Supporting Information

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Regioselective Hydroxysulfenylation of α,β-Unsaturated Imines: Enhanced Stability of an Intermediate Radical

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We investigated the hydroxysulfenylation of oxime ether 10 using several radical initiator (Table 1). Triethylborane was proved to be optimal radical initiator for this reaction (entry 1). No reaction was observed when Et2Zn[1] was employed as an initiator (entry 2). In the case of 9-BBN[2], β-hydroxysulfide 13a was obtained in 41% yield (entry 3). The use of Me3Al and Et2Zn[3] resulted in a deterioration in the yield of β-hydroxysulfide 13a (entries 4 and 5).

Table 1. Reaction of 10 using several radical initiator.

<table>
<thead>
<tr>
<th>Entry</th>
<th>Initiator (eq)</th>
<th>Yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Et3B (0.5)</td>
<td>75</td>
</tr>
<tr>
<td>2</td>
<td>Et2Zn (0.5)</td>
<td>Not detected</td>
</tr>
<tr>
<td>3</td>
<td>9-BBN (0.5)</td>
<td>41</td>
</tr>
<tr>
<td>4</td>
<td>Me3Al (0.5)</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>V-70 (1.2)</td>
<td>12</td>
</tr>
</tbody>
</table>

To study the reactivity of oxime ether 10, a competition experiment using aldehyde 9 and oxime ether 10 was conducted under the hydroxysulfenylation reaction conditions (Scheme 1). After being stirred at the room temperature for 0.5 h, the Michael adduct 12 in 40% and β-hydroxysulfide 13a in 11%. This result suggests that α,β-unsaturated aldehyde has higher reactivity toward non-radical Michael addition and radical hydroxysulfenylation of α,β-unsaturated oxime ether is slow reaction. Thus, the suppression of competitive Michael addition was essential to achieve radical hydroxysulfenylation.

Scheme 1. Crossover experiment using 9 and 10.

To a solution of triethylborane in CDCl3 was added thiophenol at the room temperature. Triethylborane immediately reacted with thiophenol to give PhSBEt3 via radical reaction pathway. We confirmed the formation of PhSBEt3 by 1H-NMR experiment (Scheme 2).

Scheme 2. 1H NMR of PhSBEt3 4.
It is assumed that PhSBEt$_2$ 4 acts as a promoter for the reduction of hydroperoxide with thiophenol. To gain further insight into the reaction mechanism, we examined the effect of PhSBEt$_2$ 4 on the reduction of hydroperoxide by using $t$-butyl hydroperoxide (Table 2). Reactions were run in CH$_2$Cl$_2$ at the room temperature for 15 h. In the absence of triethylborane, the conversion of thiophenol to diphenyl disulfide $^{17}$ is 70% (entry 1). The reduction of $t$-butyl hydroperoxide was accelerated by using triethylborane (0.5 eq.) as an additive to give diphenyl disulfide $^{17}$ in 100% conversion (entry 2).

**Table 2. Reactivity of PhSH toward reduction in the presence of Et$_3$B.**

<table>
<thead>
<tr>
<th>Entry</th>
<th>Et$_3$B (eq)</th>
<th>PhSH : PhSSPh $^{17}$</th>
<th>Conversion to $^{17}$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>none</td>
<td>3 : 1</td>
<td>70</td>
</tr>
<tr>
<td>2</td>
<td>0.5</td>
<td>1 : 1</td>
<td>100</td>
</tr>
</tbody>
</table>

The relative configuration of $\beta$-hydroxysulfides *anti*-13a and *syn*-13a was deduced from NOESY experiments of $\gamma$-lactams *cis*-16 and *trans*-16, which were prepared from *anti*-13a and *syn*-13a (Figure 1).

**Figure 1.** NOESY experiments of *cis*-16 and *trans*-16.

Diastereoselectivity and anti/syn-selectivity of oxime ether $^{28}$ were confirmed by reduction of oxime ether group, because oxime ether $^{28}$ was obtained as a 5:1 mixture of $E$- and $Z$-isomers (Scheme 3). Treatment of oxime ether $^{28}$ with NaBH$_3$CN under acidic conditions gave amine $^{35}$ as a single isomer.

**Scheme 3.** Reduction of oxime ether $^{28}$.

The relative configuration of *trans*-31, *cis*-31, 32, 33, and 34 was deduced from NOESY experiments, coupling constant analysis, the reduction of *cis*-31 into *cis*-36 and the transformation of 33 into 34 under radical reaction conditions (Figure 2).
Figure 2. Determination of relative configuration, NOESY experiments and coupling constant analysis.

References

General. Melting points are uncorrected. $^1$H and $^{13}$C NMR spectra were recorded at 300 or 500 MHz and at 75 or 125 MHz, respectively. IR spectra were recorded using FTIR apparatus. Mass spectra were obtained by EI or CI method. Medium-pressure column chromatography was performed using Lobar größe B (E. Merck 310-25, Lichroprep Si60).
General Procedure for Preparation of Oxime Ethers.

To a solution of aldehyde or ketone (8.0 mmol) in pyridine (50 mL) were added BnONHCl (1.4 g, 8.8 mmol) under N₂ atmosphere at room temperature. After being stirred at the same temperature for 1 h, the reaction mixture was diluted with 10% HCl and extracted with Et₂O. The organic phase was washed with saturated NaCl, dried over MgSO₄ and concentrated under reduced pressure. The crude product was purified by medium-pressure column chromatography (hexane:AcOEt = 20:1-10:1) to afford the corresponding oxime ethers.

Peaks of ¹³C NMR of E-20f, 14, 13b-d, 21a-c, 21f, and 28 could not be assigned due to overlap and isomers. The ¹³C NMR charts of these compounds were added at the end of supporting information.

2-Cyclohexenone (E)-O-(Phenylmethyl)oxime (7)

According to general procedure, oxime ethers E-7 (55%) and Z-7 (37%) were prepared from 2-cyclohexenone.

E-7: a colorless oil. IR νmax cm⁻¹: 3012, 2990, 2933, 2873, 1455. ¹H-NMR δ: 7.98-7.28 (5H, m), 6.21 (1H, dt, J=10.0, 4.0 Hz), 6.12 (1H, dt, J=10.0, 2.0 Hz), 5.12 (2H, s), 2.61 (2H, t, J=6.5 Hz), 2.15 (2H, tdd, J=6.5, 4.0, 2.0 Hz), 1.72 (2H, quint, J=6.5 Hz). ¹³C-NMR δ: 155.9, 137.9, 136.1, 128.2, 127.5, 124.3, 75.7, 24.9, 22.9, 20.7. HRMS m/z: Calcd for C₁₅H₁₄NO (M⁺) 237.1154, Found: 237.1137.

Z-7: a colorless oil. IR νmax cm⁻¹: 3012, 2988, 2933, 2872, 1455. ¹H-NMR δ: 7.39-7.24 (5H, m), 6.79 (1H, dt, J=10.0, 2.0 Hz), 6.27 (1H, dt, J=10.0, 4.0 Hz), 5.09 (2H, s), 2.38 (2H, t, J=6.5 Hz), 2.20 (2H, tdd, J=6.5, 4.0, 2.0 Hz), 1.82 (2H, quint, J=6.5 Hz). ¹³C-NMR δ: 153.1, 139.5, 138.1, 128.2, 127.8, 117.5, 75.4, 28.2, 26.2, 22.2. HRMS m/z: Calcd for C₁₅H₁₄NO (M⁺) 201.1154, Found: 201.1149.

4-(Phenlymethy)imino]-2-butenoic Acid Ethyl Ester (10).

According to general procedure, oxime ethers (2E, 4E)-10 (83%) and (2E, 4Z)-10 (3%) were prepared from corresponding aldehyde.

(2E, 4E)-10: a colorless oil. IR νmax cm⁻¹: 3030, 1712. ¹H-NMR δ: 7.86 (1H, dd, J=10.0, 0.5 Hz), 7.38-7.25 (5H, m), 7.22 (1H, dd, J=15.5, 10.0 Hz), 6.11 (1H, dd, J=15.5, 0.5 Hz), 5.17 (2H, s), 4.20 (2H, q, J=7.0 Hz), 1.29 (3H, t, J=7.0 Hz). ¹³C-NMR δ: 165.7, 148.3, 137.3, 136.7, 128.4, 128.3, 128.2, 127.0, 76.9, 60.7, 14.1. HRMS m/z: Calcd for C₁₃H₁₅NO₂ (M⁺) 233.1052, Found: 233.1069.

(2E, 4Z)-10: a colorless oil. IR νmax cm⁻¹: 3020, 1715. ¹H-NMR δ: 7.76 (1H, dd, J=16.0, 10.0 Hz), 7.38-7.30 (5H, m), 7.20 (1H, d, J=10.0 Hz), 6.12 (1H, d, J=16.0 Hz), 5.21 (2H, s), 4.24 (2H, q, J=7.0 Hz), 1.30 (3H, t, J=7.0 Hz). ¹³C-NMR δ: 165.9, 148.2, 145.5, 137.1, 129.7, 128.4, 128.2, 128.0, 76.8, 60.9, 14.1. HRMS m/z: Calcd for C₁₃H₁₅NO₂ (M⁺) 233.1052, Found: 233.1061.

(E)-2-Butenyl O-(Phenylmethyl)oxime (20a)

According to general procedure, oxime ethers E-20a (59%) and Z-20a (26%) were prepared from crotonaldehyde.

E-20a: a colorless oil. IR νmax cm⁻¹: 3014, 2939, 2917, 1651, 1455. ¹H-NMR δ: 7.74 (1H, d, J=9.3 Hz), 7.37-7.27 (5H, m), 6.14 (1H, ddd, J=15.6, 9.3, 1.5 Hz), 5.98 (1H, dq, J=15.6, 6.6 Hz), 5.08 (2H, s), 1.81 (3H, dd, J=6.6, 1.5 Hz). ¹³C-NMR δ: 150.7, 137.5, 137.0, 128.2, 128.0, 127.7, 125.1, 75.7, 18.3. HRMS m/z: Calcd for C₁₃H₁₅NO (M⁺) 175.0997, Found: 175.0987.

Z-20a: a colorless oil. IR νmax cm⁻¹: 3010, 1647, 1455. ¹H-NMR δ: 7.36-7.22 (5H, m), 6.99 (1H, d, J=9.5 Hz), 6.72 (1H, ddd, J=15.5, 9.5, 1.5 Hz), 6.08 (1H, dq, J=15.5, 7.0 Hz), 5.12 (2H, s), 1.83 (3H, dd, J=7.0, 1.5 Hz). ¹³C-NMR δ: 148.4, 139.1, 137.9, 128.3, 127.9, 127.7, 120.7, 75.9, 18.4. HRMS m/z: Calcd for C₁₃H₁₅NO (M⁺) 175.0997, Found: 175.1016.

3-Phenyl-2-propenal O-(Phenylmethyl)oxime (20b).

According to general procedure, oxime ethers E-20b (50%) and Z-20b (15%) were prepared from trans-3-phenyl-2-propenal.

E-20b: a colorless crystal. mp 78-81 °C (hexane:AcOEt). IR νmax cm⁻¹: 3011, 1451, 1160. ¹H-NMR δ: 7.91 (1H, d, J=9.5 Hz), 7.38-7.22 (10H, m), 6.81 (1H, dd, J=16.0, 9.5 Hz), 6.69 (1H, d, J=16.0 Hz), 5.13 (2H, s). ¹³C-NMR δ: 150.9, 138.4, 137.4, 135.9, 128.7, 128.3, 128.2, 127.8, 126.8, 121.9, 76.1. One peak of ¹³C NMR was missing due to overlap. HRMS m/z: Calcd for C₁₄H₁₂NO (M⁺) 237.1154, Found: 237.1137. Anal. Calcd for C₁₄H₁₂NO: C, 80.98; H, 6.37; N, 5.90. Found: C, 80.84; H, 6.42; N, 5.88.
Z-20b: a colorless oil. IR ν max cm⁻¹: 3060, 1451. ¹H-NMR δ: 7.49 (1H, dd, J=8.0, 2.0 Hz), 7.42-7.20 (11H, m), 6.83 (1H, d, J=16.0 Hz), 5.20 (2H, s). ¹³C-NMR δ: 148.3, 139.8, 137.8, 135.7, 129.2, 128.7, 128.3, 128.0, 127.8, 127.4, 116.3, 76.2. HRMS m/z: Calcd for C₁₆H₁₅NO (M⁺) 237.1154, Found: 237.1161.

4-[(Phenylmethoxy)imino]-3-methyl-2-butennoic Acid Ethyl Ester (20d).

\[
\text{EtO}_2\text{C} \quad \text{NOBn} \\
\text{20d}
\]

According to general procedure, oxime ether 20d (79%) was prepared from (2E)-4-oxo-3-methyl-2-butennoic acid ethyl ester. a colorless oil. IR ν max cm⁻¹: 2978, 2934, 1711, 1234. ¹H-NMR δ: 7.73 (1H, s), 7.39-7.29 (5H, m), 5.87 (1H, s), 5.17 (2H, s), 4.18 (2H, q, J=7.0 Hz), 2.32 (3H, s), 1.28 (3H, t, J=7.0 Hz). ¹³C-NMR δ: 165.9, 151.8, 147.9, 136.9, 128.4, 128.3, 123.7, 77.2, 76.8, 76.6, 60.0, 14.1, 13.0. HRMS m/z: Calcd for C₁₄H₁₇NO₃ (M⁺) 247.1208, Found: 247.1182.

(E)-3-Pentene-2-one O-(Phenylmethyl)oxime (20e).

\[
\text{Ph} \quad \text{S} \quad \text{NOBn} \\
\text{20e}
\]

According to general procedure, oxime ethers E-20e (57%) and Z-20e (31%) were prepared from 3-pentene-2-one. E-20e: a colorless oil. IR ν max cm⁻¹: 3013, 2917, 1454, 1368. ¹H-NMR δ: 7.37-7.16 (5H, m), 6.14 (1H, br d, J=15.8 Hz), 5.99 (1H, dq, J=15.8, 6.2 Hz), 5.11 (2H, s), 1.94 (3H, s), 1.78 (3H, d, J=6.2 Hz). ¹³C-NMR δ: 155.6, 138.0, 130.5, 128.8, 128.2, 127.8, 127.5, 75.6, 18.2, 10.2. HRMS m/z: Calcd for C₁₂H₁₅NO (M⁺) 189.1154, Found: 189.1180.

(Z)-3-Pentene-2-one O-(Phenylmethyl)oxime (20f).

According to general procedure, oxime ethers E-20f (24%, 2 steps) and Z-20f (16%, 2 steps) were prepared from 3-phenylthio-2-propenal, which was synthesized from acrolein by the method described in literature.\(^5\) Oxime ethers E-20f was obtained as a 4:1 mixture of olefinic E- and Z-isomers. E-20f: a colorless oil. IR ν max cm⁻¹: 3062, 3032, 2929, 1557, 1479. ¹H-NMR δ: 8.22 (1/5H, dd, J=10.0, 1.0 Hz), 7.79 (4/5H, dd, J=10.0, 1.5 Hz), 7.44-7.28 (10H, m), 6.71 (4/5H, dd, J=15.0, 1.5 Hz), 6.64 (1/5H, dd, J=10.0, 1.0 Hz), 6.28 (1/5H, br t, J=10.0 Hz), 6.15 (4/5H, dd, J=15.0, 10.0 Hz), 5.15 (2/5H, s), 5.06 (8/5H, s). HRMS m/z: Calcd for C₁₆H₁₅NOS (M⁺) 269.0874, Found: 269.0853.

(Z)-3-Pentene-2-one O-(Phenylmethyl)oxime (20g).

According to general procedure, oxime ethers E-20g (57%) and Z-20g (31%) were prepared from 3-pentene-2-one. E-20g: a colorless oil. IR ν max cm⁻¹: 3013, 2917, 1454, 1368. ¹H-NMR δ: 7.37-7.16 (5H, m), 6.14 (1H, br d, J=15.8 Hz), 5.99 (1H, dq, J=15.8, 6.2 Hz), 5.11 (2H, s), 1.94 (3H, s), 1.78 (3H, d, J=6.2 Hz). ¹³C-NMR δ: 155.6, 138.0, 130.5, 128.8, 128.2, 127.8, 127.5, 75.6, 18.2, 10.2. HRMS m/z: Calcd for C₁₂H₁₅NO (M⁺) 189.1154, Found: 189.1180.

2-Cyclopentenone O-(Phenylmethyl)oxime (23).

\[
\text{NOBn} \\
\text{23}
\]

According to general procedure, oxime ethers E-23 (73%) and Z-23 (19%) were prepared from 2-cyclopentenone. E-23: a colorless oil. IR ν max cm⁻¹: 2912, 1361. ¹H-NMR δ: 7.40-7.25 (10H, m), 6.71 (4/5H, dd, J=10.0, 1.0 Hz), 7.44-7.28 (10H, m), 5.12 (2H, s), 2.68 (2H, m), 2.35 (2H, m). ¹³C-NMR δ: 168.3, 146.6, 138.3, 128.7, 128.3, 127.8, 127.6, 75.7, 30.9, 25.3. HRMS m/z: Calcd for C₁₆H₁₅NO (M⁺) 269.0874, Found: 269.0853.

Z-23: a colorless oil. IR ν max cm⁻¹: 2917, 1451, 1363. ¹H-NMR δ: 7.38-7.22 (5H, m), 6.69 (1H, dt, J=6.0, 3.5 Hz), 6.60 (1H, dt, J=6.0, 2.0 Hz), 5.08 (2H, s), 2.60-2.47 (4H, m). ¹³C-NMR δ: 165.4, 148.4, 138.3, 128.2, 127.8, 127.5, 124.3, 75.4, 29.9, 26.5. HRMS m/z: Calcd for C₁₆H₁₅NO (M⁺) 269.0874, Found: 269.0873.

3-Methylenebicyclo[2.2.1]heptan-2-one O-(Phenylmethyl)oxime (24).

\[
\text{NOBn} \\
\text{24}
\]

According to general procedure, oxime ethers E-24 (75%) and Z-24 (21%) were prepared from 3-methylene-2-norbornanone.
**E-24**: a colorless oil. IR ν max cm⁻¹: 2967, 2874, 1453, 1365. ¹H-NMR δ: 7.39-7.27 (5H, m), 5.43 (1H, s), 5.12 (2H, s), 4.90 (1H, s), 3.55 (1H, br s), 2.89 (1H, br s), 1.80-1.67 (2H, m), 1.52 (1H, m), 1.50-1.42 (2H, m), 1.39 (1H, dt, J=10.0, 1.5 Hz). ¹³C-NMR δ: 162.2, 148.4, 138.2, 128.3, 128.0, 127.6, 103.4, 75.9, 44.3, 39.1, 38.2, 28.2, 25.4. HRMS m/z: Calcd for C₁₅H₁₇NO (M⁺) 227.1310, Found: 227.1294.

**Z-24**: a colorless oil. IR ν max cm⁻¹: 2966, 2874, 1453, 1365. ¹H-NMR δ: 7.38-7.27 (5H, m), 6.10 (1H, d, J=2.0 Hz), 5.38 (1H, d, J=2.0 Hz), 5.13 (2H, s), 2.91 (1H, br s), 2.84 (1H, br s), 1.81-1.73 (2H, m), 1.63 (1H, m), 1.55-1.43 (2H, m), 1.40 (1H, dt, J=10.0, 1.0 Hz). ¹³C-NMR δ: 159.8, 145.4, 137.9, 128.3, 127.7, 127.6, 116.1, 76.4, 46.2, 43.8, 39.4, 28.4, 26.6. HRMS m/z: Calcd for C₁₅H₁₇NO (M⁺) 227.1320.


According to general procedure, oxime ether 25 (98%) was prepared from (1R)-(-)-myrtenal.

5-(1-Hydroxy-1-methylethyl)-2-methyl-2-cyclohexenone O-(Phenylmethyl)oxime (26).

According to general procedure, oxime ether 26 (97%) was prepared from (S)(+)-5-(1-hydroxy-1-methylethyl)-2-methyl-2-cyclohexen-1-one.

5-(1-Methylethenyl)-2-methyl-cyclohexenone O-(Phenylmethyl)oxime (27).

According to general procedure, oxime ether 27 (76%) was prepared from (R)(-)-carvone.

(E)-4-[(Phenylmethoxy)imino]-2-butenoic Acid 1,1-Dimethylethyl Ester (20c).

A solution of furfural (25.52 g, 0.27 mol) and rose bengal (160 mg, 0.16 mmol) in methanol (480 ml) was bubbled by oxygen gas and the pink/orange solution irradiated by Hg lamp for 72 h.[1] The solution was concentrated under reduced pressure. To a solution of the crude product in water (85 mL) was added BnONH₃Cl (1.12 g, 7.03 mmol) under N₂ atmosphere at room temperature.[2] After being stirred at the same temperature for 1 h, the reaction mixture was diluted with AcOEt. The organic phase was washed with saturated NaCl, dried over MgSO₄ and concentrated under reduced pressure to give orange tinged solid. After a solution of crude product in concentrated HCl were stirred under N₂ atmosphere at room temperature for 4
h, the reaction mixture was neutralized with Na₂CO₃. The reaction mixture was diluted with AcOEt. The organic phase was washed with saturated NaCl, dried over MgSO₄ and concentrated under reduced pressure. To a solution of crude product (0.1 g, 0.49 mmol) in t-BuOH (5 mL) were added Boc₂O (0.23 mL, 0.98 mmol) and DMAP (30.5 mg, 0.25 mmol) under N₂ atmosphere at room temperature. After being stirred at the same temperature for 6 h, the reaction mixture was concentrated under reduced pressure. The crude product was purified by medium-pressure column chromatography (hexane:AcOEt = 10:1) to afford the corresponding oxime ether 20c (34%, 4 steps) as a colorless oil.

IR νmax cm⁻¹: 2978, 1709, 1303, 1259. ¹H-NMR δ: 7.83 (1H, d, J=10.0 Hz), 7.36-7.30 (5H, m), 7.19 (1H, dd, J=16.0, 10.0 Hz), 6.02 (1H, d, J=16.0 Hz), 5.16 (2H, s), 1.48 (9H, s). ¹³C-NMR δ: 164.9, 148.5, 136.8, 136.2, 129.2, 128.4, 128.3, 128.1, 80.9, 76.8, 28.0. HRMS m/z: Calcd for C₁₅H₁₉NO₃ (M⁺) 261.1365, Found: 261.1357.

(E)-4-(Diphenylhydrazono)-2-butenolic Acid Ethyl Ester (11).

To a solution of (2E)-4-oxo-2-butenolic acid ethyl ester (1.0 g, 7.8 mmol) in EtOH (25 mL) were added Ph₂NNH₃Cl (1.9 g, 8.6 mmol) and AcONa (0.7 g, 8.6 mmol) under N₂ atmosphere at room temperature. After being stirred at the same temperature for 15 h, the reaction mixture was diluted with saturated NaHCO₃ and extracted with CHCl₃. The organic phase was washed with saturated NaCl, dried over MgSO₄ and concentrated under reduced pressure. The crude product was purified by medium-pressure column chromatography (hexane:AcOEt = 10:1) to afford the corresponding oxime ether 11 (1.48 g, 65%) as a yellow crystal. mp 153-156 oC (hexane-AcOEt). IR νmax cm⁻¹: 3016, 1698, 1492, 1259. ¹H-NMR δ: 7.53 (1H, dd, J=16.0, 10.0 Hz), 7.46-7.38 (4H, m), 7.26-7.12 (6H, m), 6.90 (1H, d, J=10.0 Hz), 5.79 (1H, dd, J=16.0, 1.0 Hz), 4.20 (2H, q, J=7.0 Hz), 1.29 (3H, t, J=7.0 Hz). ¹³C-NMR δ: 166.7, 142.6, 142.1, 133.9, 129.8, 125.3, 121.4, 60.2, 14.2. HRMS m/z: Calcd for C₁₈H₁₈N₂O₂ (M⁺) 294.1368, Found: 294.1350.

Anal. Calcd for C₁₈H₁₈N₂O₂: C, 73.45; H, 6.16; N, 9.52, Found: C, 73.20; H, 6.31; N, 9.56.

General Procedure for Hydroxysulfenylation Reaction. To a solution of α,β-unsaturated oxime ether (0.5 mmol) in CH₂Cl₂ (6 mL) were added thiol (1.75 mmol) and Et₃B (1.0 M in hexane, 0.25 mL, 0.25 mmol) under dry air atmosphere at room temperature. After being stirred at the same temperature for 15 h, the reaction mixture was concentrated under reduced pressure. Purification of the residue by medium-pressure column chromatography (hexane:AcOEt = 10:1–4:1) afforded the corresponding β-hydroxysulfide.

2-Hydroxy-2-methyl-3-phenylthiopropanoic Acid Ethyl Ester (2).

According to general procedure for hydroxysulfenylation, hydroxysulfide 2 (46%) and sulfide 3 (33%) were obtained from α,β-unsaturated ethyl ester 1. a colorless oil. IR νmax cm⁻¹: 3505, 2978, 1731. ¹H-NMR δ: 7.44-7.39 (2H, m), 7.30-7.15 (3H, m), 4.12-4.00 (1H, m), 3.94-3.82 (1H, m), 3.57 (1H, s), 3.40 (1H, d, J=14.0 Hz), 3.20 (1H, d, J=14.0 Hz), 1.49 (3H, s), 1.15 (3H, t, J=7.0 Hz). ¹³C-NMR δ: 174.9, 135.8, 130.5, 128.8, 126.6, 74.5, 61.9, 44.9, 25.4, 13.9. HRMS m/z: Calcd for C₁₂H₁₆O₃S (M⁺) 240.0820, Found: 240.0846.

2-Methyl-3-phenylthiopropanoic Acid Ethyl Ester (3).

a colorless oil. IR νmax cm⁻¹: 3505, 2978, 1731. ¹H-NMR δ: 7.38-7.16 (5H, m), 4.12 (2H, q, J=7.0 Hz), 3.27 (1H, dd, J=13.0, 7.0 Hz), 2.92 (1H, dd, J=13.0, 7.0 Hz), 2.67 (1H, m), 1.26 (3H, s), 1.24 (3H, d, J=1.0 Hz), 1.15 (3H, t, J=7.0 Hz). ¹³C-NMR δ: 174.7, 135.8, 129.9, 128.8, 126.3, 60.5, 39.6, 37.2, 2.92 (1H, dd, J=13.0, 7.0 Hz), 2.67 (1H, m), 1.26 (3H, s), 1.24 (3H, d, J=1.0 Hz), 1.15 (3H, t, J=7.0 Hz). ¹³C-NMR δ: 174.7, 135.7, 129.9, 128.8, 126.3, 65.0, 39.6, 37.2, 16.6, 14.1. HRMS m/z: Calcd for C₁₂H₁₆O₂S (M⁺) 224.0871, Found: 224.0878.

3-Phenylthiocyclohexanone (6).

Characterization data were reported.

2-Hydroxy-3-phenylthiocyclohexanone O-(Phenylmethyl)oxime (8).
According to general procedure for hydroxysulfenylation, **trans-8** (74%) and **cis-8** (11%) were obtained.

**trans-8**: a colorless oil. IR ν\textsubscript{max} cm\textsuperscript{-1}: 3494. \textsuperscript{1}H-NMR δ: 7.52-7.50 (2H, m), 7.36-7.25 (8H, m), 5.11 (2H, s), 3.98 (1H, d, J=9.5 Hz), 3.63 (1H, br s), 3.16 (1H, m), 3.03 (1H, dd, J=11.0, 9.5, 4.0 Hz), 2.10 (1H, m), 1.80 (2H, m), 1.53 (1H, m), 1.37 (1H, m). \textsuperscript{13}C-NMR δ: 158.0, 137.4, 133.9, 132.7, 128.8, 128.3, 128.2, 127.9, 127.6, 76.2, 72.7, 54.7, 30.7, 23.9, 23.7. HRMS m/z: Caled for C\textsubscript{13}H\textsubscript{10}NO\textsubscript{2}S (M\textsuperscript{+}) 327.1293, Found: 327.1289.

**cis-8**: a white solid. IR ν\textsubscript{max} cm\textsuperscript{-1}: 3500. \textsuperscript{1}H-NMR δ: 7.47-7.44 (2H, m), 7.35-7.23 (8H, m), 5.11 (1H, d, J=12.0 Hz), 5.08 (1H, d, J=12.0 Hz), 4.24 (1H, t, J=3.5 Hz), 3.52 (1H, dt, J=9.5, 3.5 Hz), 3.03 (1H, d, J=3.5 Hz), 2.66 (1H, dt, J=14.5, 5.5 Hz), 2.51 (1H, d, J=14.5, 10.0, 5.0 Hz), 1.97-1.83 (3H, m), 1.51 (1H, m). \textsuperscript{13}C-NMR δ: 158.3, 137.6, 133.6, 132.4, 129.1, 128.3, 128.0, 127.8, 127.5, 75.8, 70.1, 54.5, 27.0, 23.3, 21.7. HRMS m/z: Caled for C\textsubscript{14}H\textsubscript{12}NO\textsubscript{2}S (M\textsuperscript{+}) 327.1293, Found: 327.1301.

4-Oxo-2-phenylthiobutanoic Acid Ethyl Ester (12).

According to general procedure for hydroxysulfenylation, β-sulfide 12 (92%) was obtained from 9.

3-Hydroxy-4-[(phenylmethoxy)imino]-2-phenylthiobutanoic Acid Ethyl Ester (13a).

**anti-13a**: a 3:1 mixture of E/Z isomers. A colorless oil. IR ν\textsubscript{max} cm\textsuperscript{-1}: 3521, 2254, 1731. \textsuperscript{1}H-NMR δ: 7.62 (3/4H, d, J=4.5 Hz), 7.48-7.19 (10H, m), 6.93 (1/4H, d, J=5.5 Hz), 5.13-5.05 (2H, m), 4.95 (1/4H, t, J=5.5 Hz), 4.62 (3/4H, dd, J=7.0, 4.5 Hz), 4.19-4.06 (2H + 1/4H, m), 3.81 (3/4H, d, J=7.0 Hz), 3.56 (1/4H, br s), 3.47 (3/4H, br s), 1.21 (3/4H, t, J=7.0 Hz). \textsuperscript{13}C-NMR δ: 170.8, 170.7, 151.2, 149.0, 137.1, 136.9, 133.4, 132.8, 132.4, 129.1, 129.0, 128.5, 128.4 (2C), 128.2 (2C), 128.1, 128.0, 76.7, 76.3, 69.7, 66.6, 61.8, 61.6, 54.2, 52.8, 13.9 (2C). Two peaks of \textsuperscript{13}C NMR were missing due to overlap. HRMS m/z: Caled for C\textsubscript{15}H\textsubscript{18}NO\textsubscript{3}S (M\textsuperscript{+}) 359.1191, Found: 359.1193.

**syn-13a**: a 3:1 mixture of E/Z isomers. A colorless oil. IR ν\textsubscript{max} cm\textsuperscript{-1}: 3533, 2253, 1730, 1370. \textsuperscript{1}H-NMR δ: 7.63 (3/4H, d, J=4.5 Hz), 7.50-7.43 (2H, m), 7.36-7.25 (8H, m), 6.99 (1/4H, d, J=4.5 Hz), 5.23 (1/4H, dd, J=4.5, 3.0 Hz), 5.08 (2H, s), 4.63 (3/4H, dd, J=5.0, 4.5 Hz), 4.22-4.04 (2H + 1/4H, m), 3.86 (3/4H, d, J=6.0 Hz), 3.72 (1/4H, br s), 3.35 (3/4H, br s), 1.20 (3/4H, t, J=7.0 Hz), 1.71 (9/4H, t, J=7.0 Hz). \textsuperscript{13}C-NMR δ: 171.9, 170.2, 151.2, 148.6, 137.2, 137.1, 133.4, 133.1, 132.5, 129.1, 129.0, 128.4 (2C), 128.2 (2C), 128.1, 127.9, 76.6, 76.3, 68.9, 66.4, 61.8, 61.6, 55.8, 53.7, 13.9 (2C). Three peaks of \textsuperscript{13}C NMR were missing due to overlap. HRMS m/z: Caled for C\textsubscript{15}H\textsubscript{18}NO\textsubscript{3}S (M\textsuperscript{+}) 359.1191, Found: 359.1196.


A 3:2 mixture of E/Z isomers was obtained.

(Z)-4-(Diphenylhydrazono)-3-hydroxy-2-phenylthiobutanoic Acid Ethyl Ester (14).
According to general procedure for hydroxysulfenylation, β-Hydroxysulfide 14 (71%) was obtained as a 4:1 mixture of *anti-* and *syn-* isomers.

A colorless oil. IR $\nu_{\text{max}}$ cm$^{-1}$: 3478, 1731. $^1$H-NMR $\delta$: 7.50-7.04 (15H, m), 6.67 (4/5H, d, $J=3.0$ Hz), 6.61 (1/5H, d, $J=3.0$ Hz), 4.70 (1H, m), 4.24-4.08 (2H, m), 3.95 (1/5H, d, $J=6.0$ Hz), 3.93 (4/5H, d, $J=6.0$ Hz), 3.79 (4/5H, d, $J=8.0$ Hz), 3.59 (1/5H, d, $J=4.0$ Hz), 1.19 (3H, t, $J=7.0$ Hz). HRMS $m/z$: Calcd for C$_{25}$H$_{37}$NO$_3$S ($M^+$) 420.1508, Found: 420.1500.

2-[(4-Chlorophenyl)thio]-3-hydroxy-4-[(phenylmethoxy)imino]butanoic Acid Ethyl Ester (13b)

According to general procedure for hydroxysulfenylation, a 6:1 mixture of *anti*-13b ($E:Z = 7:1$) and *syn*-13b ($E:Z = 7:1$) were obtained in 78% yield.

A colorless oil. IR $\nu_{\text{max}}$ cm$^{-1}$: 3467, 2983, 1731. $^1$H-NMR for *anti*,E-13b $\delta$: 7.60 (1H, d, $J=4.5$ Hz), 7.42-7.10 (9H, m), 5.08 (2H, s), 4.60 (1H, m), 4.20-4.02 (2H, m), 3.77 (1H, d, $J=7.0$ Hz), 3.47 (1H, br d, $J=7.0$ Hz), 1.20 (3H, t, $J=7.0$ Hz). HRMS $m/z$: Calcd for C$_{19}$H$_{20}$ClNO$_4$S ($M^+$) 393.0802, Found: 393.0796.

3-Hydroxy-2-[(4-hydroxyphenyl)thio]-4-[(phenylmethoxy)imino]butanoic Acid Ethyl Ester (13c)

According to general procedure for hydroxysulfenylation, a 6:1 mixture of *anti*-13c ($E:Z = 2:1$) and *syn*-13c ($E:Z = 2:1$) were obtained in 64% yield.

A colorless oil. IR $\nu_{\text{max}}$ cm$^{-1}$: 3396, 2983, 1717. $^1$H-NMR for *anti*,E-13c $\delta$: 7.65 (1H, d, $J=5.0$ Hz), 7.44-7.18 (7H, m), 6.76-6.61 (2H, m), 5.67 (1H, br m), 5.10 (2H, s), 4.55 (1H, m), 4.11 (2H, m), 3.64 (1H, d, $J=7.5$ Hz), 3.43 (1H, br m), 1.22 (3H, t, $J=7.0$ Hz). HRMS $m/z$: Calcd for C$_{19}$H$_{21}$NO$_5$S ($M^+$) 375.1140, Found: 375.1129.

2-(Dodecylthio)-3-hydroxy-4-[(phenylmethoxy)imino]butanoic Acid Ethyl Ester (13d)

According to general procedure for hydroxysulfenylation, *anti*-13d (38%) as a 3:1 mixture of E/Z isomers and *syn*-13d (6%) as a 11:1 mixture of E/Z isomers were obtained.

*anti*-13d: A colorless oil. IR $\nu_{\text{max}}$ cm$^{-1}$: 3451, 2923, 1728. $^1$H-NMR $\delta$: 7.63 (3/4H, d, $J=5.0$ Hz), 7.42-7.25 (5H, m), 6.92 (1/4H, d, $J=5.0$ Hz), 5.13 (2/4H, s), 5.09 (6/4H, s), 4.95 (1/4H, br m), 4.58 (3/4H, br m), 4.30-4.12 (2H, m), 3.62 (1/4H, d, $J=6.0$ Hz), 3.61 (1/4H, br m), 3.46 (3/4H, br d, $J=6.0$ Hz), 3.41 (3/4H, d, $J=7.0$ Hz), 2.62 (2/4H, t, $J=7.0$ Hz), 1.60-1.21 (23H, m), 0.89 (3H, br t, $J=7.0$ Hz). HRMS $m/z$: Calcd for C$_{25}$H$_{41}$NO$_4$S ($M^+$) 451.2756, Found: 451.2764.

*syn*-13d: A colorless oil. IR $\nu_{\text{max}}$ cm$^{-1}$: 3527, 2929, 1726. $^1$H-NMR $\delta$: 7.64 (11/12H, d, $J=5.0$ Hz), 7.37-7.28 (5H, m), 6.93 (1/12H, d, $J=5.0$ Hz), 5.12 (2/12H, s), 5.10 (22/12H, s), 4.95 (1/12H, m), 4.60 (11/12H, m), 4.23-4.11 (2H, m), 3.63 (1/12H, d, $J=6.0$ Hz), 3.53 (1/12H, d, $J=6.0$ Hz), 3.42 (11/12H, d, $J=7.0$ Hz), 3.33 (11/12H, d, $J=7.0$ Hz), 2.63 (2H, t, $J=7.5$ Hz), 1.66-1.22 (23H, m), 0.88 (3H, br t, $J=6.0$ Hz). HRMS $m/z$: Calcd for C$_{25}$H$_{41}$NO$_4$S ($M^+$) 451.2756, Found: 451.2772.

3-Hydroxy-3-phenylthiobutyraldehyde O-(Phenylmethyl)oxime (21a)

According to general procedure for hydroxysulfenylation, a 5:6 mixture of *anti*-21a ($E:Z = 4:1$) and *syn*-21a ($E:Z = >20:1$) were obtained in 61% yield.

A colorless oil. IR $\nu_{\text{max}}$ cm$^{-1}$: 3429, 2972. $^1$H-NMR for two major isomers $\delta$: 7.55 (1/2H, d, $J=5.0$ Hz), 7.52 (1/2H, d, $J=5.0$ Hz), 7.44-7.06 (10H, m), 5.12 (2/12H, s), 5.09 (6/12H, s), 4.95 (1/12H, m), 4.60 (11/12H, m), 4.23-4.11 (2H, m), 3.63 (1/12H, d, $J=6.0$ Hz), 3.53 (1/12H, d, $J=7.5$ Hz), 3.42 (11/12H, d, $J=7.0$ Hz), 3.33 (11/12H, d, $J=7.0$ Hz), 2.63 (2H, t, $J=7.5$ Hz), 1.66-1.22 (23H, m), 0.88 (3H, br t, $J=6.0$ Hz). HRMS $m/z$: Calcd for C$_{17}$H$_{19}$NO$_2$S ($M^+$) 301.1136, Found: 301.1158.

2-Hydroxy-3-phenyl-3-phenylthiopropenal O-(Phenylmethyl)oxime (21b)
According to general procedure for hydroxysulfenylation, a 3:1 mixture of anti-21b (E:Z = 8:1) and syn-21b (E:Z = 2:1) were obtained in 69% yield.

According to general procedure for hydroxysulfenylation, a 10:1 mixture of anti-21c (E:Z = 2:1) and syn-21c (E:Z = 2:1) were obtained in 70% yield.

According to general procedure for hydroxysulfenylation, 21d (71%) as a 3:2 mixture of stereoisomers was obtained.

According to general procedure for hydroxysulfenylation, anti-21e (60%) and syn-21e (3%) were obtained.

According to general procedure for hydroxysulfenylation, E-21f (39%) and Z-21f (33%) were obtained.

Hexahydro-8,8-dimethyl-1-[(4E/4Z)-3-hydroxy-2-phenylthio-4-[(phenylmethoxy)imino]butyl]-3H-3,6-methano-2,1-benzisothiazole 2,2-Dioxide (28)
According to general procedure for hydroxysulfenylation, 28 (70%) was obtained as a 5:1 mixture of E- and Z-isomers. A colorless oil. IR ν max cm⁻¹: 3494, 2961, 1687, 1333, 1210. ¹H-NMR δ: 7.62 (5/6H, d, J=5.0 Hz), 7.50-7.10 (10H, m), 6.97 (1/6H, d, J=5.0 Hz), 5.11 (1/6H, d, J=12.0 Hz), 5.10 (10/6H, s), 5.07 (1/6H, d, J=12.0 Hz), 4.92 (1/6H, m), 4.79 (1/6H, br s), 4.64 (5/6H, m), 4.45 (5/6H, br s), 3.93 (1/6H, br t), 3.74 (1H, br t), 3.47 (1H, d, J=14.0 Hz), 3.43 (1H, d, J=14.0 Hz), 3.23 (5/6H, br s), 2.05 (2H, m), 1.94-1.84 (3H, m), 1.40-1.31 (2H, m), 1.11 (3/6H, s), 1.09 (15/6, s), 0.96 (3H, s). Anal. Calcd for C₂₇H₃₂N₂O₅S₂: C, 59.32; H, 6.27; N, 5.12; Found: C, 59.75; H, 5.93; N, 5.14.

2-Hydroxy-3-phenylthiocyclopentanone O-(Phenylmethyl)oxime (29)

According to general procedure for hydroxysulfenylation, trans-29 (71%) and cis-29 (7%) were obtained. Trans-29: a colorless oil. IR ν max cm⁻¹: 3396. ¹H-NMR δ: 7.45-7.42 (2H, m), 7.34-7.21 (8H, m), 5.10 (2H, s), 4.31 (1H, d, J=6.0 Hz), 3.44 (1H, dd, J=13.5, 6.0 Hz), 3.03 (1H, br s), 2.56 (2H, m), 2.28 (1H, m), 1.71 (1H, m). ¹³C-NMR δ: 163.7, 137.6, 133.6, 132.1, 128.9, 128.3, 128.0, 127.8, 127.3, 76.15, 76.07, 52.2, 27.1, 24.9. HRMS m/z: Calcd for C₁₈H₁₉NO₂S (M⁺) 313.1136, Found: 313.1165.

cis-29: a colorless oil. IR ν max cm⁻¹: 3577. ¹H-NMR δ: 7.47-7.43 (2H, m), 7.37-7.23 (8H, m), 5.11 (1H, d, J=12.5 Hz), 5.08 (1H, d, J=12.5 Hz), 4.66 (1H, br d, J=5.5 Hz), 3.57 (1H, m), 3.30 (1H, br s), 2.61-2.48 (2H, m), 2.31 (1H, m), 1.74 (1H, dq, J₁=13.0, 8.0 Hz). ¹³C-NMR δ: 164.4, 137.1, 134.2, 132.4, 131.6, 129.0, 128.6, 128.2, 127.1, 76.4, 75.0, 51.6, 28.8, 28.3. HRMS m/z: Calcd for C₁₈H₁₉NO₂S (M⁺) 313.1136, Found: 313.1154.

Hydroxysulfenylation reaction of oxime ether E-24.
To a solution of oxime ether E-24 (113 mg, 0.5 mmol) in CH₂Cl₂ (6 mL) were added thiophenol (193 mg, 1.75 mmol) and Et₃B (1.0 M in hexane, 0.25 mL, 0.25 mmol) under air at room temperature. After being stirred at the same temperature for 1 h, the reaction mixture was concentrated under reduced pressure. Purification of the residue by medium-pressure column chromatography (hexane:AcOEt = 10:1) afforded the corresponding hydroxysulfide 30a (26.6 mg, 15%), more polar sulfide 30b (114 mg, 67%) and less polar sulfide 30b (4 mg, 3%).

2-Hydroxy-3-phenylthiobicyclo[2.2.1]heptane (E)-O-(Phenylmethyl)oxime (30a).

A colorless oil. IR ν max cm⁻¹: 3450, 2961, 1473. ¹H-NMR δ: 7.43-7.18 (10H, m), 5.08 (1H, d, J=12.0 Hz), 5.05 (1H, d, J=12.0 Hz), 3.40 (1H, br d, J=3.5 Hz), 3.32 (1H, d, J=14.0 Hz), 3.28 (1H, d, J=14.0 Hz), 2.72 (1H, m), 1.71 (1H, tt, J=12.0, 4.5 Hz), 1.56-1.51 (2H, m), 1.47 (1H, m), 1.37 (1H, dt, J=10.5, 1.0 Hz). ¹³C-NMR δ: 167.5, 137.9, 136.7, 129.8, 129.0, 128.3, 128.1, 127.8, 126.4, 79.0, 76.0, 44.5, 43.3, 39.3, 35.2, 26.6, 21.1. HRMS m/z: Calcd for C₂₁H₂₃NO₂S (M⁺) 353.1449, Found: 353.1451.

3-Phenylthiobicyclo[2.2.1]heptane (E)-O-(Phenylmethyl)oxime (30b).

A colorless oil. IR ν max cm⁻¹: 3450, 2961, 1473. ¹H-NMR δ: 7.43-7.18 (10H, m), 5.08 (1H, d, J=12.0 Hz), 5.05 (1H, d, J=12.0 Hz), 3.40 (1H, br d, J=3.5 Hz), 3.32 (1H, d, J=14.0 Hz), 3.28 (1H, d, J=14.0 Hz), 2.72 (1H, m), 2.52 (1H, br m), 2.06 (1H, m), 1.71 (1H, tt, J=12.0, 4.5 Hz), 1.56-1.51 (2H, m), 1.47 (1H, m), 1.37 (1H, dt, J=10.5, 1.0 Hz). ¹³C-NMR δ: 166.8, 137.8, 136.2, 128.8, 128.4 (2C), 128.2, 127.8, 125.5, 75.8, 43.8, 43.7, 38.5, 38.2, 30.2, 26.3, 22.0. HRMS m/z: Calcd for C₂₁H₂₃NO₂S (M⁺) 337.1500, Found: 337.1505.

3-Phenylthiobicyclo[2.2.1]heptane (E)-O-(Phenylmethyl)oxime (30b).

A colorless oil. IR ν max cm⁻¹: 3450, 2961, 1473. ¹H-NMR δ: 7.43-7.18 (10H, m), 5.08 (1H, d, J=12.0 Hz), 5.05 (1H, d, J=12.0 Hz), 3.40 (1H, br d, J=3.5 Hz), 3.32 (1H, d, J=14.0 Hz), 3.28 (1H, d, J=14.0 Hz), 2.72 (1H, m), 2.52 (1H, br m), 2.06 (1H, m), 1.71 (1H, tt, J=12.0, 4.5 Hz), 1.56-1.51 (2H, m), 1.47 (1H, m), 1.37 (1H, dt, J=10.5, 1.0 Hz). ¹³C-NMR δ: 166.8, 137.8, 136.2, 128.8, 128.4 (2C), 128.2, 127.8, 125.5, 75.8, 43.8, 43.7, 38.5, 38.2, 30.2, 26.3, 22.0. HRMS m/z: Calcd for C₂₁H₂₃NO₂S (M⁺) 337.1500, Found: 337.1505.
m), 1.51-1.48 (2H, m), 1.43-1.38 (2H, m), 1.30 (1H, m). 13C-NMR δ: 168.0, 138.3, 136.3, 129.2, 128.9, 128.2, 128.0, 127.6, 125.9, 75.5, 46.1, 40.2, 38.3, 37.6, 33.0, 26.6, 20.9. HRMS m/z: Calcd for C21H23NOS (M+) 337.1500, Found: 337.1496.

Hydroxysulfenylation reaction of oxime ether 25.

To a solution of oxime ether 25 (128 mg, 0.5 mmol) in CH2Cl2 (6 mL) were added thiophenol (220 mg, 2.0 mmol) and Et3B (1.0 M in hexane, 0.5 mL, 0.5 mmol) under dry O2 at room temperature. After being stirred at the same temperature for 15 h, the reaction mixture was concentrated under reduced pressure. Purification of the residue by medium-pressure column chromatography (hexane:AcOEt = 10:1) afforded the corresponding hydroxysulfides trans-31 (58.5 mg, 31%) and cis-31 (39 mg, 20%).

6,6-Dimethyl-2-hydroxy-3-phenylthiobicyclo[3.1.1]heptane-2-carbaldehyde (E)-(Phenylmethyl)oxime (31).

trans-31: a colorless oil. IR νmax cm⁻¹: 3489, 2920, 1481. 1H-NMR δ: 8.17 (1H, s), 7.50-7.47 (2H, m), 7.34-7.16 (8H, m), 4.96 (1H, d, J=11.0 Hz), 4.92 (1H, d, J=11.0 Hz), 3.97 (1H, dd, J=11.0, 9.0 Hz), 3.36 (1H, br s), 2.49 (1H, ddd, J=14.0, 10.0, 5.0 Hz), 2.23 (1H, m), 2.05 (1H, br t, J=5.5 Hz), 1.98 (1H, m), 1.84 (1H, m), 1.73 (1H, d, J=10.0 Hz), 1.21 (3H, s), 0.92 (3H, s). 13C-NMR δ: 154.3, 137.1, 135.8, 130.9, 128.7, 128.4, 128.3, 128.0, 126.5, 79.1, 76.2, 55.2, 48.4, 40.3, 39.5, 33.3, 26.9, 24.6, 24.0. HRMS m/z: Calcd for C23H27NO2S (M+) 381.1762, Found: 381.1776.

cis-31: a colorless oil. IR νmax cm⁻¹: 3431, 2922, 1454. 1H-NMR δ: 7.50-7.47 (2H, m), 7.34-7.23 (9H, m), 4.87 (2H, s), 4.27 (1H, dd, J=10.0, 7.0 Hz), 3.78 (1H, br s), 2.56 (1H, m), 2.27 (1H, m), 2.23 (1H, br t, J=7.0 Hz), 2.03 (1H, ddd, J=14.0, 7.0, 2.5 Hz), 1.95 (1H, m), 1.56 (1H, d, J=10.0 Hz), 1.23 (3H, s), 0.87 (3H, s). 13C-NMR δ: 153.2, 137.3, 134.9, 132.8, 128.9, 128.5, 128.3, 127.9, 127.4, 76.0, 75.3, 51.5, 47.7, 41.1, 38.3, 37.0, 27.7, 27.6, 23.2. HRMS m/z: Calcd for C23H27NO2S (M+) 381.1762, Found: 381.1781.

Hydroxysulfenylation reaction of oxime ether 26.

To a solution of oxime ether 26 (82 mg, 0.3 mmol) in CH2Cl2 (6 mL) were added thiophenol (123 mg, 4.0 mmol) and Et3B (1.0 M in hexane, 0.3 mL, 0.3 mmol) under dry O2 at room temperature. After being stirred at the same temperature for 15 h, the reaction mixture was concentrated under reduced pressure. Purification of the residue by medium-pressure column chromatography (hexane:AcOEt = 10:1–4:1) afforded the corresponding hydroxysulfide 32 (69 mg, 58%).

5-(1-Hydroxy-1-methylethyl)-2-hydroxy-2-methyl-3-phenylthiocyclohexenone (E)-(Phenylmethyl)oxime (32).

Hydroxysulfenylation reaction of oxime ether 27.

To a solution of oxime ether 27 (128 mg, 0.5 mmol) in CH2Cl2 (6 mL) were added thiophenol (248 mg, 2.25 mmol) and Et3B (1.0 M in hexane, 0.5 mL, 0.5 mmol) under dry O2 at room temperature. After being stirred at the same temperature for 15 h, the reaction mixture was concentrated under reduced pressure. Purification of the residue by medium-pressure column chromatography (hexane:AcOEt = 10:1–4:1) afforded the corresponding hydroxysulfide 34 (121 mg, 50%).

2-Hydroxy-2-methyl-5-[1-methyl-2-phenylthioethyl]-3-phenylthiocyclohexanone (E)-(Phenylmethyl)oxime (34).

The hydroxysulfide 34 was obtained as a 1:1 mixture of diastereoisomers concerning stereocenter on the side chain.
(1/2H, dd, J=12.0, 8.0 Hz), 2.77 (1/2H, dd, J=15.0, 5.0 Hz), 2.71 (1/2H, m), 2.53 (1/2H, dd, J=12.0, 8.0 Hz), 2.53 (1/2H, dd, J=14.0, 5.0 Hz), 2.45 (1/2H, dd, J=14.0, 5.0 Hz), 2.13 (1H, m), 2.02 (1H, m), 1.71-1.56 (2H, m), 1.51 (3H, s), 1.02 (3/2H, d, J=7.0 Hz), 0.85 (3/2H, d, J=7.0 Hz). 13C-NMR (125 MHz): δ: 160.0, 160.0, 137.6, 137.4, 137.3, 136.9, 135.1, 135.0, 133.8, 132.7, 129.2, 129.0, 128.9 (2C), 128.8, 128.4 (2C), 128.3, 127.9 (2C), 127.3, 125.8, 125.6, 76.3, 76.2, 74.4, 74.3, 57.5, 57.4, 39.2, 38.8, 37.2, 36.9, 34.4, 34.2, 31.7, 30.9, 25.4, 24.5, 23.8, 23.7, 17.1, 16.2. Three peaks of 13C NMR were missing due to overlap. HRMS m/z: Calcd for C23H31NO2S (M+) 429.1794, Found: 429.1756.

2-Hydroxy-2-methyl-5-(1-methylethenyl)-3-phenylthiocyclohexanone (E)-O-(Phenylmethyl)oxime (33).

Transformation of anti-13a into lactam cis-16. To a solution of β-hydroxysulfide anti-13a (500 mg, 1.39 mmol) in ethanolic HCl (0.1 M, 50 mL) was added NaBH₄CN (175 mg, 2.78 mmol) at room temperature. After the reaction mixture was stirred at the same temperature for 5 h, additionally NaBH₄CN (2.78 mmol) was added. After being stirred at the same temperature for 24 h, the reaction mixture was neutralized with saturated aqueous NaHCO₃ and then extracted with CHCl₃. The organic phase was dried over MgSO₄ and concentrated under reduced pressure. Purification of the residue by medium-pressure column chromatography (hexane:AcOEt = 10:1) afforded the amine (366 mg, 73%) as a colorless oil. IR ν max cm⁻¹: 3285, 2928, 1720. 1H-NMR (75 MHz) δ: 7.46-7.21 (10H, m), 5.14 (1H, d, J=12.0 Hz), 5.12 (1H, d, J=12.0 Hz), 4.73 (2H, br s), 3.41 (1H, dd, J=10.0, 3.0 Hz), 3.05 (1H, ddd, J=15.0, 5.0, 1.5 Hz), 2.55 (1H, br quint, J=5.0 Hz), 2.44 (1H, ddd, J=15.0, 5.0 Hz), 2.20 (1H, m), 1.82 (1H, ddd, J=14.0, 10.0, 5.0 Hz), 1.55 (3H, s), 1.51 (3H, s). 13C-NMR (125 MHz): δ: 160.4, 145.7, 137.4, 135.2, 132.2, 128.9, 128.4 (2C), 127.0, 111.1, 76.2, 74.3, 55.9, 39.4, 23.6, 25.6, 23.9, 21.6. HRMS m/z: Calcd for C23H31NO2S (M+) 431.1872, Found: 431.1771.

trans-16: a colorless oil. IR ν max cm⁻¹: 3285, 2928, 1720. 1H-NMR (75 MHz) δ: 7.64-7.59 (2H, m), 7.44-7.33 (5H, m), 7.31-7.19 (3H, m), 6.04 (1H, d, J=6.0 Hz), 3.42 (1H, dd, J=9.0, 5.0 Hz), 3.17 (1H, ddd, J=9.0, 3.0 Hz), 0.90 (9H, s), 0.11 (3H, s), 0.03 (3H, s). 13C-NMR (75 MHz) δ: 167.2, 134.9, 134.7, 131.8, 129.3, 128.7, 128.6, 128.4, 127.0, 76.7, 65.8, 54.5, 53.5, 25.6, 18.0, -5.1, -5.2. HRMS m/z: Calcd for C23H31NO2SSi (M+) 429.1974, Found: 429.1818.

Reaction of PhSBEt₂ with TEMPO. To a hexane solution of Et₃B (1.0 M in hexane, 0.5 mL, 0.5 mmol) was added PhSBEt₂ at room temperature. After the reaction solution was added TEMPO (155 mg, 1.0 mmol) and then the reaction mixture was stirred at the same temperature for 15 h. After evaporation of solvent, the residue was purified by medium-pressure column chromatography (hexane:AcOEt = 10:1) to form (PhS)₂ (20.4 mg, 38%) and 18 (25.5 mg, 20%).
2,2,6,6-Tetramethyl-1-(phenylthiooxy)piperidine (18).

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\text{N} \quad \text{SPh}
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a colorless oil. IR \( \nu_{\text{max}} \text{ cm}^{-1} \): 2934, 1472, 1442. \(^1\)H-NMR \( \delta \): 7.70-7.67 (2H, m), 7.46-7.42 (2H, m), 7.38 (1H, tt, \( J = 7.5 \), 1.5 Hz), 1.90-1.32 (6H, br m), 1.67 (3H, br s), 1.57 (3H, br s), 1.51 (3H, br s), 0.91 (3H, br s). \(^{13}\)C-NMR \( \delta \): 150.3, 129.3, 128.5, 126.0, 61.3, 58.8, 43.5, 41.4, 35.4, 32.6, 28.8, 28.0, 17.3. HRMS \( m/z \): Calcd for C\(_{15}\)H\(_{23}\)NOS (M\(^+\)) 265.1500, Found: 265.1512.

**Crossover reaction of 10 and 20a.** To a solution of oxime ethers 10 (57.6 mg, 0.3 mmol) and 20a (70 mg, 0.3 mmol) in CH\(_2\)Cl\(_2\) (8 mL) were added thiophenol (116 mg, 3.5 mmol) and Et\(_3\)B (1.0 M in hexane, 0.15 mL, 0.15 mmol) under dry air atmosphere at room temperature. After being stirred at the same temperature for 15 h, the reaction mixture was concentrated under reduced pressure. Purification of the residue by medium-pressure column chromatography (hexane:AcOEt = 10:1–4:1) afforded the corresponding \( \beta \)-hydroxysulfide 13a (80.7 mg, 38%) and \( \beta \)-hydroxysulfide 21a (29.8 mg, 17%).

\(^{13}\)C NMR charts of E-20f, 14, 13b-d, 21a-c, 21f, and 28.
References