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# Rh(II)-Catalyzed Sommelet–Hauser Rearrangement

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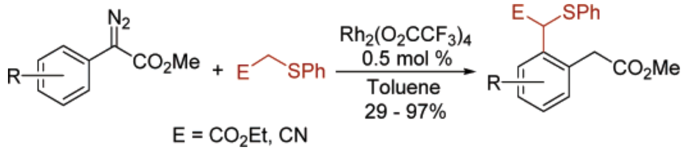
## ABSTRACT



**Catalytic Sommelet–Hauser rearrangement is reported. The Rh(II)-catalyzed reaction of aryldiazoacetates with ethyl benzylthioacetate affords Sommelet–Hauser rearrangement products in good to excellent yields. This reaction provides a reliable and efficient way to introduce a substituent to the ortho position of arylacetates.**

[2,3] sigmatropic rearrangement is one of the most remarkable bond reorganization processes in organic chemistry.[1] Among various types of [2,3] sigmatropic rearrangements, the Sommelet−Hauser reaction of ammonium or sulfonium ylide is an attractive and unique reaction, in which an aromatic unsaturated double bond is involved.[2−6] The [2,3] sigmatropic dearomatization followed by the [1,3] shift rearomatization process is facile with low activation energy. It affords a unique method for the preparation of ortho-substituted aromatic compounds.[5] It also serves as a powerful approach for constructing cyclic quaternary carbon centers from aromatic rings.[6]

The common method for ammonium or sulfonium ylide generation in Sommelet−Hauser rearrangement involves the removal of a proton from the ammonium or sulfonium salt with strong base. An improvement is the application of fluoride ion-induced desilylation of [1-(trimethylsilyl)alkyl]-ammonium or -sulfonium salts, in which the ylide is quantitatively formed at room temperature.[7,8] Besides, the reaction of *N*-[(trialkylstannyl)methyl]benzylammonium salts with organolithium compounds to generate benzylammonium ylides was also reported.[9] However, each of these methods requires prior preparation of the corresponding salts and then use of at least 1 equiv of reagent to generate the ylides.

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(1) For reviews, see: (a) Trost, B. M.; Melvin, L. S., Jr. *Sulfur Ylides*; Academic Press: New York, 1975; Chapter 7. (b) Vedejs, E. *Acc. Chem. Res.* **1984**, *17*, 358.

(2) For seminal publications, see: (a) Sommelet, M. *Compt. Rend.* **1937**, *205*, 56. (b) Kantor, S. W.; Hauser, C. R. *J. Am. Chem. Soc.* **1951**, *73*, 4122. (c) Hauser, C. R.; Kantor, S. W.; Brasen, W. R. *J. Am. Chem. Soc.* **1953**, *75*, 2660.

(3) For recent reviews, see: (a) Marko, I. E. In *Compresive Organic Synthesis*; Trost, B. M., Freming, I., Eds.; Pergamon Press: Oxford, UK, 1991; Vol. 6, p 913. (b) Beall, L. S.; Padwa, A. *Adv. Nitrogen Heterocycl.* **1998**, *3*, 117−158. (c) Clark, J. S. *Nitrogen, Oxygen, Sulfur Ylide Chem.* **2002**, 1−113.

(4) For most recent examples, see: (a) Hanessian, S.; Talbot, C.; Saravanan, P. *Synthesis* **2006**, 723. (b) Tayama, E.; Kimura, H. *Angew. Chem., Int. Ed.* **2007**, *46*, 8869.

(5) (a) Robert, A.; Thomas, M. T.; Foucaud, A. *J. Chem. Soc., Chem. Commun.* 1**979**, 1048. (b) Jończyk, A.; Lipiak, D. *J. Org. Chem.* **1991**, *56*, 6933. (c) Ishibashi, H.; Tabata, T.; Kobayashi, T.; Takamuro, I.; Ikeda, M. *Chem. Pharm. Bull.* **1991**, *39*, 2878.

(6) (a) Hauser, C. R.; Van Eenam, D. N. *J. Am. Chem. Soc.* **1957**, *79*, 5512. (b) Van Eenam, D. N.; Hauser, C. R. *J. Am. Chem. Soc.* **1957**, *79*, 5520. (c) Hauser, C. R.; Van Eenam, D. N.; Bayless, P. L. *J. Org. Chem.* **1958**, *23*, 354. (d) Shirai, N.; Sumiyama, F.; Sato, Y.; Hori, M. *J. Org. Chem.* **1989**, *54*, 836. (e) Berger, R.; Ziller, J. W.; Van Vranken, D. L. *J. Am. Chem. Soc*. **1998**, *120*, 841. (f) McComas, C. C.; Van Vranken, D. L. *Tetrahedron Lett.* **2003**, *44*, 8203.

(7) Vedejs, E.; West, F. G. *Chem. Rev.* **1986**, *86*, 941.

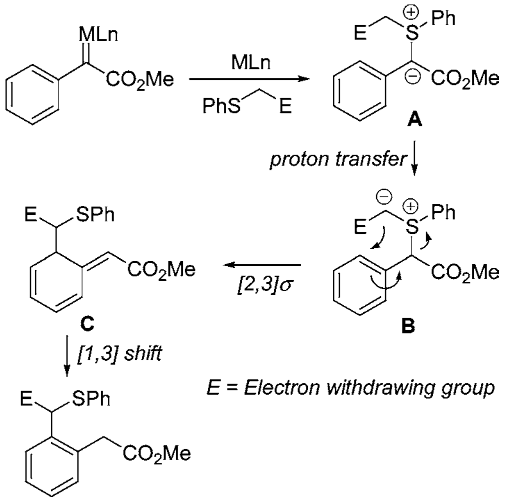
(8) (a) Nakano, M.; Sato, Y. *J. Org. Chem.* **1987**, *52*, 1844. (b) Shirai, N.; Sato, Y. *J. Org. Chem.* **1988**, *53*, 194. (c) Shirai, N.; Watanabe, Y.; Sato, Y. *J. Org. Chem.* **1990**, *55*, 2767. (d) Sato, Y.; Shirai, N.; Machida, Y.; Ito, E.; Yasui, T.; Kurono, Y.; Hatano, K. *J. Org. Chem.* **1992**, *57*, 6711. (e) Maeda, Y.; Shirai, N.; Sato, Y.; Tatewaki, H. *J. Org. Chem.* **1994**, *59*, 7897. (f) Tanzawa, T.; Ichioka, M.; Shirai, N.; Sato, Y. *J. Chem. Soc., Perkin Trans. 1* **1995**, 431. (g) Tanzawa, T.; Shirai, N.; Sato, Y.; Hatano, K.; Kurono, Y. *J. Chem. Soc., Perkin Trans. 1* **1995**, 2845.

(9) Maeda, Y.; Sato, Y. *J. Org. Chem.* **1996**, *61*, 5188.

10.1021/ol703058p CCC: $40.75

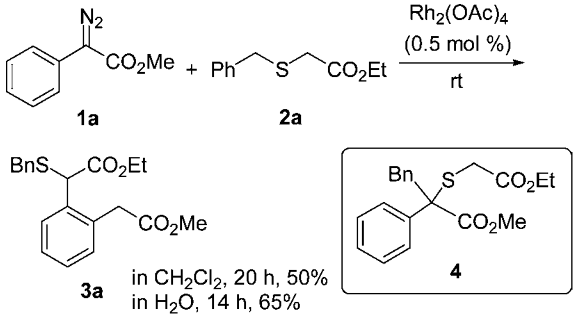
On the other hand, transition metal-catalyzed reactions of diazo compounds in the presence of sulfides or amines have been developed into an efficient way to generate sulfonium or ammonium ylides.[10] This approach has been extensively investigated by several groups in sulfur ylide [1,2] shift and [2,3] sigmatropic rearrangement.[11,12] It has also been applied by Aggarwal and co-workers in epoxidation and cyclopropanation reactions.[13] However, this catalytic process so far has not been utilized for Sommelet−Hauser rearrangement, except in one case in which $Rh_2(OAc)_4$-catalyzed thia-Sommelet−Hauser rearrangement has been reported as a side reaction.[14] Here we report a catalytic thia-Sommelet−Hauser rearrangement of sulfonium ylides. The ylide is derived from sulfide and Rh(II) carbene, which is generated from the Rh(II)-catalyzed reaction of α-diazocarbonyl compounds (Scheme 1). The initially formed sulfur ylide **A** subsequently undergoes tautomerization to generate ylide **B**, which is required for Sommelet−Hauser rearrangement.

**Scheme 1.** Thia-Sommelet−Hauser Rearrangement under Transition Metal-Catalyzed Conditions



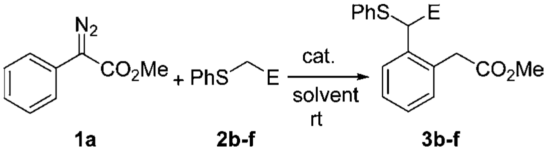
At the outset of this investigation, we examined the reaction of methyl phenyldiazoacetate **1a** and ethyl benzylthioacetate **2a** with transition metal catalysts (Scheme 2).

**Scheme 2.** $Rh_2(OAc)_4$-Catalyzed Reaction of **1a** and **2a**



When **1a** and **2a** were catalyzed with $Rh_2(OAc)_4$ in $CH_2Cl_2$ at room temperature, thia-Sommelet−Hauser rearrangement product **3a** was isolated in 50% yield. The reaction also occurred in $H_2O$ with 65% isolated yield. It was worth noting that no product **4**, which might be formed from competing [1,2] shift of the benzyl group (Stevens rearrangement),[15] could be detected in this reaction. This indicates proton transfer and the subsequent [2,3] sigmatropic rearrangements are faster than the [1,2] shift, which has been suggested as a radical process.[16]

**Table 1.** The Reaction of **1a** and Sulfides **2b**−**f** under Various Conditions[a]



| entry | sulfide (**2**, E) | catalyst | solvent | time | yield (%)[b] |
|---|---|---|---|---|---|
| 1 | **2b**, $CO_2Et$ | $Rh_2(OAc)_4$ | $CH_2Cl_2$ | 2.5 h | 51 |
| 2 | **2b**, $CO_2Et$ | $Rh_2(OAc)_4$ | toluene | 2 h | 67 |
| 3 | **2b**, $CO_2Et$ | $Rh_2(OAc)_4$ | *n*-hexane | 24 h | 65 |
| 4 | **2b**, $CO_2Et$ | $Rh_2(OAc)_4$ | $H_2O$ | 1 h | 54 |
| 5 | **2b**, $CO_2Et$ | $Cu(CH_3CN)_4PF_6$[c] | $CH_2Cl_2$ | 16 h | trace |
| 6[d] | **2b**, $CO_2Et$ | $Rh_2(acam)_4$ | toluene | 1.5 h | 64 |
| 7 | **2b**, $CO_2Et$ | $Rh_2(O_2CCF_3)_4$ | toluene | 0.5 h | 87 |
| 8 | **2b**, $CO_2Et$ | $Rh_2(O_2CCF_3)_4$ | *n*-hexane | 40 min | 70 |
| 9 | **2b**, $CO_2Et$ | $Rh_2(O_2CC_3F_7)_4$ | toluene | 0.5 h | 76 |
| 10 | **2b**, $CO_2Et$ | $Rh_2(O_2CC_7H_{15})_4$ | toluene | 2 h | 78 |
| 11 | **2b**, $CO_2Et$ | $Rh_2(S\text{-DOSP})_4$[e] | toluene | 4.5 h | 74[f] |
| 12 | **2c**, CN | $Rh_2(O_2CCF_3)_4$ | toluene | 3.5 h | 56 |
| 13 | **2d**, $NO_2$ | $Rh_2(O_2CCF_3)_4$ | toluene | 24 h | *g* |
| 14 | **2e**, *p*-$NO_2C_6H_4$ | $Rh_2(O_2CCF_3)_4$ | toluene | 0.5 h | *h* |
| 15 | **2f**, *n*-Pr | $Rh_2(OAc)_4$ | toluene | 22 h | *i* |

[a] Unless otherwise noted, reaction conditions are as follows: **1a** (0.2 mmol), **2b**−**f** (0.3 mmol), 0.5 mol % catalyst, 5 mL of solvent. [b] Isolated yields after column chromatography. [c] 10% mol catalyst was used. [d] The reaction was carried out at 80 °C. [e] $Rh_2(S\text{-DOSP})_4$: tetrakis {1-[(4-alkyl($C_{11}-C_{13}$)phenyl)sulfonyl]-(2*S*)-pyrrolidinecarboxylate}dirhodium. [f] The reaction gave a racemic product. [g] The reaction was carried out at 80 °C and no reaction occurred. [h] The reaction gave [1,2]-shift product in 54% isolated yield. [i] No reaction occurred.

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(10) For reviews, see: (a) Ye, T.; McKervey, M. A. *Chem. Rev.* **1994**, *94*, 1091. (b) Doyle, M. P.; McKervey, M. A.; Ye, T. *Modern Catalytic Methods for Organic Synthesis with Diazo Compounds*; Wiley-Interscience: New York, 1998. (c) Li, A.-H.; Dai, L.-X.; Aggarwal, V. K. *Chem. Rev.* 1**997**, *97*, 2341. (d) Doyle, M. P.; Forbes, D. C. *Chem. Rev.* **1998**, *98*, 911. (e) Hodgson, O. M.; Pierard, F. Y. T. M.; Stupple, P. A. *Chem. Soc. Rev.* **2001**, *30*, 50.

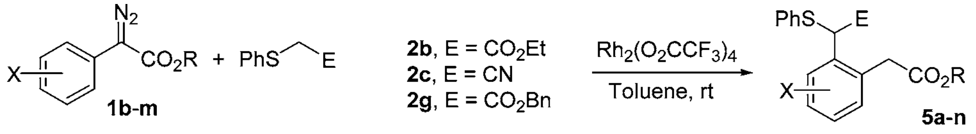
(11) For recent reports on transition metal-catalyzed sulfur ylide [1,2] shift, see: (a) Nair, V.; Nair, S. M.; Mathai, S.; Liebscher, J.; Ziemer, B.; Narsimulu, K. *Tetrahedron Lett.* **2004**, *45*, 5759. (b) Ellis-Holder, K. K.; Peppers, B. P.; Kovalevsky, A. Y.; Diver, S. T. *Org. Lett.* **2006**, *8*, 2511. (c) Stepakov, A. V.; Molchanov, A. P.; Magull, J.; Vidovic, D.; Starova, G. L.; Kopfc, J.; Kostikov, R. R. *Tetrahedron* **2006**, *62*, 3610.

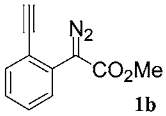
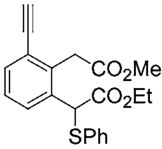
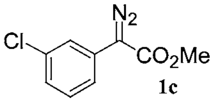
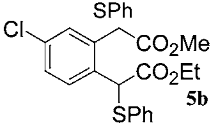
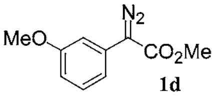
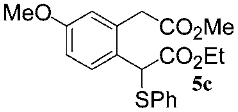
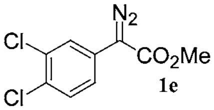
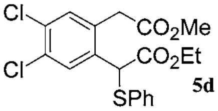
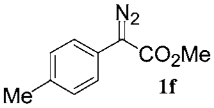
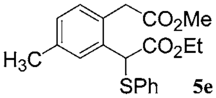
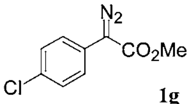
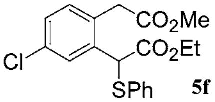
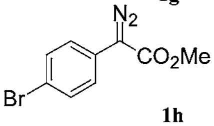
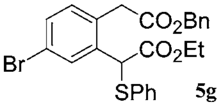
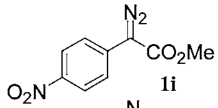
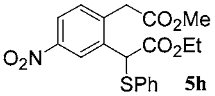
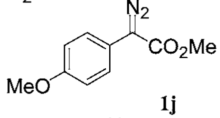
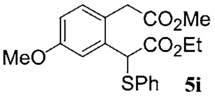
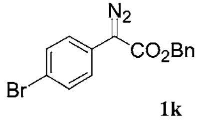
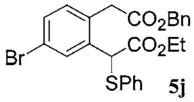
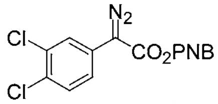
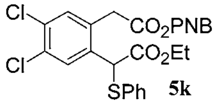
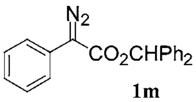
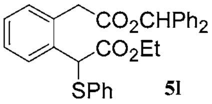
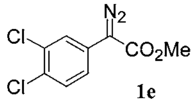
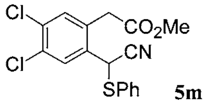
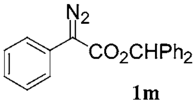
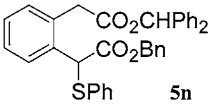
(12) For selected recent reports on transition metal-catalyzed sulfur ylide [2,3] sigmatropic rearrangement, see: (a) Novikov, A. V.; Kennedy, A. R.; Rainier, J. D. *J. Org. Chem.* **2003**, *68*, 993. (b) Nyong, A. M.; Rainier, J. D. *J. Org. Chem.* **2005**, *70*, 746. (c) Ma, M.; Peng, L.; Li, C.; Zhang, X.; Wang, J. *J. Am. Chem. Soc.* **2005**, *127*, 15016. (d) Liao, M.; Wang, J. *Green Chem.* **2007**, *9*, 184.

(13) For reviews, see: (a) Aggarwal, V. K.; Winn, C. L. *Acc. Chem. Res.* **2004**, *37*, 611. (b) Fulton, J. R.; Aggarwal, V. K.; Vicente, J. D. *Eur. J. Org. Chem.* **2005**, 1479.

(14) Aggarwal, V. K.; Smith, H. W.; Hynd, G.; Jones, R. V. H.; Fieldhouse, R.; Spey, S. E. *J. Chem. Soc., Perkin Trans. 1* **2000**, 3267.

**Table 2.** Reaction of Diazo Compounds **1b−m** with Sulfides **2b**,**c**,**g**[a]



| entry | diazo substrate 1 | product 5 | time | yield (%)[b] |
|---|---|---|---|---|
| 1 |  **1b** |  **5a** | 1 h | 38 |
| 2 |  **1c** |  **5b** | 3 h | 75 |
| 3 |  **1d** |  **5c** | 1 h | 75 |
| 4 |  **1e** |  **5d** | 4 h | 77 |
| 5 |  **1f** |  **5e** | 18 min | 75 |
| 6 |  **1g** |  **5f** | 30 min | 82 |
| 7 |  **1h** |  **5g** | 5 h | 97 |
| 8[c] |  **1i** |  **5h** | 30 min | 78 |
| 9 |  **1j** |  **5i** | 1 min | 29 |
| 10 |  **1k** |  **5j** | 4 h | 90 |
| 11 |  **1l** |  **5k** | 16 h | 56<br>(79)[d] |
| 12 |  **1m** |  **5l** | 5 h | 81 |
| 13 |  **1e** |  **5m** | 17 h | 55 |
| 14 |  **1m** |  **5n** | 4 h | 70 |

[a] Reaction conditions: diazo compound (0.2 mmol), sulfide (0.3 mmol), 0.5 mol % $Rh_2(O_2CCF_3)_4$, 5 mL of toluene. [b] Isolated yields after column chromatography. [c] The reaction was carried out at 60 °C. [d] The data in parentheses refer to the conversion yield. PNB: *p*-$NO_2C_6H_4CH_2$−.

Further investigation by altering reaction parameters (solvent, sulfide, and catalyst) reveals some interesting aspects about this reaction (Table 1). First, the reaction could be carried out in various solvents to afford the product in similar yields, but the reaction time varied. Second, polar solvent was found to accelerate the reaction (entries 1−4). Third, the reaction was affected by catalysts. $Cu(CH_3CN)_4PF_6$ was found not to be effective (entry 5). Among the Rh(II) catalysts, $Rh_2(O_2CCF_3)_4$ afforded the optimal result (entry 7). The reaction with chiral Rh(II) complex $Rh_2$(*S*-DOSP)$_4$[17] gave the rearrangement product in good yield, but with essentially no asymmetric induction (entry 11). Finally, the effect of sulfides was investigated. Compared with the benzylthioacetate **2a**, the reaction time with phenylthioacetate **2b** was significantly shortened. The ester group could be replaced with the cyano group (entry 12). Alternatively, when the ester group of **1a** was replaced by a nitro group, no reaction occurred even at elevated temperature (entry 13). The reaction with phenyl *p*-nitrobenzyl sulfide **2e**, on the other hand, gave the [1,2] shift product in 54% yield (entry 14). No reaction occurred with *n*-propylphenyl sulfide **2f**. This indicates the requirement of electron-withdrawing substituents in sulfides for this reaction.

Subsequently, the optimized reaction conditions were applied to a series of aryldiazoacetates **1b−m**[18] and sulfides **2b**,**c**,**g** (Table 2). For ortho-substituted diazo compounds, we expected that the reaction should occur at another ortho position. However, the reactions of *o*-methyl-, *o*-chloro-, or

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(15) For a recent study about competition between [1,2] Stevens and [2,3] Sommelet−Hauser rearrangement, see: Jończyk, A.; Lipiak, D.; Sienkiewicz, K. *Synlett* **1991**, 493.

(16) (a) Ollis, W. D.; Rey, M.; Sutherland, I. O. *J. Chem. Soc., Perkin Trans. 1* **1983**, 1009. (b) Eberlein, T. H.; West, F. G.; Tester, R. W. *J. Org. Chem.* **1992**, *57*, 3479.

(17) (a) Davies, H. M. L.; Hutcheson, D. K. *Tetrahedron Lett.* **1993**, *34*, 7243. (b) Davies, H. M. L.; Bruzinski, P. R.; Lake, D. H.; Kong, N.; Fall, M. J. *J. Am. Chem. Soc.* **1996**, *118*, 6897.

(18) Qu, Z.; Shi, W.; Wang, J. *J. Org. Chem.* **2001**, *66*, 8139.

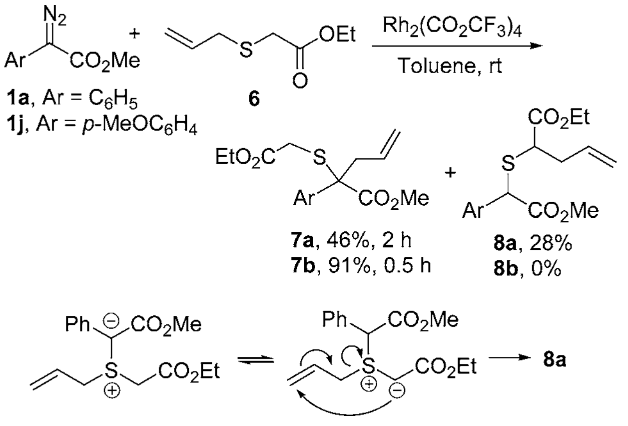
*o*,*p*-dichloro-substituted diazo compounds only gave a complex mixture. When the ortho substituent was ethynyl, the reaction worked, but afforded the corresponding product in low yield (entry 1).

For meta-substituted diazo compounds, the reaction may give two products since there are two discriminative ortho positions. To our delight, the reaction afforded only one product in good yield (entries 2 and 3). The reaction occurred at the less sterically hindered ortho position.[19] This result may indicate [2,3] sigmatropic rearrangement is sensitive to the steric effect of the aromatic substituents.[20] For para-substituted diazo compounds, the reactions proceeded smoothly and afforded the corresponding products in high yields when the substituents were *p*-Me, *p*-Cl, *p*-Br, and *p*-NO$_2$ (entries 5−8). When the substituent was *p*-MeO, the diazo substrate disappeared rapidly, but the expected product was isolated in low yield (entry 9). This might be attributed to the high reactivity of the *p*-MeO-substituted diazo compound, thus resulting in side reactions. In comparison, the reaction with *p*-NO$_2$-substituted sulfide proceeded sluggishly and required higher temperature (60 °C) (entry 8).

In further experiments, it was found that increasing the bulk of the ester group of the diazo substrates resulted in longer reaction time, but the yields were comparable to those of other substrates (entires 10−12). Finally, reactions with phenylthioacetonitrile **2c** and benzyl phenylthioacetate **2g** were also found to proceed well (entries 13 and 14).

To further explore the scope of this catalytic process, we examined the reactions with allylthioacetate **6** (Scheme 3).

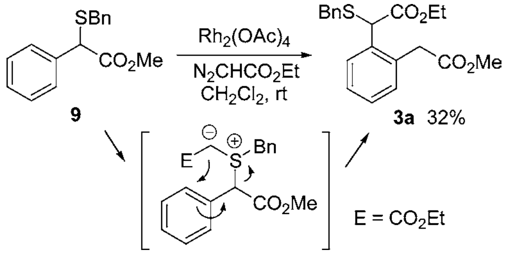
**Scheme 3.** Rh(II)-Catalyzed Reaction of **1a**,**j** and **6**



In these cases, the [2,3] sigmatropic rearrangement of the intially generated sulfur ylide would compete with the proton transfer-Sommelet−Hauser rearrangement process. In the reaction with methyl phenyldiazoacetate **1a**, direct [2,3] sigmatropic rearrangement product **7a** was isolated in 46% yield, together with a diastereomeric mixture of **8a** (28%). **8a** presumably results from the proton transfer and subsequent [2,3] sigmatropic rearrangement of the allyl group as shown in Scheme 3. The reaction with methyl *p*-methoxyphenyldiazoacetate **1j**, however, afforded the direct [2,3] sigmatropic rearrangement product **7b** in 91% yield without detectable formation of **8b**. These results indicate that sulfur [2,3] sigmatropic rearrangement is a very facile process.[1,12]

Finally, we conceived that the key intermediate ylide **B** in Scheme 1 could also be generated directly by the transition metal-catalyzed reaction of ethyl diazoacetate with sulfide **9** (Scheme 4). Thus, ethyl diazoacetate (EDA) and sulfide **9** were subjected to the reaction in the presence of Rh$_2$(OAc)$_4$. In this case the sulfur ylide intermediate corresponding to **B** in Scheme 1 should be formed directly and then underwent Sommelet−Hauser rearrangement to afford **3a**. As expected, thia-Sommelet−Hauser rearrangement product **3a** was obtained, albeit in low yield (32%). The generally good yields obtaind with aryldiazoacetates in this Rh(II)-catalyzed process are a further demonstration of balanced reactivity and selectivity of donor/acceptor-susbstituted metal carbenes derived from these diazo compounds.[21]

**Scheme 4.** Rh$_2$(OAc)$_4$-Catalyzed Reaction of **9** with EDA



In conclusion, we have reported the catalytic Sommelet−Hauser rearrangement of sulfonium ylides derived from Rh(II) carbenes and sulfides. The reaction can be carried out under essentially neutral condition at room temperature. A variety of aryldiazoacetates and sulfides are suitable substrates for this reaction and the corresponding products are obtained in good to excellent yields, thus providing an effective and unique method for preparing ortho-substituted aromatic compounds.[22]

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**Supporting Information Available:** Experiment procedure, characterization data, X-ray structure of sulfone, and $^1$H and $^{13}$C NMR spectra for all new compounds. This material is available free of charge via the Internet at http://pubs.acs.org.

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(19) To unambiguously establish the structure of product, **5d** was converted to the corresponding sulfone, which was analyzed by X-ray crystallography, see the Supporting Information.

(20) Similar selectivity has been recently reported in the ammonium ylide Sommelet−Hauser rearrangement, see ref 4b.

(21) (a) Davies, H. M. L.; Bruzinski, P. R.; Fall, M. J. *Tetrahedron Lett.* **1996**, *37*, 4133. (b) Davies, H. M. L.; Beckwith, R. E. J. *Chem. Rev.* **2003**, *103*, 2861.

(22) For a recent review, see: Smith, K.; El-Hiti, G. A. *Curr. Org. Synth.* **2004**, *1*, 253.