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Stereochemistry of Dithiirane 1-Oxides: Optical Resolution, Absolute Configuration, and Racemization and Isomerization of Dithiirane 1-Oxides

Akihiko Ishii, Shin-ya Nakamura, Tsuyoshi Yamada, and Juzo Nakayama*

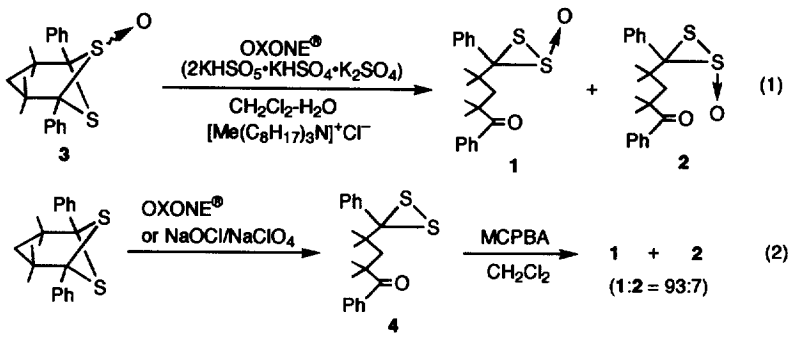
Department of Chemistry, Faculty of Science, Saitama University, Urawa, Saitama 338, Japan

Abstract: Optical resolution of (1*RS*, 3*SR*)- (**1**) and (1*RS*, 3*RS*)- (**2**) dithiirane 1-oxides was achieved by HPLC equipped with a chiral column to give **1a** and **1b** and **2a** and **2b**, respectively. X-ray analyses proved absolute configurations of **1a** and **1b** to be (1*R*, 3*S*) and (1*S*, 3*R*), while those of **2a** and **2b** were determined to be (1*R*, 3*R*) and (1*S*, 3*S*), respectively, since **2a** and **2b** isomerized stereospecifically to **1b** and **1a**, respectively. Enantiomeric dithiirane 1-oxides **1a** and **1b** racemized to each other whereas **2a** and **2b** did not. To the racemization (oxygen migration) is proposed a mechanism involving homolysis of the S(O)–S bond at the initial step followed by a ring closure giving a 1,2,4-oxathietane intermediate. Isomerization between **1** and **2** was inhibited by a radical scavenger, DPPH. © 1997 Elsevier Science Ltd.

INTRODUCTION

The chemistry of thiosulfinates has drawn considerable attention not only from their biological activities, e.g., allicin isolated from garlic, but also as precursors and condensation products of sulfenic acids.[1] Until today, some optically active thiosulfinates have been prepared.[2–11] Kice[2] and Fava[3] independently prepared optically active *S*-aryl arenethiosulfinates by asymmetric oxidation of diaryl disulfides though in very low optical yields. Later, asymmetric oxidation with a chiral oxaziridine,[4] a chiral titanium complex,[5] and an enzyme[6] gave optically active thiosulfinates in low to moderate optical yields. On the other hand, Mikołajczyk and Drabowicz prepared optically active thiosulfinates by asymmetric condensation.[7,8] While optical resolution of racemic thiosulfinates via β-cyclodextrin inclusion complexes gave optically active thiosulfinates in 2.5—13.6% ee,[9] complete optical resolution of *S*-aryl arenethiosulfinates was achieved by high-performance liquid chromatography (HPLC) using a chiral column.[10]

Recently, we found the formation of the first isolable dithiirane 1-oxide derivatives **1** and **2** by the reaction of 6,7-dithiabicyclo[3.1.1]heptane 6-oxide **3** with $2KHSO_5{\cdot}KHSO_4{\cdot}K_2SO_4$ (OXONE®, Aldrich) (Eq. 1).[12] This finding promoted the chemistry of dithiiranes to the new stage, and thus we have succeeded in the synthesis of the first isolable, unoxidized dithiirane derivative **4**.[13] Dithiirane 1-oxides **1** and **2** were also obtained by oxidation of **4** with MCPBA (Eq. 2).[13a,d]



Dithiirane 1-oxides correspond to three-membered cyclic thiosulfinates and have two asymmetric centers in the case of the two substituents on the carbon atom being nonequivalent; one is the dithiirane carbon and the other is the sulfinyl sulfur. Therefore, there exist a pair of diastereomers and two pairs of enantiomers with respect to each diastereomer (Fig.1). In the case of dithiirane 1-oxides **1** and **2** (R^1 = Ph; R^2 = $CMe_2CH_2CMe_2COPh$ in Fig.1), the (1*RS*, 3*SR*)-dithiirane 1-oxide **1** and the (1*RS*, 3*RS*)-isomer **2** are diasteromeric to each other; they are separable by silica-gel column chromatography and the structures of **1** and **2** were unequivocally determined by X-ray single-crystal analysis.[13d]

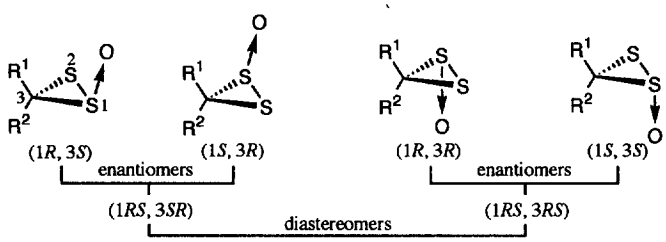


Fig. 1. Diastereomers and enantiomers of dithiirane 1-oxides (R^1>R^2).

Here we report the optical resolution of (1*RS*, 3*SR*)-dithiirane 1-oxide **1** and (1*RS*, 3*RS*)-isomer **2** by HPLC equipped with a chiral column and the determination of the absolute configurations of the four stereoisomers. During the course of the study, we have observed racemization (oxygen migration) of the enantiomers and isomerization (inversion at the sulfinyl sulfur) between **1** and **2**. We also discuss the mechanisms of the racemization and the isomerization.

RESULTS AND DISCUSSION

Optical resolution of (1RS, 3SR)- and (1RS, 3RS)-dithiirane 1-oxides 1 and 2 and determination of the absolute configurations of the enantiomers

(1RS, 3SR)-Dithiirane 1-oxide 1. An X-ray analysis of the racemic dithiirane 1-oxide **1** (m.p. 124—125 °C decomp) disclosed that the space group is $P\bar{1}$ and the Z value is 2, indicating that the enantiomers

make a pair in a unit cell. This means that optical resolution of **1** by fractional recrystallization is impossible. Therefore, we examined the separation of the enantiomers by HPLC equipped with a chiral column. As a result of screening of some chiral columns,[14] it was found that **1** was completely resolved by using a column packed with amylose tris(3,5-dimethylphenylcarbamate) coated on silica gel as the stationary phase.[15] An HPLC chromatogram of **1** was depicted in Fig. 2, where (1*RS*, 3*RS*)-isomers **2**, dicarbonyl compound **5**, and thioketone *S*-oxide **6** (overlapped with the peak of **1a** in Fig. 2) were also detected as contaminants.

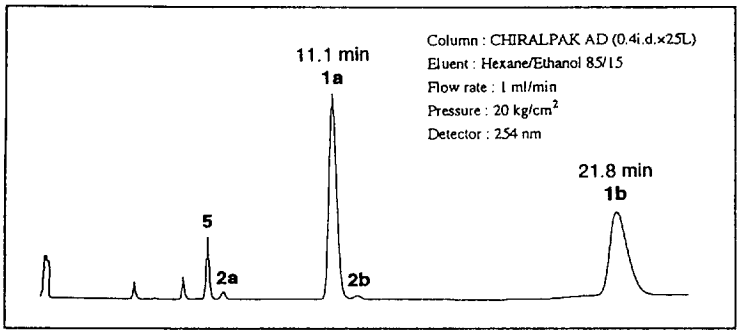


Fig. 2. HPLC chromatogram of dithiirane 1-oxide **1**.

Colorless crystals (**1a**, m.p. 112—115 °C decomp) obtained from the first fraction (t_R = 11.1 min) showed a specific rotation of –210° (*c* 0.305, $CHCl_3$, 22 °C). The HPLC analysis of the crystals, however, indicated that the enantiomeric excess (ee) was 97% and their ^1H NMR showed that they are composed of 86% of **1**, 7% of the isomer **2**, and 7% of thioketone *S*-oxide **6**. The contamination of **6** in this fraction is mostly caused by incomplete separation of the HPLC fractionation. On the other hand, colorless crystals (**1b**, mp. 113—115 °C, decomp), obtained from the second fraction (t_R = 21.8 min), showed a specific rotation of +226° (*c* 0.305, $CHCl_3$, 22 °C) and are composed of 93% of **1** (95.5% ee), 6% of **2**, and 1% of **6**.

Circular dichroism (CD) spectra of the enantiomers **1a** and **1b** are presented in Fig.3. The (–)-enantiomer **1a** exhibits a negative Cotton effect at 307 nm, a positive second Cotton effect at 270 nm, and a negative third Cotton effect at 229 nm. The (+)-enantiomer **1b** shows a CD spectra symmetric to that of **1a**.

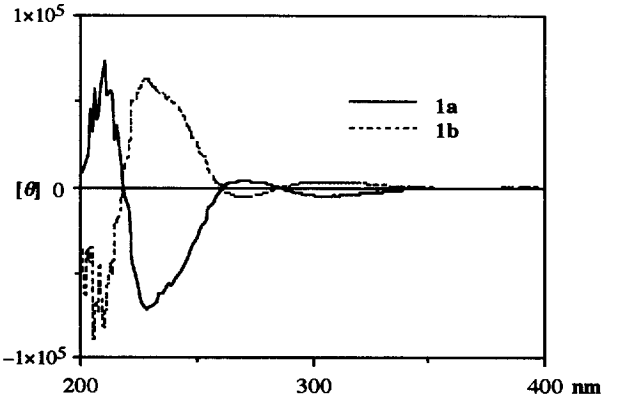
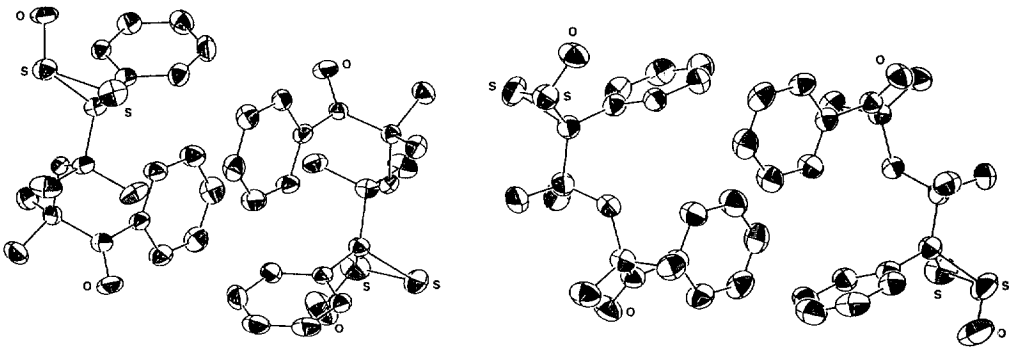


Fig.3. CD spectra of **1a** and **1b**.

Absolute configurations of **1a** and **1b** were determined by X-ray single-crystal structure analysis, in which the value of η defined by Rogers was the criterion of the determination.[16] The analysis on **1a** showed that its absolute configuration is *R* on the sulfinyl sulfur and *S* on the dithiirane carbon [triclinic, *P*1, $Z = 2$, $R = 0.0580$, $R_w = 0.0587$, and $\eta = 0.8(1)$]. An ORTEP drawing of **1a** is depicted in Fig. 4a. Thus, **1a** was determined to be (1*R*, 3*S*)-(–)-dithiirane 1-oxide. Similarly, the X-ray analysis on **1b** [triclinic, *P*1, $Z = 2$, $R = 0.0498$, $R_w = 0.0516$, $\eta = 0.9(1)$] gave the absolute configuration, (1*S*, 3*R*), reasonably opposite to that of **1a** (Fig. 4b).



(a) (b)

Fig. 4. ORTEP drawings of **1a** (a) and **1b** (b).

Both **1a** and **1b** thus obtained were not enantiomerically pure because they lost their ee gradually in solution; (+)-**1b** in 1,2-dichloroethane ($c = 3.1\times10^{-3}$ mol dm^{-3}) lost optical activity almost completely after 5—6 days at 25 °C ($k = 4.1\times10^{-6}$ s^{-1}). On the other hand, the contamination of 6—7% of the isomer **2** is partly due to isomerization of **1** to **2** during a series of operations. The racemization and the isomerization are discussed later.

(1RS, 3RS)-Dithiirane 1-oxide 2. A racemate of **2** (m.p. 110—114 °C decomp) was also optically resolved in a similar manner. Since some isomerization to **1** and decomposition to dicarbonyl compound **5** and thioketone *S*-oxide **6** took place during the operations, colorless solids obtained by evaporation of the solvent were purified again by HPLC (silica gel). Thus, it was disclosed that the first fraction ($t_R = 6.7$ min, m.p. 104—106 °C decomp) was the (–)-enantiomer (**2a**) and the second one ($t_R = 11.2$ min, m.p. 107—109 °C decomp) (+)-enantiomer (**2b**). Interestingly, in contrast to **1**, the enantiomers of **2** were optically stable; optical purity of (+)-**2b** (94% ee) in 1,2-dichloroethane did not change for 2 d at 30 °C. Another important observation was that (–)-**2a** (97% ee) and (+)-**2b** (>95% ee) were contaminated with a small amount of (+)-**1b** (>95% ee) and (–)-**1a** (>95% ee), respectively. The optical stability and the stereospecfic isomerization of **2** to **1** mean that isomerization of **2** to **1** is due to inversion at the sulfinyl sulfur without oxygen migration. Therefore, we determined the absolute configurations of **2a** and **2b** to be (1*R*, 3*R*) and (1*S*, 3*S*), respectively (Fig. 5).

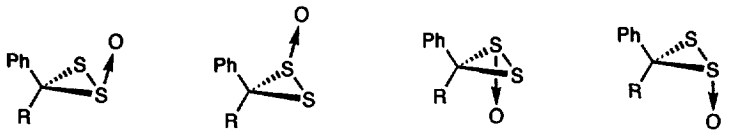


Fig. 5. Absolute configurations of stereoisomers, **1a**, **1b**, **2a**, and **2b**.

Mechanisms of racemization and isomerization of dithiirane 1-oxides

Optical instability of thiosulfinates in the presence[17] or absence[3–5,7,9] of catalysts was often observed and aroused controversy on the mechanism.[9,18,19] These racemization reactions do not involve an oxygen migration and the present isomerization between **1** and **2** holds for these cases. The racemization of optically active dithiirane 1-oxides is practically an oxygen migration which has been observed only in a few cases.[20,21]

Racemization (oxygen migration) between (1R, 3S)- and (1S, 3R)-dithiirane 1-oxides, 1a and 1b. The progress of the racemization of (1*S*, 3*R*)-(+)-dithiirane 1-oxide **1b** was traced with HPLC. The racemization obeyed reversible first-order kinetics and the rate constants (k) were calculated by the following equation; $\ln(\%\ ee/100) = -2kt - \ln[([\mathbf{1b}]_0 + [\mathbf{1a}]_0)/2([\mathbf{1b}]_0 - [\mathbf{1b}]_\infty)]$, where $[\mathbf{1a}]_0$ and $[\mathbf{1b}]_0$ are the initial concentrations of **1a** and **1b**, respectively, and $[\mathbf{1b}]_\infty$ is the concentration of **1b** after a time of ∞ (Table 1).

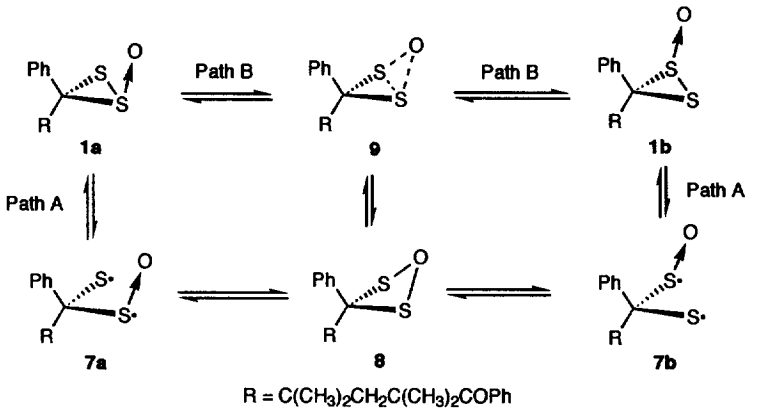
Table 1.

Run	Temp. °C	Solvent	Conc. 10^{-3} mol dm^{-3}	k 10^{-6} s^{-1}
1	25	CH_2Cl_2	1.3	4.3
2	25	CH_2Cl_2	13.0	4.1
3	25	Hexane-EtOH (1:1)	1.3	4.4
4	25	C_6H_6	3.1	6.2
5	20.4	$ClCH_2CH_2Cl$	3.1	1.90
6	25.2	$ClCH_2CH_2Cl$	3.1	4.09
7	30.0	$ClCH_2CH_2Cl$	3.1	7.76
8	34.8	$ClCH_2CH_2Cl$	3.1	14.0
9	39.8	$ClCH_2CH_2Cl$	3.1	27.7
10[a]	25	$ClCH_2CH_2Cl$	3.1	3.8
11[b]	25	CH_2Cl_2	1.3	4.1

a) Under argon atmosphere.
b) 2,6-Di-*t*-butyl-4-methylphenol was added.

As shown in Runs 1—4, the rate constants were almost independent of concentration and solvent polarity, indicating that the racemization is a unimolecular reaction and does not involve ionic species in the rate-controlling step. Activation parameters are obtained from the rate constants measured in a temperature range from 20.4 to 39.8 °C (Runs 5—9); $\Delta H^{\neq} = 24.3$ kcal mol^{-1}; $\Delta S^{\neq} = -2.0$ cal deg^{-1}.

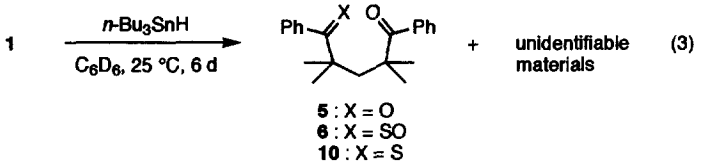
Taking the kinetic studies into account, a radical (Path A) or a concerted (Path B) mechanism is probably operative in the racemization (Scheme 1). In the Path A, homolysis of the S(O)–S bond of **1a** gives the biradical intermediate **7a**, which yields the 1,2,4-oxadithietane intermediate **8** by an intramolecular ring closure.[19,20,22] The S–O bond cleavage of **8** would give another biradical **7b** whose ring closure results in the formation of the stereoisomer **1b**, and vice versa. In the Path B, the oxygen atom migration to the adjacent sulfenyl sulfur proceeds through a transition state **9**.



Scheme 1

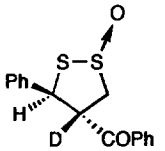
In the disproportionation of aryl arenethiosulfinates, $2ArS(O)SAr \rightarrow ArSO_2SR + ArSSAr$, oxygen migration from the sulfinyl sulfur to the sulfenyl sulfur was involved and, in addition, some radical trapping experiments using styrene, 1,1-diphenylethylene, and diphenylpicrylhydrazyl (DPPH) proved the intervention of radical species. Therefore, Fava came to a conclusion that homolytic cleavage of the S(O)–S bond is involved in the disproportionation.[20,23] Also to our racemization, we propose an S(O)–S homolysis mechanism as the initial step (Path A) for the following reasons, although more rigid experimental evidence for the existence of the biradical intermediate still remains to be found. The rate of the racemization of **1b** is not influenced by radical scavengers such as molecular oxygen (Table 1, Run 10 and other Runs), 2,6-di-*t*-butyl-4-methylphenol (Run 11), and DPPH. In addition, remarkable decomposition of racemic dithiirane 1-oxide **1** did not take place when **1** was stirred in the presence of DPPH ($CDCl_3$, r.t., 14 d), 2,6-di-*t*-butyl-4-methylphenol (hexane-EtOH 1:1, 25 °C, 3 d), $PhSiH_3$ (benzene, 60 °C, 2 d), $(Me_3Si)_3SiH$ (C_6D_6, r.t., 6 d) or 1,1-diphenylethylene[24] ($CDCl_3$, r.t., 20 d). However, when a solution of the racemic dithiirane 1-oxide **1** in C_6D_6 was stirred in the presence of *n*-Bu_3SnH at 25 °C for 6 d under argon, there resulted in considerable decomposition of **1** to dicarbonyl compound **5** (28%), thioketone *S*-oxide **6** (14%), thioketone **10** (7%), and some unidentifiable materials (^1H NMR, Eq. 3). These experiments can be explained in terms of bond strengths: bond dissociation energies (ΔH°_{298}) of PhO–H, PhH_2Si–H, $(Me_3Si)_3Si$–H, and *n*-Bu_3Sn–H are 86.5,[25] 88.2,[26] 79.0[27] and 73.7[28] kcal mol^{-1}, respectively. The biradical intermediate **7** corresponds to the biradical generated from a *gem*-mercaptosulfenic acid [PhRC(SH)SOH] by double hydrogen abstraction. Reported bond dissociation energy of RS-H is 91—92 kcal mol^{-1} [25,29] and that of RSO–H was estimated to be comparable with that of ArO–H.[30] Thus, the intramolecular ring closure of **7** to **8** or **1** is generally more

favorable both in bond energy and steric demand than intermolecular hydrogen abstraction except in the case of *n*-Bu_3SnH, where the biradical **7** can abstract the hydrogen atom effectively from *n*-Bu_3SnH, thus promoting the decomposition of **1**. However, we can not rule out the possibility that the decomposition of **1** was induced by a radical species generated by decomposition of *n*-Bu_3SnH. Incidentally, no ESR signal appeared in a solution of dithiirane 1-oxide **1** up to 40 °C,[31] as Block did not observe any ESR signals in a photochemical reaction of EtS(O)SMe in which homolysis of the S(O)–S bond was proved by other experiments.[19]



It was reported that activation parameters, $\Delta H^{\neq}$ and $\Delta S^{\neq}$, for the homolytic cleavage of the S(O)–S bond of PhS(O)SPh were 34.5 kcal mol^{-1} and 12.1 cal deg^{-1} (80 °C), respectively,[20] and the experimental bond energy of the S(O)–S bond of MeS(O)SMe was 46 kcal mol^{-1}.[32] The much lower $\Delta H^{\neq}$ of the present racemization ($\Delta H^{\neq}$ = 24.3 kcal mol^{-1}) would be reasonably explained in terms of the large ring strain of the three-membered ring.

The concerted mechanism (Path B) is seemingly less probable compared with that of the biradical mechanism, although we do not have any experimental evidence at the present stage to exclude this mechanism. If the oxygen migration of dithiirane 1-oxide **1** proceeds through a highly strained transition state like **9** with such a low activation energy, 1,2-oxygen shift of *S*-oxide derivatives of five-membered di- and trisulfides, such as **12** and **13**, should take place more or at least equally easily. However, the dithiolane 1-oxide **12** is stable up to 166 °C[33] and benzotrithiole 2-oxide **13** isomerizes to the 1-oxide **14** only photochemically.[21] These facts are in agreement with an idea that the ring size of substrates controls the oxygen migration and the S(O)-S bond of the three-membered dithiirane 1-oxide is considerably weakened by the large ring strain.



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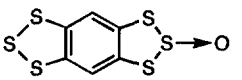

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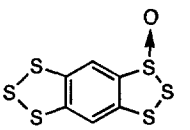
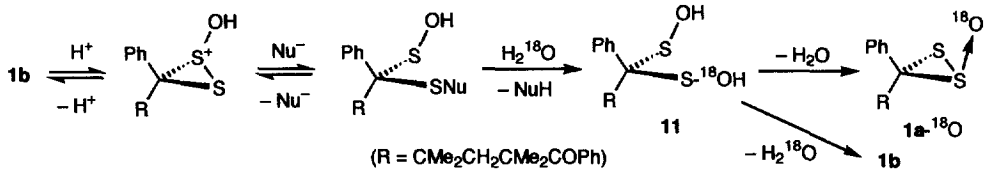


14

On the other hand, the enantiomers of **2** were optically stable in contrast to those of **1**. This is probably attributed to the steric hindrance due to the bulky tertiary alkyl substituent cis to the oxygen atom, which hinders the approach of the oxygen of the other sulfur atom.

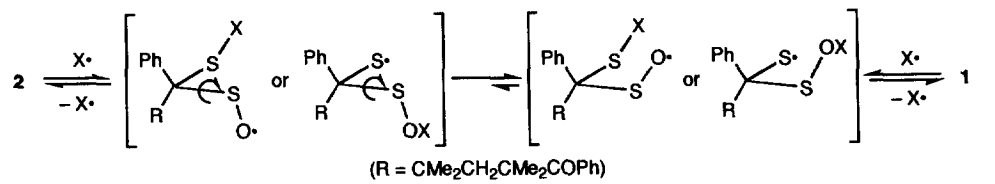
Incidentally, there is a suspicion that the racemization is either induced by adsorption on the surface of a glass vessel or catalyzed by a contaminating acidic material and a trace amount of water. In a dichloromethane solution of **1b** in a Teflon® vessel, however, the racemization proceeded at a rate similar to that in a glass vessel. Kice reported the nucleophile- and acid-catalyzed ^{18}O exchange reactions of PhS(^{18}O)SPh in 60% dioxane.[34] If this is also the case in the present reaction, the reaction in the presence of $H_2{}^{18}O$ proceeds as

shown in Scheme 2 and ^{18}O should be taken into the dithiirane 1-oxide **1** through the *gem*-disulfenic acid intermediate **11**. But, none of ^{18}O was introduced into **1** on standing a solution of dithiirane 1-oxide **1b** in dichloromethane wetted with $H_2{}^{18}O$.



Scheme 2

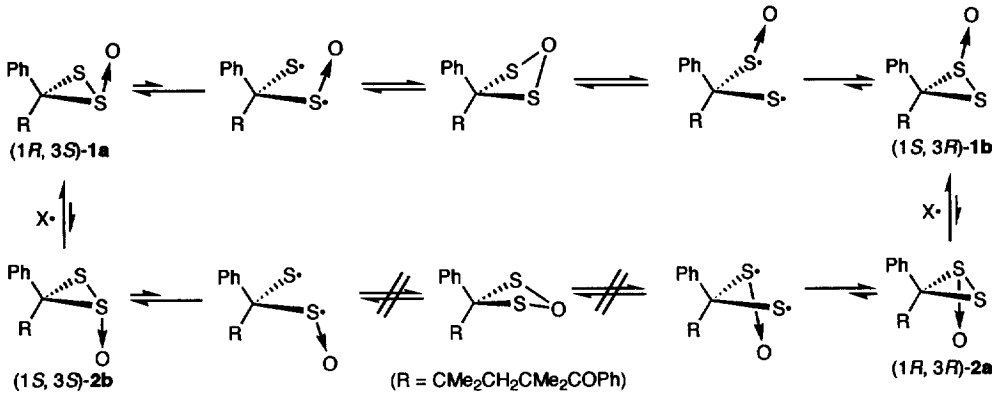
Isomerization (inversion at the sulfinyl sulfur) between (1RS, 3SR)- (1) and (1RS, 3RS)- (2) dithiirane 1-oxides. When a solution of a 9:91 mixture of **1** and **2** in $CDCl_3$ (c = 5.4×10^{-3} mol dm^{-3}) or C_6D_6 (c = 1.4×10^{-2} mol dm^{-3}) was stood at 30 °C, the molar ratio changed to 52:48 after 15 d or 96:4 after 4 d, respectively, indicating that **1** is thermodynamically more stable than **2**. Although kinetic experiments of the isomerization did not give reproducible results, the isomerization of **2** to **1** was faster in a more concentrated solution and was retarded in the dark though not much. Furthermore, the isomerization of **2** to **1** was completely inhibited by addition of DPPH to the solution, which shows that the isomerization is catalyzed by a contaminating radical species represented as X• in Scheme 3. This mechanism is in harmony with the stereospecific isomerization between **1** and **2** mentioned above.



Scheme 3

CONCLUSION

We have succeeded in optical resolution of (1*RS*, 3*SR*)- (**1**) and (1*RS*, 3*RS*)- (**2**) dithiirane 1-oxides by HPLC equipped with a chiral column and determined absolute configurations of the four stereoisomers. We found that enantiomeric (1*R*, 3*S*)- (**1a**) and (1*S*, 3*R*)- (**1b**) dithiirane 1-oxides racemize to each other, whereas (1*R*, 3*R*)- (**2a**) and (1*S*, 3*S*)- (**2b**) dithiirane 1-oxides do not. As to the racemization (oxygen migration), we propose a mechanism involving homolysis of the S(O)–S bond at the rate-controlling step. We also found that isomerization between **1** and **2** takes place and is catalyzed by a radical species. The whole interconversion among the four stereoisomers is summarized in Scheme 4.



Scheme 4

Acknowledgment. This work was supported by a Grant-in-Aid for Scientific Research No. 08640669 from the Ministry of Education, Science, Sports and Culture of Japan. The authors wish to thank Saneyoshi Scholarship Foundation for the financial support.

EXPERIMENTAL

General. Melting points were determined on a Mel-Temp capillary tube apparatus and are uncorrected. ^{1}H-NMR spectra were measured on a Bruker AM400 (400 MHz) or a Bruker AC200 (200 MHz) spectrometers. Optical rotations were measured on a JASCO DIP-370 digital polarimeter and circular dichroism spectra on a JASCO J-600 spectropolarimeter.

Dithiirane 1-oxides **1** and **2** were prepared by oxidation of dithiirane **4** with MCPBA or dimethyldioxirane[35] as reported previously.[13a,d]

HPLC procedure. The HPLC was performed by a system equipped with a Hitachi 655 liquid chromatograph, a Hitachi 638-41 variable wavelength UV monitor, and a Hitachi 833A data processor. For the optical resolution of dithiirane 1-oxides **1** and **2** and the analysis of racemization was used a chiral column, CHIRALPAK AD (4.6 mm i.d. × 250 mm; Daicel Chemical Industries, Ltd.) and for the separation of a mixture of **1** and **2** was used a packed SiO_2 column, INERTSIL PREP-SIL (10 mm i.d. × 250 mm, GC Sciences Inc.). All separations and analyses were carried out at room temperature.

Optical resolution of (1RS, 3SR)-dithiirane 1-oxide 1. An aliquot (ca. 0.5 ml) of a saturated solution of **1** (50 mg) in hexane-EtOH (85:15) was subjected to HPLC (hexane-EtOH 85:15 as the eluent). Each of the separated enantiomers was collected in a round-bottom flask cooled by an ice-water bath and the solvent was removed under reduced pressure. Accumulation of 34 runs of these operations gave 22 mg of **1a** (the first fraction) and 21 mg of **1b** (the second one). The colorless solids were washed with hexane several times and then recrystallized from hexane-dichloromethane by cooling in a freezer.

(1*R*, 3*S*)-3-Phenyl-3-(1,1,3,3-tetramethyl-4-oxo-4-phenylbutyl)dithiirane 1-oxide (**1a**): colorless crystals, m.p. 112—115 °C decomp (hexane-dichloromethane). $[\alpha]_D$ (22 °C) = –210° (*c* 0.305, $CHCl_3$). CD: λ_{max} (θ): 307 (-4.5×10^3), 270 (4.4×10^3), and 229 (7.2×10^4) (*c* = 1.1×10^{-4} mol dm^{-3}, hexane-EtOH 98:2).

Optical purity (determined by HPLC) and chemical purity (determined by ^{1}H NMR) of the crystals were 97.1% ee and 87%, respectively.

X-Ray Crystal Structure Determination of **1a**. *X-ray data* for **1a**: $C_{21}H_{24}O_2S_2$, M_w 372.5. Crystal size, 0.42 × 0.30 × 0.22 mm, triclinic, space group *P*1 (No.1), a = 10.080(3), b = 10.351(2), c = 10.249(4) Å, α = 86.41(2), β = 68.93(2), γ = 71.26(2)°, V = 959.9(4)Å^3, D_c = 1.29 g cm^{-3}, Z = 2, F(000) = 395, μ(Cu-Kα) = 25.467 cm^{-1}. Mac Science MXC3K diffractometer with graphite-monochromated Cu-Kα radiation (λ = 1.54178 Å), ω-2θ scan method in the range 3° < 2θ < 140°, 4088 reflections measured, 3650 unique reflections. The structure was solved by direct methods using SIR92[36] in the CRYSTAN GM program system and refined by a full-matrix least-squares method using 3327 reflections [$I \geq 3\sigma(I)$] for 637 parameters. The non-hydrogen atoms were refined anisotropically. The final R , R_w , and η values are 0.0580, 0.0587, and 0.791, respectively.

(1*S*, 3*R*)-3-Phenyl-3-(1,1,3,3-tetramethyl-4-oxo-4-phenylbutyl)dithiirane 1-oxide (**1b**): colorless crystals, m.p. 113—115 °C decomp (hexane-dichloromethane). [α]$_D$ (22 °C) = +226° (*c* 0.305, $CHCl_3$). CD: λ_{max} (θ): 306 (3.7×10^3), 270 (–4.6×10^3), and 229 (6.3×10^4) (*c* = 1.1×10^{-4} mol dm^{-3}, hexane-EtOH 98:2). Optical purity (HPLC) and chemical purity (^{1}H NMR) of the crystals were 95.5% ee and 93%, respectively.

X-Ray Crystal Structure Determination of **1b**. *X-ray data* for **1b**: $C_{21}H_{24}O_2S_2$, M_w 372.5. Crystal size, 0.50 × 0.28 × 0.26 mm, triclinic, space group *P*1 (No.1), a = 10.087(2), b = 10.337(3), c = 10.439(2) Å, α = 86.32(2), β = 68.82(2), γ = 71.25(2)°, V = 959.4(4)Å^3, D_c = 1.29 g cm^{-3}, Z = 2, F(000) = 395, μ(Cu-Kα) = 25.479 cm^{-1}. Mac Science MXC3K diffractometer with graphite-monochromated Cu-Kα radiation (λ = 1.54178 Å), ω-2θ scan method in the range 3° < 2θ < 140°, 4187 reflections measured, 3643 unique reflections. The structure was solved by direct methods using SIR92[36] in the CRYSTAN GM program system and refined by a full-matrix least-squares method using 3476 reflections [$I \geq 3\sigma(I)$] for 637 parameters. The non-hydrogen atoms were refined anisotropically. The final R , R_w , and η values are 0.0498, 0.0516, and 0.895, respectively.

Optical resolution of (1RS, 3RS)-dithiirane 1-oxide 2. In a manner similar to the case of **1**, 12 mg of **2** was resolved and 5 mg of **2a** (the first fraction) and 5 mg of **2b** (the second one) were obtained as accumulation of 13 runs. Each of the colorless solids was further purified by HPLC (silica gel, CH_2Cl_2 as the eluent) to give 4.3 mg of **1a** and 4.2 mg of **1b**, which were recrystallized from hexane-dichloromethane by cooling in a freezer.

(1*R*, 3*R*)-3-Phenyl-3-(1,1,3,3-tetramethyl-4-oxo-4-phenylbutyl)dithiirane 1-oxide (**2a**): colorless crystals, m.p. 104—106 °C decomp (hexane-dichloromethane). The exact specific rotation value of **2a** could not be determined because of decomposition except that it has a negative sign.

(1*S*, 3*S*)-3-Phenyl-3-(1,1,3,3-tetramethyl-4-oxo-4-phenylbutyl)dithiirane 1-oxide (**2b**): colorless crystals, m.p. 107—109 °C decomp (hexane-dichloromethane). [α]$_D$ (22 °C) = +98° (*c* 0.100, $CHCl_3$, ≈100% ee).

Kinetics. The racemization and isomerization reactions were carried out in a glass vessel under air unless otherwise noted. Progress of the racemization was traced by HPLC (hexane-EtOH 98:2 as the eluent) at appropriate intervals until the optical purity decreased to 5—10% ee and that of isomerization by ^{1}H NMR. Racemization of **1b** in the presence of DPPH at 25 °C was traced by taking up an aliquot of the solution after 48.5 and 72 h followed by measuring ^{1}H NMR with (*R*)-(–)-*N*-(3,5-dinitrobenzoyl)-α-phenylethylamine as the chiral shift reagent.[37]

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