Preparation and Reaction of Phenylsulfonyl-substituted Dizinciomethane

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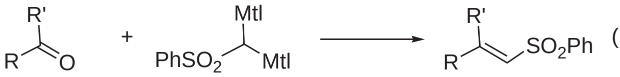
Treatment of dibromomethyl phenyl sulfone with zinc powder in the presence of a catalytic amount of lead in THF afforded phenylsulfonyl-substituted dizinciomethane. The species converts a ketone or aldehyde into an alkenyl sulfone via a Wittig-type olefination reaction with the assistance of β-$TiCl_3$.

Vinyl sulfones have been frequently used as intermediates in organic synthesis, as the highly electron-withdrawing property of sulfonyl group makes the alkenyl moiety highly electrophilic.[1] In addition, the sulfonyl group itself can be converted into various functional groups.[2] Preparation of these sulfones has been performed in various ways; for example, Horner–Emmons reactions of a carbonyl compound and a sulfonyl-substituted phosphonate carbanion,[3a] β-elimination of halosulphones,[3b,3c] hydrozirconation of terminal alkynes followed by reaction with sulfonyl chlorides,[3d] cerium(IV) ammonium nitrate mediated oxidative addition of sulfinate and iodine to alkenes,[3e] and the Mizoroki–Heck reaction of arylboronic acids with phenyl vinyl sulfones[3f] are available. Among them, Horner–Emmons reactions are attractive, as the use of various ketones and aldehydes will give a chance to prepare a variety of vinyl sulfones. However, a lack of nucleophilicity of a stable sulfonyl-substituted phosphonate carbanion creates a limitation to this method. During our course of studies on gem-dizinc species,[4] we found that the species performs Wittig-type olefination reactions under the mediation of titanium salt.[5] Because the reactivity of *gem*-dizinc species, which has a carbon substituted with two electropositive zinc atoms, is much higher than the normal alkylmonozinc, the olefination proceeds to an easily enolizable ketone, such as β-tetralone. Thus, the preparation of sulfone-substituted *gem*-dizinc species may give a useful alternative for the preparation of vinyl sulfones from carbonyl compounds (eq 1).



(1)

Phenylsulfonyldibromomethane (**1**) was prepared from bromoform and sodium phenylsulfinate by a modification of the reported method.[6] Zinc powder[7] (90 mmol) and THF (3.0 mL) was sonicated for 15 min using an ultrasonic cleaner bath under Ar atmosphere. Dibromide (**1**, 30 mmol) in THF (27 mL) was added dropwise over 40 min to the suspension at 0 °C under Ar atomosphere. The exothermic reaction began immediately. After the whole mixture was stirred for 4 h at 25 °C, it was left to stand without stirring. The sedimentation of excess zinc powder gave a pale yellow solution. The supernatant was used as a solution of dizinc species in THF. Treatment of the dizinc solution with 1 M DCl in D_2O gave a mixture of $PhSO_2CD_2H$ and $PhSO_2CDH_2$. Their molar ratio, which was determined by an integration of the ^1H NMR signal at phenyl and methyl group, was 89/11. Figure 1 shows the ^1H NMR spectra of the solution, which was obtained from 2.0 mmol of dibromide, 6.0 mmol of zinc powder, and 4.0 mL of THF-d_8. The complex signal at δ 1.2–2.2 was supposed to be from dizinc reagent **2**, as an addition of acetic acid little by little to the obtained mixture converted the signal into the monozinc species **3** and methyl phenyl sulfone **4**. This result means that the complex signal came from dizinc species **2** (eq 2 and Figure 1). The concentration of **2** was determined by an integration of these complex signals using an internal standard.

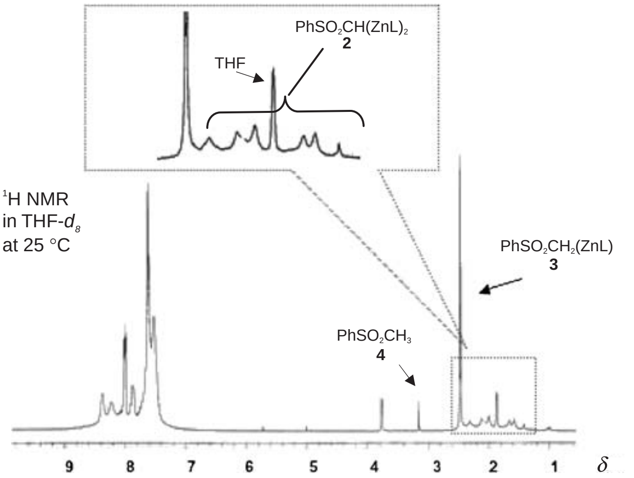
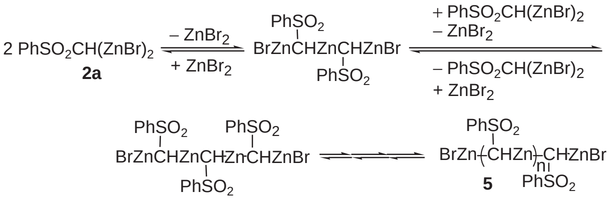


Figure 1. ^1H NMR spectra of the reaction mixture from dibromide **1** (2.0 mmol) and Zn powder (5.0 mmol) in THF-d_8 (4.0 mL) at 25 °C (eq 2).

$$\underset{\textbf{1}}{PhSO_2CHBr_2} \xrightarrow[THF]{Zn\ (Pb)} \underset{\textbf{2a}}{PhSO_2CH(ZnBr)_2} \longrightarrow \underset{\textbf{2}}{PhSO_2CH(ZnL)_2}$$

$$\xrightarrow{CH_3CO_2H} \underset{\textbf{3}}{PhSO_2CH_2(ZnL)} + \underset{\textbf{4}}{PhSO_2CH_3} \quad (2)$$

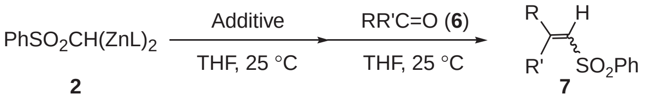
The complex signal of **2** can be rationalized as follows: The initially formed bis(bromozincio)methyl phenyl sulfone (**2a**) will form sulfone-substituted polymethylene zinc species via the Schlenk equilibrium.[8] As the formed oligomeric species **5** includes chiral centers as shown in eq 3, each species would have a number of diastereomers. As a result, the species will show a complex signal.



$$\underset{\textbf{2a}}{2\ PhSO_2CH(ZnBr)_2} \underset{+\,ZnBr_2}{\overset{-\,ZnBr_2}{\rightleftharpoons}} BrZn\overset{PhSO_2}{\underset{PhSO_2}{CHZnCH}}ZnBr \underset{\substack{-\,PhSO_2CH(ZnBr)_2\\+\,ZnBr_2}}{\overset{\substack{+\,PhSO_2CH(ZnBr)_2\\-\,ZnBr_2}}{\rightleftharpoons}}$$

$$BrZn\overset{PhSO_2\quad PhSO_2}{\underset{PhSO_2}{CHZnCHZnCH}}ZnBr \rightleftharpoons \underset{\textbf{5}}{BrZn\overset{PhSO_2}{(CHZn)_n}\underset{PhSO_2}{CH}ZnBr} \quad (3)$$

Table 1. Preparation of vinyl sulfone from carbonyl compounds and dizinc **2** under an assistance of various mediators[a]



Run	RR′C=O (**6**)	**2**/equiv.	Additive/equiv.	**7**/%
1	Cyclohexanone	1.0	β-TiCl$_3$ (1.0)[b]	13 (**7a**)
2		2.0	β-TiCl$_3$ (2.0)	40 (**7a**)
3		4.0	β-TiCl$_3$ (4.0)	59 (**7a**)
4		4.0	β-TiCl$_3$ (4.0), ZnI$_2$ (4.0)	88 (**7a**)
5	PhCHO	4.0	—	0
6		4.0	BF$_3$·OEt$_2$ (2.0)	0
7		4.0	TiCl$_4$ (2.0)	4 (**7b**)[c]
8		4.0	β-TiCl$_3$ (2.0)	56 (**7b**)[c]
9		4.0	β-TiCl$_3$ (4.0), ZnI$_2$ (4.0)	59 (**7b**)[c]
10	3-Phenylpropanal	4.0	β-TiCl$_3$ (4.0), ZnI$_2$ (4.0)	64 (**7c**)[c]
11	*t*-Butyl methyl ketone	4.0	β-TiCl$_3$ (4.0), ZnI$_2$ (4.0)	36 (**7d**)[c]
12	2-Dodecanone	4.0	β-TiCl$_3$ (4.0), ZnI$_2$ (4.0)	54 (**7e**)[d]
13	α-Tetoralone	4.0	β-TiCl$_3$ (4.0), ZnI$_2$ (4.0)	40 (**7f**)[d]

[a]All reactions were examined using 1.0 mmol carbonyl compound **6**. See Ref. 9. [b]β-TiCl$_3$ was prepared from TiCl$_4$ and hexamethyldisilane according to the repoted method. See Ref. 10. [c]Only E isomer was formed diastereoselectively. See Ref. 11. [d]The product was obtained as a mixture of E and Z isomers (ca. 1/1).

A Wittig-type olefination using **2**, which is the typical reaction of a *gem*-dizinc reagent, will transform carbonyl compounds into vinyl sulfones. As shown in Table 1, ketones and aldehydes were treated with dizinc **2** in the presence of various additives. A combination of β-TiCl$_3$ and ZnI$_2$ was effective mediator for this transformation. In our previous report concerning methylenation of ketones using bis(iodozincio)-methane, β-TiCl$_3$ was an effective Lewis acid. In the present system, we also supposed that β-TiCl$_3$ works as an activator of carbonyl compounds. An addition of ZnI$_2$ was expected to be an activator of polymeric reagent **2**. Considering the Schlenk equilibrium, an addition of zinc salt may shift the equilibrium to break up the oligomer. It is notable that a bulky ketone (Run 11) and a highly enolizable ketone (Run 13) were also transformed into the corresponding vinyl sulfones.

The prepared phenylsulfonyl-substituted *gem*-dizinc was a stable reagent, which can be stored as a THF-solution in a sealed bottle for at least a month. It also has a chance to be a new synthetic tool for preparation of organic sulfone compounds.

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7 Pyrometallurgy zinc (Wako Chemical) was used. It contains 0.04–0.07% lead (Pb) originally. A combination of pure zinc powder and catalytic amount of PbCl$_2$ (0.05 mol %) was also possible to be used. See: K. Takai, T. Kakiuchi, Y. Kataoka, K. Utimoto, *J. Org. Chem.* **1994**, *59*, 2668.

8 Bis(iodozincio)methane can be prepared as a monomeric CH$_2$(ZnI)$_2$ in THF solution (ca. 0.5 M). The structure in solution was studied using neutron scattering; See: S. Matsubara, K. Oshima, H. Matsuoka, K. Matsumoto, K. Ishikawa, E. Matsubara, *Chem. Lett.* **2005**, *34*, 952. An attempt to prepare **2a** as the monomeric form under diluted condition also resulted in the formation of the oligomeric form shown in eq 3.

9 To a suspension of β-TiCl$_3$ (4.0 mmol) in THF (4 mL), a solution of dizinc **2** (0.7–0.85 M, 4.0 mmol) and a solution of ZnI$_2$ (4.0 mmol) in THF (3.0 mL) was added successively at 25 °C. After the resulting mixture was stirred for 10 min, carbonyl compound (1.0 mmol) in THF (1.0 mL) was added. The whole was stirred for 4 h. After a typical aqueous work-up, the obtained crude product was purified by silica-gel column chromatography.

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11 **7b**: (^{1}H NMR in CDCl$_3$) δ 7.91–7.97 (m, 2H), 7.69 (d, $J = 15.6$ Hz, 1H), 7.37–7.67 (m, 8H), 6.87 (d, $J = 15.6$ Hz, 1H). **7d**: (^{1}H NMR in CDCl$_3$) δ 7.87–7.95 (m, 2H), 7.4–7.7 (m, 3H), 6.27 (q, $J = 1.2$ Hz, 1H), 2.09 (d, $J = 1.2$ Hz, 3H), 1.07 (s, 9H).

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