ratio of 3:1.

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