Enantioface-differentiating Reactions Using (2*S*,2′*S*)-2-Hydroxymethyl-1-[(1-alkyl-2-pyrrolidinyl)methyl]pyrrolidines as Chiral Ligands. Addition of Lithium Derivatives of Methyl Phenyl Sulfide, Acetonitrile, *N*-Nitrosodimethylamine, and 2-Methylthiothiazoline to Aldehydes

Kenso Soai and Teruaki Mukaiyama*

Department of Chemistry, Faculty of Science, The University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113

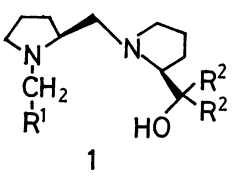
(Received May 2, 1979)

Optically active oxiranes, β-hydroxy nitrile, β-hydroxy *N*-nitrosoamine, and thiirane were obtained (up to 72% optical purity) by the enantioface-differentiating addition of lithium derivatives of methyl phenyl sulfide, acetonitrile, *N*-nitrosodimethylamine, and 2-methylthiothiazoline to aldehydes using (2*S*,2′*S*)-2-hydroxymethyl-1-[(1-alkyl-2-pyrrolidinyl)methyl]pyrrolidines (**1a**—**f**) as chiral ligands. Optical purity of the products depended greatly on the reaction medium (dimethoxymethane or dimethyl ether gave the best results) and the structure of pyrrolidine moieties of **1a**—**f**.)

One of the current interests in organic chemistry is asymmetric syntheses, and recently there have been many investigations reported on various types of asymmetric synthesis.[1] Among these, *enantioselective* reactions are one of the most difficult problems.

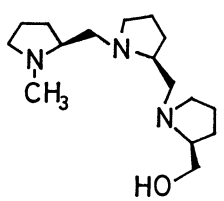
Concerning the enantioselective asymmetric reactions of organolithium compounds, several reports have been given on asymmetric reductions using metal hydride complexes.[2] However, on the *enantioselective* addition of organolithium compounds to aldehydes, very few investigations have been reported.[3] Recently, (+)-2,3-dimethoxy-*N*,*N*,*N*′,*N*′-tetramethyl-1,4-butanediamine (**2**) was reported as an effective chiral ligand for the enantioface-differentiating addition of butyllithium to aldehydes by Seebach *et al.*[4] In the synthesis, the highest optical yield of the alcohols obtained is 40%, probably due to the rather weak interaction of the chiral ligand **2** with the reactants.

In the preceding papers,[5] it was shown that **1** and (2*S*,2′*S*,2″*S*)-2-hydroxymethyl-1-[[1-[(1-methyl-2-pyrrolidinyl)methyl]-2-pyrrolidinyl]methyl]pyrrolidine (**3**), easily derived from (*S*)-proline, are very effective chiral ligands for the enantioface-differentiating addition of alkyl-, alkynyllithium, and dialkylmagnesium to aldehydes, and that the corresponding secondary alcohols of very high optical purity are obtained (Fig. 1). The explosive increase of the use of lithium compounds in organic synthesis[6] during the last decade prompted us to extend the above enantioface-differentiating reaction to addition of some lithium derivatives of various functionalized organic compounds such as methyl phenyl sulfide, acetonitrile, *N*-nitrosodimethylamine, and 2-methylthiothiazoline (Eq. 1).



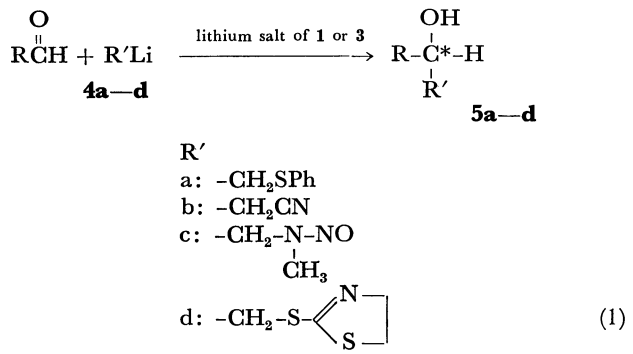
1

	R^1	R^2
1a	H	H
1b	Me	H
1c	t-Bu	H
1d	H	Me
1e	H	Et
1f	Et	H



3

Fig. 1.

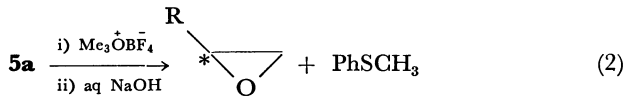


(1)

In this paper, we wish to describe the scope and limitations of the enantioface-differentiating additions of these functionalized lithium compounds to aldehydes.

Optically active **5a**—**d** are known to be converted respectively to the corresponding optically active compounds (oxirane, thiirane, *etc.*). The conventional methods are as follows.

Optically active β-hydroxy sulfides (**5a**) can be converted to optically active oxiranes with little racemization by the use of trimethyloxonium tetrafluoroborate and aq sodium hydroxide (Eq. 2).[7a]

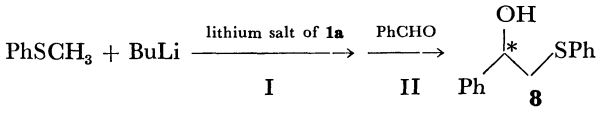


(2)

Since optically active oxiranes play an important role in metabolic processes,[8] many attempts have been reported on the asymmetric syntheses of the oxiranes.[9] For example, epoxidation of olefins by optically active peroxy acids,[9a] or by hydrogen peroxide in the presence of an optically active phase transfer catalyst,[9b] nucleophilic alkylidene transfer by optically active oxosulfonium ylides,[9c] and optically active metal complex catalyzed epoxidation of allylic alcohols with alkyl hydroperoxide,[9d] however, optical yields of oxiranes obtained by these methods are not high in general (maximum 50% e.e.[9d]).

As to the formation of β-hydroxy nitrile (**5b**), a report was given in 1974 utilizing aldehydes and the

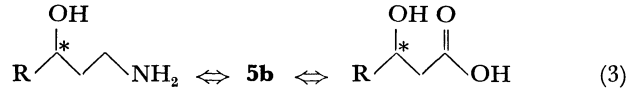
Table 1. Effects of solvents in the enantioface-differentiating addition of phenylthiomethyllithium to benzaldehyde



Entry[a]	I			II		8	
	Solvent	Temp/°C	Time/h	Solvent[c]	Temp/°C	Yield/%	Opt. yield/% e.e.[b]
1	Me_2O	−40	2	Me_2O	−123	22	12
2	Et_2O	0	overnight	Et_2O	−123	68	10
3	Pr_2O	0	overnight	Pr_2O	−123	67	0
4	THF	0	1	THF	−78	85	21
5	Hexane	0	overnight	Hexane	−78	50	15
6	$CH_2(OMe)_2$	0	overnight	$CH_2(OMe)_2$	−100	72	60
7	$CH_2(OMe)_2$	0	overnight	$CH_2(OMe)_2$[d]	−100	67	25
8	$CH_2(OMe)_2$	0	overnight	$CH_2(OMe)_2$[e]	−100	63	24
9	$CH_2(OMe)_2$	0	overnight	$CH_2(OMe)_2$ Me_2O(1 : 1)	−123	74	33
10	$CH_2(OMe)_2$	0	overnight	1,3-Dioxolane	−95	74	15
11	$CH_2(OMe)_2$	0	overnight	DME[f]	−78	80	11

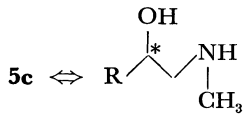
a) Molar ratio of the reactants. [PhCHO] : [$PhSCH_3$] : [BuLi] : [**1a**] = 1.0 : 2.7 : 6.7 : 4.0. b) Optical yields were determined by quantitative analyses of NMR spectra of the corresponding esters of (*R*)-(+)-α-methoxy-α-trifluoromethylphenylacetic acid. c) Otherwise noted, the amount of solvent was 20 ml. d) The amount of solvent was 120 ml. e) The amount of solvent was 10 ml. f) 1,2-Dimethoxyethane.

lithium salt of **1a**. It was also found that the enantiomeric excess of **8** depended on the concentrations and β-hydroxy carboxylic acid (Eq. 3), no report has appeared on the asymmetric synthesis of **5b** itself, to our knowledge.



(3)

Moreover **5c** is obtained by the reaction of aldehydes and the lithium derivative of *N*-nitrosodimethylamine, a masked nucleophilic α-(alkylamino)methylating reagent[11] (Eq. 4).



Halostahine **11**
(R = Ph)

(4)

Seebach *et al.* reported the asymmetric synthesis of **5c** (15% optical purity) by the enantioface-differentiating addition of **4c** to benzaldehyde using **2** as a chiral media.[6]

The compound **5d** is known as an intermediate for the formation of thiirane.[12] Concerning the asymmetric synthesis of thiirane, there have been two methods reported, namely, (a) the reaction of chiral 2-methylthiooxazoline (**6**)[13a] and (b) the reaction utilizing the chiral lithiocarboxylate (**7**).[13b] Reactants possessing a chiral moiety are employed in both methods (a) and (b), and as yet no method for the preparation of optically active thiiranes by enantioface-differentiating reactions utilizing chiral ligands has been reported. Therefore this report deals with the first example of enantioface-differentiating reactions using chiral ligands.

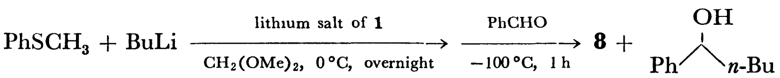
Results and Discussion

Oxiranes. As for the generation of phenylthiomethyllithium (**4a**) from methyl phenyl sulfide, Corey and Seebach reported a method using 1,4-diazabicyclo-[2.2.2]octane (DABCO).[14] However, it was found in the preliminary study, that the reaction of equimolar amounts of methyl phenyl sulfide, butyllithium, and the lithium salt of (2*S*,2′*S*)-2-hydroxymethyl-1-[(1-methyl-2-pyrrolidinyl)methyl]pyrrolidine (**1a**) in THF at 0 °C for 45 min or in dimethoxymethane at 0 °C overnight produced **4a** in 95% yield, as determined by subsequent quenching with deuterium oxide and quantitative NMR analysis.

To a mixture of **4a** and the lithium salt of **1a**, formed under the above reaction conditions, benzaldehyde in various solvents was added at low temperatures (−78—−123 °C), and the reaction mixture was stirred for 1 h. Usual work-up gave 1-phenyl-2-phenylthioethanol (**8**), of which enantiomeric excess was determined by quantitative analysis of NMR spectra of the corresponding esters of (+)-α-methoxy-α-trifluoromethylphenylacetic acid (Table 1).

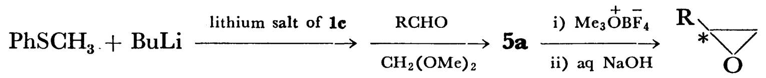
As shown in Table 1, effects of solvents were remarkable. The best result was obtained when the reaction was carried out in dimethoxymethane (entry 6). Moreover it is noted that the enantiomeric excesses of the alcohols obtained became higher as the solvating ability of the reaction media increased (entry 1, 2, and 3), and this tendency was the same as that of alkyllithium, reported in the preceding papers.[5b,d] This might suggest that solvation plays an important role in the formation of the complex of **4a** and the

TABLE 2. EFFECTS OF STRUCTURES OF CHIRAL LIGANDS



Entry	Chiral ligand	8 Yield/%	8 Opt. yield/% e.e.	1-Phenyl-1-pentanol Yield/%
1	**1a**	72	60	—
2	**1b**	56	54	20
3	**1c**	30	72	34
4	**1d**	48	28	—
5	**3**	31	60	29

TABLE 3. ASYMMETRIC SYNTHESIS OF OXIRANES



R[a)]		5a Yield/%	5a $[\alpha]_D$ (c, CH_2Cl_2)	5a Enantiomeric ratio[b)]	Oxirane Yield/%	Oxirane $[\alpha]_D$ (c, solvent)	Oxirane Opt. purity/%
Ph	**8**	83	$[\alpha]^{28}$ +7.96°(8.7)	84 : 16	54	$[\alpha]^{26}$ +4.5°(4.0, acetone)	68[c)]
i-Pr	**9**	57	$[\alpha]^{28}$ −28.2°(3.8)	70 : 30			
n-$C_{11}H_{23}$	**10**	54	$[\alpha]^{29}$ −6.79°(2.7)	69 : 31	83	$[\alpha]^{28}$ +3.3°(1.2, THF)	35[d)]

a) Molar ratio of reactants. [RCHO] : [BuLi] : [$PhSCH_3$] : [Ligand **1c**] = 1.0 : 6.7 : 2.7 : 4.0. b) Determined by quantitative analysis of NMR spectra of the corresponding esters of (+)-α-methoxy-α-trifluoromethylphenylacetic acid. c) Calculated from optical rotation based upon the value available. $[\alpha]_D^{22}$ +6.64° (c 4.9, acetone), See Ref. **7b**. d) Calculated from optical rotation based upon the value available. $[\alpha]_D^{22}$ +9.61° (c 1.2, THF). J. L. Coke and A. B. Richon, *J. Org. Chem.*, **41**, 3516 (1976).

lithium derivative of acetonitrile.[10)] Though **5b** is a synthetic equivalent to optically active γ-amino alcohol of the reactants (entry 6, 7, and 8), and that the most suitable concentration of benzaldehyde was found to be 5 M (entry 6). In the preceding paper[5)] it was shown that optical purity of secondary alcohols obtained by asymmetric addition of alkyllithium or dialkylmagnesium to aldehydes are greatly influenced by the structure of chiral ligands. Therefore we examined asymmetric addition of **4a** to benzaldehyde in dimethoxymethane using various kinds of chiral ligands (**1a—d, 3**). (Table 2).

The highest enantiomeric excess (72% e.e.) of **8** was achieved by the use of (2*S*,2′*S*)-2-hydroxymethyl-1-[(1-neopentyl-2-pyrrolidinyl)methyl]pyrrolidine (**1c**) which has bulky neopentyl substituent at the nitrogen atom (entry 3). However, in this case, 1-phenyl-1-pentanol was also produced in 34% yield by the side reaction of butyllithium with benzaldehyde. These results suggest that steric hindrance of the neopentyl group at the nitrogen atom of **1c** decreased the rate of the formation of **4a**. After a number of unsuccessful attempts to develop a satisfactory method, we devised an excellent method; the formation of the complex of **4a** with **1c** was carried out in petroleum ether at 25—30 °C overnight, and the asymmetric addition was carried out at −100 °C after the substitution of petroleum ether for dimethoxymethane.

When benzaldehyde was employed under the above mentioned reaction conditions, optically active (+)-**8** was obtained in 83% yield $[\alpha]_D^{28}$+ 7.96° (c 8.7, CH_2Cl_2) and its enantiomeric ratio (84:16) was determined by quantitative NMR (100 MHz) analysis of the corresponding ester of (+)-α-methoxy-α-trifluoromethylphenylacetic acid. According to the procedure of Shanklin *et al.*,[7a)] the compound **8** thus obtained was converted without racemization to (*R*)-(+)-2-phenyloxirane (54%, $[\alpha]_D^{26}$ +4.5° (c 4.0, acetone), 68% optical purity).[7b)]

In a similar manner, several optically active 2-substituted oxiranes were obtained from the corresponding aldehydes and the results are summarized in Table 3.

Lithium Derivatives of Acetonitrile and N-*Nitrosodimethylamine.* It is well known that the abstraction of a proton from acetonitrile by butyllithium at −78 °C easily produces lithium derivatives (**4b**).[10)] The reaction conditions of the enantioface-differentiating addition of **4b** to benzaldehyde were studied by varying both, type of solvents and structure of chiral ligands. The results are summarized in Table 4.

The highest enantiomeric excess (40% e.e.) of β-hydroxy nitrile (**5b**) was achieved when the reaction was carried out in dimethyl ether at −123 °C using the lithium salt of **1d** as a chiral ligand (Table 4, entry 3).

As to the asymmetric addition of the lithium derivative of *N*-nitrosodimethylamine (**4c**) to benzaldehyde in dimethoxymethane at −100 °C, the corresponding 2-(*N*-nitrosomethylamino)-1-phenylethanol (**5c**)[15)] was

Table 4. Enantioface-differentiating addition of lithium derivative of acetonitrile

$$LiCH_2CN + PhCHO \xrightarrow{\text{lithium salt of chiral ligand}} Ph\text{-}\underset{H}{\overset{OH}{C^*}}\text{-}CH_2CN$$

4b **5b**

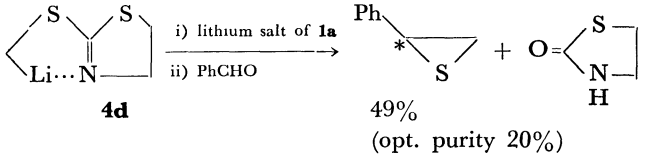
Entry[a]	Ligand	Solvent	Temp/°C	Yield/%	Opt. yield/%[b]
1	**1c**	$CH_2(OMe)_2$	−100	80	26
2	**1d**	$CH_2(OMe)_2$	−100	94	35
3	**1d**	Me_2O	−123	76	40
4	**1d**	Et_2O	−123	52	9
5	**1e**	$CH_2(OMe)_2$	−100	78	17
6	**1f**	$CH_2(OMe)_2$	−100	86	16
7	**3**	$CH_2(OMe)_2$	−100	83	0
8	**1c**	$CH_2(OMe)_2$	−100	76	0

a) Molar ratio of the reactant; [PhCHO] : [BuLi] : [CH_3CN] : [Ligand] = 1.0 : 6.7 : 2.7 : 4.0. b) Determined by quantitative analysis of NMR spectra of the corresponding ester of (+)-α-methoxy-α-trifluoromethylphenylacetic acid.

obtained in 96% yield ($[\alpha]_D^{25}$ +12.46°), and subsequent denitrosation gave 2-methylamino-1-phenylethanol (**11**) Halostahine, $[\alpha]_D^{24}$ +11.9° (*c* 1.68, EtOH), opt. purity 25%.[16]

The reason that enantiomeric excesses of the adducts **4b** and **4c** are not so high as those of the addition of alkyllithium as reported in the previous papers[5] may be explained as follows; it is clear that efficient complexes of lithium derivatives with chiral ligand should be tight and stable for achievement of higher enantioselectivity. It is also well known that ionic character of the lithium–carbon bond of lithium derivatives increases as the pK_a value of the parent compound decreases. Hence, the lithium–carbon bond of **4b** and **4c** becomes looser than that of alkyllithium. Therefore, the enantiomeric excesses of the adducts obtained may depend on the decrease in the stability of the chelated complexes of **4b** and **4c** with chiral ligand **1** as compared with that of alkyllithium.

Thiirane. Enantioface-differentiating addition of lithium compound (**4d**) to benzaldehyde was carried out in dimethoxymethane at −100 °C for 1 h in the presence of lithium salt of **1a**. The optical purity of the obtained (*R*)-(−)-2-methylthiirane was 20%[17] (Eq. 5).



(5)

It is noticeable that **4d** has a rather rigid structure because of the coordination between the nitrogen atom and the lithium atom.[18]

This rigidity of **4d** may interfere in the formation of the complex between **4d** and the lithium salt of **1a**, and decreases enantioselectivity. Though optical purity of this procedure is comparable to that of the previously reported method using chiral **6**,[13a] this procedure has an advantage over previous methods in that there is no need to synthesize chiral thiazoline derivatives.

In conclusion, the chiral ligands **1** and **3**, easily prepared from (*S*)-proline, are efficient for the enantioface-differentiating addition of a wide variety of organolithium compounds to aldehydes. Optical yields of the various products thus obtained are higher than those illustrated in the previous methods. Furthermore, this method has an advantage over previous methods of asymmetric syntheses, in the simplicity of the reaction procedure, namely, there is no necessity of introducing and removing chiral moieties in the reactants at any stage.

Experimental

General. NMR spectra were taken on a Hitachi R-24B Spectrometer. Infrared spectra were taken on a Hitachi EPI-G2 spectrometer. Optical rotation was taken on a JASCO DIP-SL automatic polarimeter. THF, dimethoxyethane, dimethoxymethane, diethyl ether, and dipropyl ether were distilled from $LiAlH_4$ prior to use. Dimethyl ether was dried by passing the gas through a tube packed with calcium chloride. Reactions involving air-sensitive compounds were carried out under an atmosphere of argon. For evaporative bulb-to-bulb distillation, a Büchi Kugelrohrofen was used. According to the reported procedure,[5d] preparation of chiral ligands from (*S*)-proline and recovery of them after the asymmetric reactions were carried out.

*Asymmetric Addition of Phenylthiomethyllithium (**4a**) to Aldehydes Using **1c** as Chiral Ligand.* Methyl phenyl sulfide (0.670 g, 5.4 mmol) in 8 ml of petroleum ether (bp 37 °C) was added to a mixture of hexane (8.65 ml) solution of butyllithium (13.5 mmol) and petroleum ether (36 ml) solution of **1c** (2.057 g, 8.1 mmol) at 0 °C, and the mixture was stirred at room temperature (25—30 °C) for 17 h. Solvent was removed by evaporation with vacuum pump (1 mmHg) for 10 min at room temperature.[19] The residue was dissolved in 40 ml of dimethoxymethane, and was added a dimethoxymethane solution (4 ml) of benzaldehyde (0.212 g, 2 mmol) at −100 °C, and the stirring was continued for 1 h. The reaction was quenched with 3 M hydrochloric acid, extracted with ether and dried over Na_2SO_4. After removal of the solvent, the residue was purified by silica-gel TLC (CH_2Cl_2) and the isolated product was further purified by short-path distillation. 1-Phenyl-2-phenylthioethanol (**8**) (0.384 g, 83%, $[\alpha]_D^{28}$ +7.96° (*c* 8.7, CH_2Cl_2), optical yield

68%e.e.) was obtained as a yellow oil of which enantiomeric excess was determined according to Mosher's method.[20] In a similar manner, isobutyraldehyde and dodecanal were employed and the spectra data of the adducts were as follows; **8**; IR (neat) 3400, 3050, 2900, 1580, 1485, 1475, 1450, 1435, 1055, and 1025 cm^{-1}; NMR ($CDCl_3$) δ=2.77—3.30 (3H, m), 4.66 (1H, m) and 7.23 (10H, m). **9**; IR (neat) 3420, 3050, 2960, 2950, 2870, 1590, 1480, 1440, 1100, 1050, 1030, and 1000 cm^{-1}; NMR ($CDCl_3$) δ=0.90 (6H, d, J=6 Hz), 1.46—2.06 (1H, m), 2.30—3.65 (4H, m), and 7.16 (5H, m). **10**; Mp 52—53 °C IR (KBr) 3380, 2920, 2840, 1585, 1475, 1460, 1435, 1345, 1090, 1065, 1060, 735, 730, and 690 cm^{-1}, NMR ($CDCl_3$) δ=1.22—1.60 (23H, m), 2.44 (1H, broad), 2.75—3.35 (2H, m), and 3.70 (1H, m).

Optically Active 2-Substituted Oxiranes. According to the procedure of Shanklin *et al.*,[7a] **8a** was converted to 2-phenyloxirane (0.107 g, 54%, optical purity 68%).[7b] Optically active 2-undecyl oxirane was obtained in a similar manner. The structures of these compounds were identified by their IR and NMR spectra.

*Asymmetric Addition of Lithium Derivative of Acetonitrile to Benzaldehyde Using **1d**.* Diethyl ether (0.5 ml) solution of **1d** (0.915 g, 4.0 mmol) was added to dimethyl ether (20 ml) at −78 °C, and butyllithium (6.7 mmol) was added subsequently. After the reaction mixture was stirred for 15 min, acetonitrile (0.111 g, 2.7 mmol) in Et_2O (1 ml) was added. Stirring was continued for further 15 min, then benzaldehyde (0.106 g, 1.0 mmol) in Et_2O (1 ml) was added at −123 °C to the reaction mixture. After the mixture was stirred for 30 min, the reaction was quenched by adding 3 M hydrochloric acid, and the mixture was extracted with diethyl ether, dried over Na_2SO_4. The organic layer was concentrated under reduced pressure. The residue, subjected to preparative TLC on silica gel (CH_2Cl_2) yielded 3-hydroxy-3-phenylpropanenitrile (0.111 g, 76%), $[\alpha]_D^{18}$ +24.4° (c 4.1, CH_2Cl_2). The enantiomeric exess (40%e.e.) was determined by Mosher's method.[20] The structure was identified by IR and NMR.

Asymmetric Addition of Lithium Derivative of N-*Nitrosodimethylamine Using **1a** as Chiral Ligand.* Butyllithium (6.7 mmol) was added to dimethoxymethane (12 ml) solution of **1a** at 0 °C, and the mixture was stirred for 30 min. Then, *N*-nitrosodimethylamine[21] (0.200 g, 2.7 mmol) in dimethoxymethane (4 ml) was added to the mixture at −100 °C and the stirring was continued for 10 min. To the reaction mixture, benzaldehyde (0.106 g, 1.0 mmol) in dimethoxymethane (1.5 ml) was added at −100 °C. After the reaction mixture was stirred for 1.5 h, the reaction was quenched with water (5 ml), then the aqueous layer was adjusted to pH 5. The mixture was extracted with diethyl ether, and the extract was dried over anhydrous sodium sulfate. After the extract was concentrated under reduced pressure, the residue was purified by preparative TLC on silica gel [CH_2Cl_2–AcOEt (1 : 1)]. 2-(*N*-nitrosomethylamino)-1-phenylethanol (**5c**) (0.172 g, 96%, $[\alpha]_D^{25}$ +12.5° (c 5.8, CH_2Cl_2) was obtained which was further purified by short-path distillation. The structure of **5c** was identified by IR and NMR spectra.

*Halostahine (**11**).* According to the procedure of denitrosation[15] reported by Seebach and Enders, **5c** was converted to halostahine. $[\alpha]_D^{24}$ +11.9° (c 1.7, EtOH). Optical purity 25% [based upon the reported rotation $[\alpha]_D$ −47.03°].[16] Mp 74—75 °C [lit, 75—76 °C][16] IR (KBr) 3320, 1445, 1345, 1200, 1140, 1115, 1085, 1065, 930, 760, 750, and 700 cm^{-1}. NMR ($CDCl_3$) δ=2.40 (3H, 5), 2.72 (2H, d, J=6 Hz), 3.56 (2H, s), 4.75 (1H, t, J=6 Hz), and 7.34 (5H, s).

Asymmetric Addition of Lithium Derivative of 2-Methylthiothiazoline to Benzaldehyde. Butyllithium (6.7 mmol) was added to a dimethoxymethane (15 ml) solution of **1a** (0.803 g, 4.0 mmol) at 0 °C, and the mixture was stirred for 30 min. After the mixture was cooled to −78 °C, 2-methylthiothiazoline[22] (0.359 g, 2.7 mmol) in dimethoxymethane (2 ml) was added, and the stirring was continued for 1 h. Then, benzaldehyde (0.106 g, 1.0 mmol) in dimethoxymethane (2 ml) was added at −100 °C to the reaction mixture. The mixture was stirred for 1 h, the reaction was quenched with water (15 ml). Organic layer was extracted with ether, and the extract was dried over anhydrous sodium sulfate. After the concentration of the extract under reduced pressure, the residue was subjected to silica gel column chromatography (CH_2Cl_2) to remove chiral ligand **1a**. Further purification utilizing preparative silica-gel TLC (hexane) gave 2-phenylthiirane (0.067 g, 50%) $[\alpha]_D^{27}$ −8.8° (c 2.6, heptane). Optical purity 20% [based upon the reported value, lit $[\alpha]_D$ −43.85° (heptane)].[17] IR (neat) 2930, 1600, 1500, 1495, 1450, 1070, 1045, 760, 695, and 665 cm^{-1}, NMR ($CDCl_3$) δ= 2.43 (1H, dd, J=6 Hz, 2 Hz), 2.70 (1H, dd, J=6 Hz, 2 Hz), 3.70 (1H, t, J=6 Hz), and 7.05 (5H, s).

The present work was partially supported by a Grant-in-Aid for Scientific Research from the Ministry of Education.

References

1) a) J. D. Morrison and H. S. Mosher, "Asymmetric Organic Reactions," Prentice-Hall, Englewood Cliffs., N. J. (1971); b) Y. Izumi, A. Tai, K. Hirota, and T. Harada, *Kagaku Sosetsu*, **4** (1971).

2) a) R. S. Brinkmeyer and V. M. Kappor, *J. Am. Chem. Soc.*, **99**, 8339 (1977); b) M. Asami, H. Ohno, S. Kobayashi, and T. Mukaiyama, *Bull. Chem. Soc. Jpn.*, **51**, 1869 (1978), and references cited therein.

3) See Ref. 1a) pp. 415—419.

4) D. Seebach, H. Kalinowski, B. Bastani, G. Grass, H. Daum, H. Dorr, N. P. Dupreez, W. Langer, C. Nussler, H.-A. Oei, and M. Schmidt, *Helv. Chim. Acta*, **60**, 301 (1977).

5) a) T. Mukaiyama, K. Soai, and S. Kobayashi, *Chem. Lett.*, **1978**, 219; b) K. Soai and T. Mukaiyama, *ibid*, **1978**, 491; c) T. Sato, K. Soai, K. Suzuki, and T. Mukaiyama, *ibid*, **1978**, 601; d) T. Mukaiyama, K. Soai, T. Sato, H. Shimizu, and K. Suzuki, *J. Am. Chem. Soc.*, **101**, 1455 (1979); e) T. Mukaiyama, K. Suzuki, K. Soai, and T. Sato, *Chem. Lett.*, **1979**, 447.

6) D. Seebach and K.-H. Greiss, "New Application of Organometallic Reagents in Organic Synthesis," Elsevier, Amsterdam (1976).

7) a) J. R. Shanklin, C. R. Johnson, J. Ollinger, and R. M. Coates, *J. Am. Chem. Soc.*, **95**, 3429 (1973); b) C. R. Johnson and C. W. Schroeck, *J. Am. Chem. Soc.*, **95**, 7418 (1973).

8) T. Shishibori, T. Fukui, and T. Suga, *Chem. Lett.*, **1973**, 1137, and references cited therein.

9) a) W. H. Pirkle and P. L. Rinaldi, *J. Org. Chem.*, **42**, 2080 (1977); b) R. Helder, J. C. Hummelen, R. W. P. M. Laane, J. S. Wiering, and H. Wynberg, *Tetrahedron Lett.*, **1976**, 1831; c) C. R. Johnson and C. W. Schroeck, *J. Am. Chem. Soc.*, **95**, 7418 (1973); d) S. Yamada, T. Mashiko, and S. Terashima, *J. Am. Chem. Soc.*, **99**, 1988, (1977); R. C. Michaelson, R. E. Palermo, and K. B. Sharpless, *ibid.*, **99**, 1990 (1977).

10) D. S. Watt, *Tetrahedron Lett.*, **1974**, 707.

11) D. Seebach and D. Enders, *Angew. Chem. Int. Ed.*

Engl., **14**, 15 (1975).
12) C. R. Johnson, A. Nakanishi, N. Nakanishi, and K. Tanaka, *Tetrahedron Lett.*, **1975**, 2865.
13) a) A. I. Meyers and M. Ford, *J. Org. Chem.*, **41**, 1735 (1976); b) C. R. Johnson and K. Tanaka, *Synthesis*, **1976**, 413.
14) E. J. Corey and D. Seebach, *J. Org. Chem.*, **31**, 4097 (1966).
15) D. Seebach and D. Enders, *Chem. Ber.*, **108**, 1293 (1975).
16) G. P. Men'shikov and G. M. Borodina, *J. Gen. Chem. USSR*, **17**, 1569 (1947); *Chem. Abstr.*, **42**, 2245a (1948).
17) E. Chiellini, M. Marchetti, and G. Ceccarelli, *Int. J. Sulfur Chem., Part A*, **1**, 73 (1971).
18) K. Narasaka, M. Hayashi, and T. Mukaiyama, *Chem. Lett.*, **1972**, 259.
19) The enantiomeric excess of β-hydroxy sulfide is greatly influenced by the presence of petroleum ether. In order to evaporate petroleum ether completely, the use of a larger reaction vessel (300-ml) is preferable.
20) J. A. Dale and H. S. Mosher, *J. Am. Chem. Soc.*, **95**, 512 (1973).
21) H. H. Hatt, *Org. Synth.*, Coll. Vol. II, 211 (1948).
22) K. Hirai, H. Matsuda, and Y. Kishida, *Chem. Pharm. Bull.*, **20**, 2067 (1972).