Novel asymmetric catalytic synthesis of sulfimides

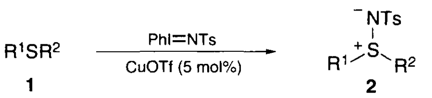
Hiroya Takada, Yoshiaki Nishibayashi, Kouichi Ohe and Sakae Uemura*†

Department of Energy and Hydrocarbon Chemistry, Graduate School of Engineering, Kyoto University, Sakyo-ku, Kyoto 606-01, Japan

Prochiral sulfides react with PhI=NTs in the presence of a catalytic amount of $\mathrm{Cu^I}$ salt together with chiral 4,4'-disubstituted bis(oxazoline) ligands to afford the corresponding chiral sulfimides.

Recently the sodium salts of chiral sulfimides have been demonstrated as asymmetric methylidene transfer reagents to prochiral carbonyl groups, leading to optically active epoxides.[1] Despite the fact that other optically active organosulfur compounds such as sulfonium ylides[2,3,4] and sulfoxides[5] have many asymmetric synthetic applications, the chemistry of their nitrogen analogues, sulfimides,[6] has been much less investigated. The synthesis of chiral sulfimides has long been limited to the following two procedures; the conversion of the enantiomerically pure sulfoxides into the corresponding sulfimides by Cram *et al.*[7] and the kinetic resolution of racemic sulfimides by Annunziata *et al.*[8] Recently, Evans *et al.* have reported that PhI=NTs is an effective asymmetric nitrene transfer reagent to alkenes in the presence of a catalytic amount of $\mathrm{Cu^I}$ salt together with a chiral 4,4'-disubstituted bis(oxazoline) ligand.[9] We aimed to find a new synthesis of chiral sulfimides by application of this methodology.

Our initial attempts were to explore and exploit a new imidation of sulfides **1** with PhI=NTs[10] using $\mathrm{Cu^I}$ salt as catalyst, eqn. (1).[11] The synthesis of sulfimides was carried out by treatment of suitable sulfides with 1 equiv. PhI=NTs in MeCN in the presence of 5 mol% of $\mathrm{Cu^I}$ triflate (CuOTf). Representative results are summarized in Table 1. Treatment of methyl *p*-tolyl sulfide with PhI=NTs at 25 °C for 26 h afforded the corresponding sulfimide **2a** in 83% isolated yield (entry 1). A variety of sulfides, even those having an electron-withdrawing moiety, could be converted smoothly to the corresponding sulfimides (entries 2–9).



$$\underset{\mathbf{1}}{\mathrm{R^1SR^2}} \xrightarrow[\text{CuOTf (5 mol\%)}]{\text{PhI=NTs}} \underset{\mathbf{2}}{\mathrm{R^1}\overset{^{-}\mathrm{NTs}}{\overset{|}{\mathrm{S}^{+}}}\mathrm{R^2}} \qquad (1)$$

When the reaction was applied to allylic sulfides **3**, aziridination[11] to the double bond did not occur and, instead, allylic sulfenamides were obtained selectively in good yields, Table 2. This fact shows that nitrogen attack occurs only at the sulfur atom to give **4** as an intermediate and the [2,3]-sigmatropic rearrangement follows, Scheme 1.[12]

Table 1 Catalytic synthesis of sulfimides **2**[a]

Entry	$\mathrm{R^1}$	$\mathrm{R^2}$	Product **2**	Yield (%)
1[b]	*p*-Tol	Me	**a**	83
2	$\mathrm{EtO_2CCH_2}$	Me	**b**	53
3[c]	Et	Me	**c**	50
4[b]	Ph	Ph	**d**	79
5	Ph	Bn	**e**	82
6[b]	$\mathrm{PhCH_2CH_2}$	Bn	**f**	50
7	$\mathrm{4\text{-}MeOC_6H_4}$	Bn	**g**	70
8	1-Nap	Bn	**h**	54
9	$\mathrm{4\text{-}NO_2C_6H_4CH_2}$	Ph	**i**	72

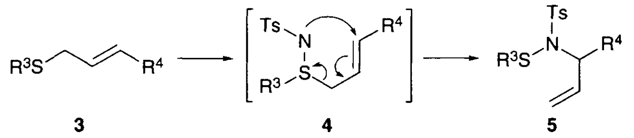
[a] All the reactions were carried out in acetonitrile with 1.0 equiv. (to PhI=NTs) of sulfide in the presence of 5 mol% $\mathrm{Cu^I}$ catalyst at 25 °C for 48 h unless otherwise noted.[b] For 26 h. [c] For 28 h.

We then applied this methodology to asymmetric synthesis of sulfimides **2** using optically active 4,4'-disubstituted bis(oxazolines) **6a–c** as chiral ligands, Table 3.† For example, in the imidation of benzyl phenyl sulfide, an optimum ee was obtained

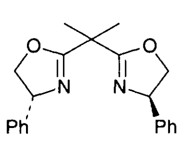
Table 2 Catalytic synthesis of sulfenamides **5**[a]

Entry	$\mathrm{R^3}$	$\mathrm{R^4}$	Product	Yield (%)
1	Me	H	**5j**	78
2	Allyl	H	**5k**	82
3	Ph	Ph	**5l**	75

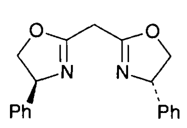
[a] All the reactions were carried out in acetonitrile with 1.0 equiv. (to PhI=NTs) of sulfide in the presence of 5 mol% $\mathrm{Cu^I}$ catalyst at 25 °C for 48 h.



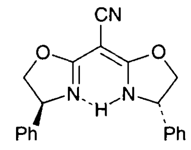
Scheme 1



6a



6b



6c

Table 3 Asymmetric catalytic synthesis of sulfimides[a]

Entry	Sulfide	Chiral ligand **6**	Product	Yield (%)	ee (%)[b]
1	*p*-TolSMe	**a**	**2a**	82	13
2	PhSBn	**a**	**2e**	78	64
3[c]	PhSBn	**a**	**2e**	62	65
4[c]	PhSBn	**b**	**2e**	69	3
5[c]	PhSBn	**c**	**2e**	51	55
6	$\mathrm{PhCH_2\text{-}CH_2SBn}$	**a**	**2f**	63	22[d]
7	$\mathrm{4\text{-}MeOC_6H_4\text{-}SBn}$	**a**	**2g**	72	9
8	1-NapSBn	**a**	**2h**	75	71
9	$\mathrm{4\text{-}NO_2C_6H_4\text{-}CH_2SPh}$	**a**	**2i**	37	25
10	$\mathrm{PhSCH_2CH{=}CHPh}$	**a**	**5l**	40	27[e]

[a] All the reactions were performed in toluene (0.2 mol $\mathrm{dm^{-3}}$) in the presence of 6 mol% chiral ligand and 5 mol% CuOTf at 25 °C for 48 h unless otherwise noted. [b] Determined by HPLC using suitable chiral columns. [c] At 0 °C for 66 h. [d] Determined by ^{1}H NMR analysis (270 MHz) in the presence of $\mathrm{Eu(hfc)_3}$. [e] After product **5l** was converted to the corresponding amine by treatment with NaOH in MeOH, the ee was determined by HPLC using a suitable chiral column.

when the reaction was carried out using **6a** as ligand in toluene (65% ee, 0 °C). Meanwhile, in MeCN and CH_2Cl_2, the optical yields were lower; 12 and 35% ee, respectively. It is noteworthy that the reaction proceeded smoothly even at room temperature without any decrease of the enantioselectivity. Furthermore, in the case of cinnamyl phenyl sulfide, the corresponding chiral allylic amide **5l** was obtained, showing that the chirality transfer occurred during the [2,3]-sigmatropic rearrangement of the intermediate chiral allylic sulfimide **4l**.[13]

Footnotes

† E-mail: uemura@ scl. kyoto-u.ac.jp

‡ Representative experimental procedure for the sulfide imidation: To a solution of CuOTf (0.010 mmol, 0.050 equiv) and 4,4'-disubstituted bis(oxazoline) **6** (0.012 mmol, 0.060 equiv, Aldrich) in toluene (1.0 ml) were added PhI=NTs (0.20 mmol, 1.0 equiv) followed by the sulfide (0.20 mmol, 1.0 equiv). The resulting mixture was stirred under nitrogen at 0 or 25 °C for the appropriate time as shown in Table 3. Water was then added and the mixture extracted with diethyl ether, dried (anhydrous $MgSO_4$) and then evaporated to give the crude product. Purification by silica gel column chromatography (hexane–diethyl ether = 1:4) gave the pure chiral sulfimide.

References

1 C. P. Baird and P. C. Taylor, *J. Chem. Soc., Chem. Commun.*, 1995, 893.

2 N. Furukawa, Y. Sugihara and H. Fujihara, *J. Org. Chem.*, 1989, **54**, 4222; L. Breau, W. W. Ogilvie and T. Durst, *Tetrahedron Lett.*, 1990, **31**, 35; A. Solladié-Cavallo and A. Adib, *Tetrahedron*, 1992, **48**, 2453; V. K. Aggarwal, H. Abdel-Rahman, R. V. H. Jones, H. Y. Lee and B. D. Reid, *J. Am. Chem. Soc.*, 1994, **116**, 5973.

3 L. Breau and T. Durst, *Tetrahedron: Asymmetry*, 1991, **2**, 367.

4 Y. Nishibayashi, K. Ohe and S. Uemura, *J. Chem. Soc., Chem. Commun.*, 1995, 1245.

5 For example, J. Brunel, P. Diter, M. Deutsch and H. B. Kagan, *J. Org. Chem.*, 1995, **60**, 8086 and references cited therein.

6 I. V. Koval, *Russ. Chem. Rev.*, 1990, **59**, 819; C. R. Johnson, in *Comprehensive Organic Chemistry*, ed. D. H. R. Barton and W. D. Ollis, Pergamon, 1979, vol. 3, section 11.10; T. L. Gilchrist and C. J. Moody, *Chem. Rev.*, 1977, **77**, 409.

7 D. J. Cram, J. Day, D. R. Rayner, D. M. von Schriltz, D. J. Duchamp and D. C. Garwood, *J. Am. Chem. Soc.*, 1970, **92**, 7369.

8 R. Annunziata, M. Cinquini, S. Colonna and F. Cozzi, *J. Chem. Soc., Perkin Trans. 1*, 1981, 3118.

9 D. A. Evans, M. M. Faul, M. T. Bilodeau, B. A. Anderson and D. M. Barnes, *J. Am. Chem. Soc.*, 1993, **115**, 5328.

10 Y. Yamada, T. Yamamoto and M. Okawara, *Chem. Lett.*, 1975, 361.

11 D. A. Evans, M. M. Faul and M. T. Bilodeau, *J. Org. Chem.*, 1991, **56**, 6744.

12 A. S. F. Ash, F. Challenger and D. Greenwood, *J. Chem. Soc.*, 1951, 1877; A. S. F. Ash, F. Challenger, T. S. Stevens and J. L. Dunn, *J. Chem. Soc.*, 1952, 2792; P. A. Briscoe, F. Challenger and P. S. Duckworth, *J. Chem. Soc.*, 1956, 1755; M. Kakimoto, T. Yamamoto and M. Okawara, *Tetrahedron Lett.*, 1979, 623.

13 Similar phenomena have been observed in chiral selenimides and tellurimides: Y. Nishibayashi, T. Chiba, K.Ohe and S. Uemura, *J. Chem. Soc., Chem. Commun.*, 1995, 1243; Y. Nishibayashi, S. K. Srivastava, K. Ohe and S. Uemura, *Tetrahedron Lett.*, 1995, **36**, 6725.

Received, 2nd January 1996; Com. 6/00045B