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ARTICLE

Facile synthesis of thietanes via ring expansion of thiiranes

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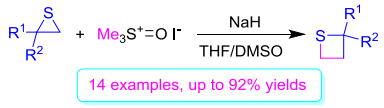

Abstract: Thietanes are importantly pharmaceutical core of some biological compounds and intermediates of organic synthesis. Various thietanes were prepared from thiiranes via ring expansion through the reaction with trimethyloxosulfonium iodide in the presence of sodium hydride. The reaction process is a nucleophilic ring-opening reaction of thiiranes with dimethyloxosulfonium methylide, generated from trimethyloxosulfonium iodide and sodium hydride, and subsequent intramolecular displacement (cyclization) of thiolates to dimethyloxosulfonium moiety. The current method provides a new strategy in efficient preparation of thietanes from readily available thiiranes.

Introduction

Thietanes are importantly pharmaceutical core or moiety of some biological compounds, such as thietane nucleosides[1] and spiroannulated glyco-thietane nucleosides,[2] which are thiaanalogues of antiviral (anti-HIV and HSV) oxetanocin A[1] and their conformationally restricted analogues,[2] thia derivatives of decetaxels, D-ring modified anti-cancer drug toxoids,[3] thiathromboxane A2,[4] pesticide,[5] and sweetener (Figure 1).[6] They also serve as important intermediates in organic synthesis for the preparation of sulfur-containing acyclic and heterocyclic compounds.[7] Several synthetic methods to thietanes have been developed.[8] One traditional route is intermolecular double substitution (cyclization) of 1,3-dihaloalkanes,[1a] methanesulfonates/tosylates of 3-halo-1-alkanols, or dimethanesulfonates/ditosylates of alkane-1,3-diols[1b] with sodium sulfide. Alternatively, the photo-assistant [2+2] cycloadditions (Thia-Paternò-Büchi reaction) of alkenes and thiocarbonyl compounds are another route for the synthesis of thietanes,[9] especially, spirothietanes.[10] Alkylidenethietanes have been prepared via the amine-catalyzed tunable formal [2+2] cycloadditions of allenoates and dithioester.[11] The ring-contraction of tetrahydrothiophenes has been seldom applied in the preparation of thietanes.[12] 2-Vinylthietanes are prepared in moderate to good yields by treating thiiranes with 1- or 3-chloroallyl lithiums.[13] 3-Substituted thietanes have been prepared from reactions of (1-chloroalkyl)thiiranes, especially epithiochlorohydrin, and nucleophiles,[14-16] including carboxylates and dicarboxylates,[14] phenoxides,[15] potassium cyanide, sodium azide, hydroxylamine, trifluoromethanesulfonamide, and pyridine.[16] However, the method can only synthesize 3-substituted thietanes from (1-chloroalkyl)thiiranes. Considering that only limited methods have been developed for the preparation of important thietanes, we designed and realized a new synthetic strategy for the preparation of 2-monosubstituted and 2,2-disubstituted thietanes. In our strategy, we used a nucleophile with a good leaving group as a reagent to react with various thiiranes through nucleophilic ring-opening and subsequent cyclization to generate thietanes (Scheme 1). Herein, we present efficient synthesis of thietanes from thiiranes via a ring-enlargement reaction under mild conditions.

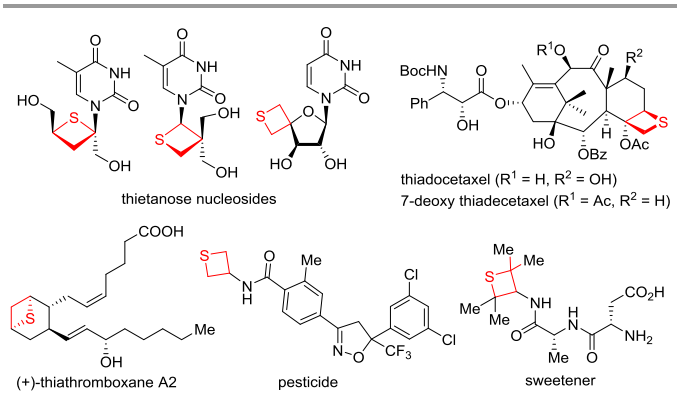

Figure 1. Biologically active molecules containing thietanes

Results and discussion

Although cyclization of 1,3-dihaloalkanes or dimethanesulfonates/ditosylates of alkane-1,3-diols with sodium sulfide is a common method for the preparation of thietanes, the method is only suitable for the preparation of 3-monosubstituted and 3,3-disubstituted thietanes and hardly applied in the

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preparation of 2-monosubstituted and 2,2-/2,4-disubstituted thietanes due to steric hindrance in the substitution step and accompanied elimination during the substitution. Our design for the preparation of 2-monosubstituted and 2,2-disubstituted thietanes is based on the nucleophilic ring-opening of 2-monosubstituted and 2,2-disubstituted thiiranes with one carbon-containing nucleophiles with a good leaving group and subsequent intramolecular nucleophilic substitution. In the nucleophilic ring-opening of thiiranes, thiolates generate and serve as nucleophiles to undergo further intramolecular displacement. To realize our design, dimethyloxosulfonium methylide and dimethylsulfonium methylide are good choice. Although dimethyloxosulfonium methylide has been successfully applied in preparations of oxetanes and azetidines from oxiranes and aziridines via ring expansion,[17,18] both thiiranes and thietanes are less stable than the corresponding oxa- and aza-analogues.

Double substitution of 1,3-dihaloalkanes, sulfonates of alkane-1,3-diols or 3-haloalkane-1-ols with Na_2S

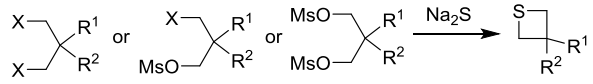
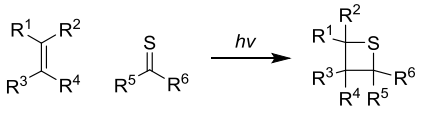
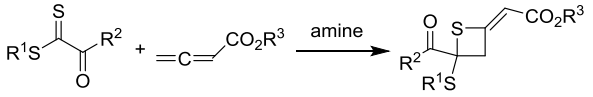


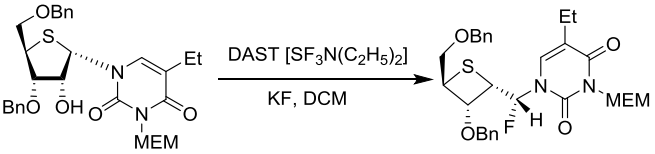
Photo-assistant [2+2] cycloadditions of alkenes and thiocarbonyls



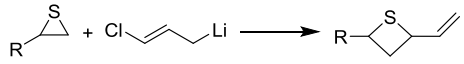
Formal [2+2] cycloadditions of allenoates and dithioesters



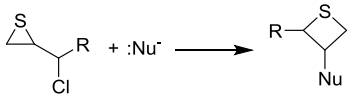
Ring contraction of tetrahydrothiophenes



Reaction of thiiranes with 3-chloroallyllithiums

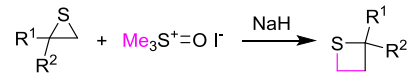


Reactions of (1-chloroalkyl)thiiranes with nucleophilies



$:Nu^-$ = RCO_2^-, ArO^-, CN^-, N_3^-, $HONH_2$, $CF_2SO_2NH_2$, Py, etc.

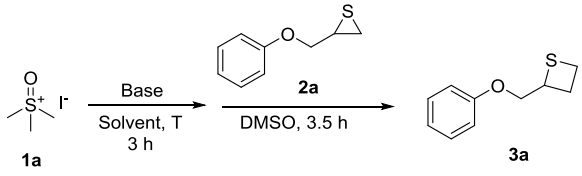
The current work:
Facile synthesis from thiiranes and trimethyloxosulfonium iodide



Scheme 1. Methods for synthesis of thietanes

The reaction of trimethyloxosulfonium iodide (**1a**) and phenoxymethylthiirane (**2a**) was selected as a model reaction to optimize the reaction conditions. Initially, the reaction of **1a** and **2a** was conducted in the presence of NaH in DMSO at 40 °C in a molar ratio of 2:0.5:2 of **1a**:**2a**:NaH. Only trace amount of the desired product 2-phenoxymethylthietane (**3a**) was observed in GC-MS analysis of the reaction mixture (Table 1, entry 1). No product was observed when the reaction was carried out at 65 °C (Table 1, entry 2). Trace amount of the product was also determined when the reaction was conducted in THF at 40 °C (Table 1, entry 3). However, the yield was improved to 57% when DMSO (0.1 mL) was added into the reaction mixture at 40 °C (Table 1, entry 4). The yield increased slightly with increase of added DMSO from 0.1 mL to 0.5 mL (Table 1, entry 5). A high yield was obtained when the reaction with **1a**:**2a**:NaH in a molar ratio 1.5:0.5:1.5 was conducted in THF (6 mL) and DMSO (0.1 mL) at 40 °C (Table 1, entry 6). The yield decreased obviously when increasing or decreasing amount of DMSO (Table 1, entries 7–9). No product was observed when DMSO was increased to 1.5 mL (Table 1, entry 10). Moreover, elevating the reaction temperature resulted in slightly decrease of the yield (Table 1, entries 6 vs 11). The yield only increased slightly when the reaction was conducted under atmosphere of nitrogen (Table 1, entries 6 vs 12). Considering the role of DMSO in the reaction, it was assumed that the electrophilic sulfonium part of dipole solvent DMSO can coordinate with the electron-rich sulfur atom of thiiranes, activating the three-membered heterocycle thiiranes. Thus, thiiranes prefer the nucleophilic ring-opening reaction with dimethyloxosulfonium methylide. However, excessive DMSO would coordinate with the methylide, decreasing its nucleophilicity. That is the reason why no desired product was observed in excessive DMSO. It is noteworthy that no desired product generated when lithium hydride and calcium hydride were used as base instead of sodium hydride (Table 1, entries 13 and 14). When the reaction was carried out in *tert*-BuOH with ^{t}BuOK as base at 40 °C, product **3a** was obtained in low yield of 13% (Table 1, entry 15).[17c] The other choice dimethylsulfonium methylide, which generated from trimethylsulfonium iodide (**1b**) as precursor by treatment with sodium hydride, was also attempted and no desired product was observed (Table 1, entry 16).

Table 1. Optimization for the reaction of trimethyloxosulfonium iodide (**1a**) and phenoxymethylthiirane (**2a**)[a]



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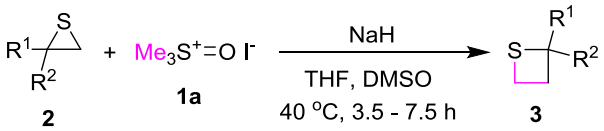
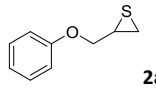
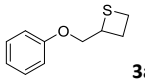
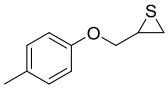
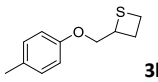
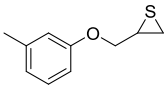
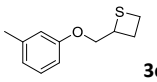
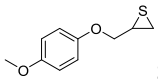
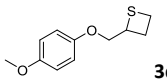
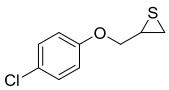
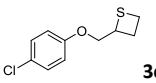
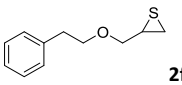
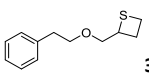
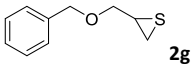
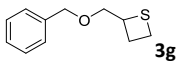
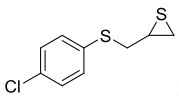
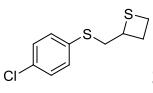
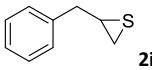
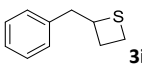
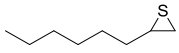
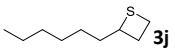
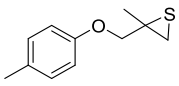
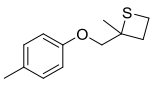
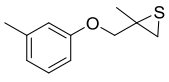
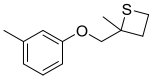
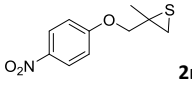
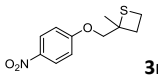
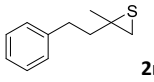
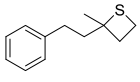
Entry	**1a** (mmol)	Base (mmol)	Solvent	DMSO (mL)	T (℃)	Yield[b] (%)
1	2	NaH (2)	DMSO	----	40	trace
2	2	NaH (2)	DMSO	----	65	No
3	2	NaH (2)	THF	0	40	trace
4	2	NaH (2)	THF	0.1	40	57
5	2	NaH (2)	THF	0.5	40	59
6	**1.5**	**NaH (1.5)**	**THF**	**0.1**	**40**	**62(80[c])**
7	1.5	NaH (1.5)	THF	0.05	40	14
8	1.5	NaH (1.5)	THF	0.5	40	28
9	1.5	NaH (1.5)	THF	1	40	14
10	1.5	NaH (1.5)	THF	1.5	40	0
11	1.5	NaH (1.5)	THF	0.1	70	60
12	1.5	NaH (1.5)	THF	0.1	40	64[d]
13	1.5	LiH (1.5)	THF	0.1	40	0
14	1.5	CaH_2 (1.5)	THF	0.1	40	0
15	5.0	^{t}BuOK (5.0)	^{t}BuOH		40	13
16	1.5 (**1b**)	NaH (1.5)	THF	0.1	40	0

a) All reactions were conducted as following: To a stirred suspension/solution of base in solvent (6.0 mL) was added trimethyloxosulfonium iodide (**1a**). The mixture was further stirred at 40 ℃ for 3 h. Then phenoxymethylthiirane (**2a**) was added (followed by addition of DMSO as indicated). The mixture was stirred in air at 40 ℃ for 3.5 h. b) Isolated yield. c) Yield determined by ^{1}H NMR analysis using dimethyl maleate as an internal standard. d) Conducted under atmosphere of nitrogen.

Various 2-monosubstituted and 2,2-disubstituted thiiranes **2** were prepared from the corresponding oxiranes **4** followed our previous procedure.[19] Under the optimized reaction conditions, 2-monosubstituted and 2,2-disubstituted thiiranes **2** were subjected the ring expansion reactions with trimethyloxosulfonium iodide (**1a**) in the presence of sodium hydride in THF and DMSO (60:1, V:V). The results are presented in Table 2. Phenoxymethylthiirane (**2a**) and electron-rich aryloxymethylthiiranes **2b**-**d** gave rise to the corresponding products **3a-d** in satisfactory to good yields (Table 2, entries 1–4). However, electron-deficient aryloxymethylthiirane **2e** produced the desired product **3e** in low yield (Table 2, entry 5). Furthermore, both (2-phenylethoxymethyl)thiirane (**2f**) and benzyloxymethylthiirane (**2g**) generated the corresponding products **3f** and **3g** in good yields of 74% and 75%, respectively (Table 2, entries 6 and 7). Similarly, electron-deficient (4-chlorophenylthio)methylthiirane (**2h**) gave the desired product **3h** in low yield as well (Table 2, entry 8). Benzyl and *n*-hexylthiiranes (**2i** and **2j**) also gave rise to the corresponding products **3i** and **3j** in good yields (Table 2, entries 9 and 10). For 2,2-disubstituted thiiranes, similar phenomenon was observed. Electron-rich 2-aryloxymethyl-2-methylthiiranes **2k** and **2l** converted into 2,2-disubstituted thietanes **3k** and **3l** in excellent yields (Table 2, entries 11 and 12). However, electron-deficient (4-nitrophenoxymethyl)thiirane (**2m**) formed the desired product **3m** in low yield (Table 2, entry 13). 2-Methyl-2-(2-phenylethyl)thiirane (**2n**) generated the desired product **3n** in satisfactory yield (Table 2, entry 14). To extend the substrate scope, vicinal disubstituted thiirane, cyclohexene sulfide (**2o**), and trisubstituted thiirane, 1-methyl-7-thiabicyclo[4.1.0]heptane (**2p**), were also attempted under our optimal reaction conditions. However, only trace amount of the desired product **3o** was observed in GC-MS analysis of the reaction mixture of **2o** and no desired product was observed for the trisubstituted thiirane **2p**.

Table 2. Synthesis of thietanes (**3**) from thiiranes (**2**)[a]



Entry	Thiirane **2**	Thietane **3**	Reaction Time (h)	Yield[b] (%)
1	 **2a**	 **3a**	3.5	62
2	 **2b**	 **3b**	3.5	75
3	 **2c**	 **3c**	3.5	63
4	 **2d**	 **3d**	4.0	59
5	 **2e**	 **3e**	3.5	38
6	 **2f**	 **3f**	4.0	74
7	 **2g**	 **3g**	4.0	75
8	 **2h**	 **3h**	4.0	18
9	 **2i**	 **3i**	4.0	66[c]
10	 **2j**	 **3j**	7.5	72[c]
11	 **2k**	 **3k**	4.5	91
12	 **2l**	 **3l**	4.5	92
13	 **2m**	 **3m**	4.5	17
14	 **2n**	 **3n**	4.0	52[c]

a) To a stirred suspension of NaH (62 mg, 1.5 mmol) in THF (6.0 mL) was added trimethyloxosulfonium iodide (**1a**, 330 mg, 1.5 mmol). The mixture was further stirred at 40 ℃ for 3.5 to 7.5 h as indicated. Then a thiirane **2** (0.5 mmol) followed by DMSO (0.1 mL) were added. The mixture was stirred in air at 40 ℃ for the indicated time until complete consumption of thiirane **2**. b) Isolated yield. c) 0.5 mL of DMSO was added.

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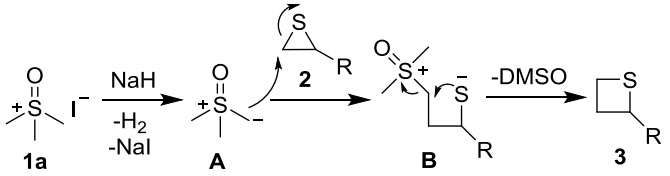
Considering the reaction mechanism, it was proposed that treatment of trimethyloxosulfonium iodide (**1a**) with sodium hydride generates dimethyloxosulfonium methylide (C-S ylide) **A**, which nucleophilically attacks thiiranes **2** from their less substituted ring carbon atom to generate intermediates **B**, showing good regioselectivity.[20] Similar regioselectivity was also observed in the preparation of oxetanes from oxiranes[17b] and in nucleophilic ring-opening reactions of oxiranes.[21] The generated thiolate in intermediates **B** undergoes intramolecularly nucleophilic displacement to give rise to the desired products **3** by loss of a molecule of DMSO.



Scheme 2. Proposed mechanism for the synthesis of thietanes from thiiranes via ring-expansion.

Conclusions

An efficient synthesis of 2-substituted and 2,2-substituted thietanes was developed. The synthesis is characterized as the ring expansion of readily available 2-substituted and 2,2-disubstituted thiiranes, showing regiospecific, convenient, and practical advantages. In the current strategy, dimethyloxosulfonium methylide serves as a one-carbon-containing nucleophile with a good leaving group to realize ring-expansion of thiiranes.

Experimental

Unless otherwise noted, all materials were purchased from commercial suppliers and used directly. DMSO was refluxed over CaH_2, and freshly distilled prior to use. THF was refluxed over sodium with benzophenone as an indicator, and freshly distilled prior to use. Flash column chromatography was performed using silica gel (normal phase, 200–300 mesh) from Branch of Qingdao Haiyang Chemical. 2-Hexyloxirane (**4j**) was purchased from Tokyo Chemical Industry. Petroleum ether (PE) used for column chromatography were 60–90 °C fraction, and the removal of residue solvent was accomplished under rotovap. Reactions were monitored by thin-layer chromatography on silica gel GF254 coated 0.2 mm plates from Institute of Yantai Chemical Industry. The plates were visualized under UV light, as well as other TLC stains (10% phosphomolybdic acid in ethanol; 1% potassium permanganate in

water; 10 g of iodine absorbed on 30 g of silica gel). Melting points were obtained on a Yanaco MP-500 melting point apparatus and are uncorrected. ^{1}H and ^{13}C NMR spectra were recorded on a Bruker 400 MHz spectrometer in $CDCl_3$ with TMS as an internal standard, and the chemical shifts (δ) are reported in parts per million (ppm). The IR spectra (KBr pellets, ν [cm^{-1}]) were taken on a Nicolet 5700 FTIR spectrometer. HRMS measurements were carried out on an Agilent LC/MSD TOF mass spectrometer. LRMS measurements were carried out on Agilent 7890 LC System with an Agilent 5975 Mass Selective Detector. GC-MS were performed on a Thermo Fisher GC Trace 1300 and ISQ QD mass spectrometer.

General procedure for synthesis of oxiranes 4a-c, 4h, and 4k-m

To a stirred solution of phenol or thiophenol (25.0 mmol) in ethanol (30 mL) was added NaOH (30.0 mmol, 1.20 g). After stirring for 20 min at room temperature, 2-(chloromethyl)oxirane (75.0 mmol, 6.94 g) or 2-(chloromethyl)-2-methyloxirane (75.0 mmol, 7.99 g) was added dropwise during 30 min. The resulting mixture was stirred at room temperature for 24 h (TLC-monitoring). When the reaction was complete, the solvent was removed under reduced pressure. The residue was extracted with EtOAc (3 × 30 mL). The combined organic layers were washed with brine (20 mL), dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The obtained crude product was purified by column chromatography (silica gel, petroleum ether-ethyl acetate (PE-EtOAc), 100:1, *v/v*) to give pure oxirane **4**. The analytical data of known oxiranes **4a-c** and **4h** are identical to those reported previously.[19,22]

2-Methyl-2-(4-methylphenyloxymethyl)oxirane (4k)

Colorless liquid, 1.39 g, yield 31%, R_f = 0.49 (PE/DCM = 10:1, *v/v*). IR (KBr): ν = 3033, 2927, 1614, 1585, 1511, 1456, 1383, 817 cm^{-1}. ^{1}H NMR ($CDCl_3$, 400 MHz) (δ, ppm) = 7.07 (d, *J* = 8.4 Hz, 2H, ArH), 6.81 (d, *J* = 8.0 Hz, 2H, ArH), 3.98 (d, *J* = 10.4 Hz, 1H in OCH_2), 3.92 (d, *J* = 10.4 Hz, 1H in OCH_2), 2.86 (d, *J* = 4.8 Hz, 1H in OCH_2), 2.72 (d, *J* = 4.4 Hz, 1H in OCH_2), 2.28 (s, 3H, $ArCH_3$), 1.48 (s, 3H, $OCCH_3$). ^{13}C NMR (101 MHz, $CDCl_3$) (δ, ppm) = 156.5, 130.3, 129.9, 114.5, 71.6, 55.6, 52.0, 20.4, 18.5. GC-MS (EI) *m/z* = 194 $(M)^+$ for $C_{11}H_{14}O_2$. HR-MS (ESI) *m/z* $[M+Na]^+$ calcd for $C_{11}H_{14}NaO_2^+$: 201.0886, found: 201.0882.

2-Methyl-2-(3-methylphenyloxymethyl)oxirane (4l)

Colorless liquid, 1.79 g, yield 31%, R_f = 0.59 (PE/DCM = 10:1, *v/v*). IR (KBr): ν = 3047, 2924, 2868, 1601, 1584, 1456, 1383, 899, 773, 690 cm^{-1}. ^{1}H NMR ($CDCl_3$, 400 MHz) (δ, ppm) = 7.15 (t, *J* = 8.0 Hz, 1H, ArH), 6.77 (d, *J* = 8.0 Hz, 1H, ArH), 6.74 (s, 1H, ArH), 6.71 (d, *J* = 8.0 Hz, 1H, ArH), 3.99 (d, *J* = 10.4 Hz, 1H in OCH_2), 3.92 (d, *J* = 10.4 Hz, 1H in OCH_2), 2.85 (d, *J* = 4.8 Hz, 1H in OCH_2), 2.71 (d, *J* = 4.8 Hz, 1H in OCH_2), 2.32 (s, 3H, CH_3), 1.47 (s, 3H, CCH_3). ^{13}C NMR (101 MHz, $CDCl_3$) (δ, ppm) = 158.6, 139.4, 129.1, 121.9, 115.4, 111.4, 71.3, 55.5, 52.0, 21.4, 18.4. GC-MS (EI) *m/z* = 178 $(M)^+$ for $C_{11}H_{14}O_2$. HR-MS (ESI) *m/z* $[M+Na]^+$ calcd for $C_{11}H_{14}NaO_2^+$: 201.0886, found: 201.0884.

2-Methyl-2-(4-nitrophenyloxymethyl)oxirane (4m)

Colorless liquid, 1.67 g, yield 32%, R_f = 0.49 (PE/DCM = 10:1, *v/v*). IR (KBr): ν = 3085, 2925, 2849, 1608, 1511, 1451, 1386, 848 cm^{-1}. ^{1}H NMR ($CDCl_3$, 400 MHz) (δ, ppm) = 8.20 (d, *J* = 8.9 Hz, 2H, ArH), 7.00 (d, *J* = 8.9 Hz, 2H, ArH), 4.20 (d, *J* = 10.6 Hz, 1H in OCH_2), 4.01 (d, *J* = 10.6 Hz, 1H in OCH_2), 2.89 (d, *J* = 4.6 Hz, 1H in OCH_2), 2.77 (t, *J* = 4.6 Hz, 1H in OCH_2), 1.50 (s, 3H, CH_3). ^{13}C NMR (101 MHz, $CDCl_3$) (δ, ppm) = 163.4, 141.8, 125.8, 114.6, 72.1, 55.1, 51.6, 18.2. GC-MS (EI) *m/z* = 209 $(M)^+$ for $C_{10}H_{11}NO_4$. HR-MS (ESI) *m/z* $[M+H]^+$ calcd for $C_{10}H_{12}NO_4^+$: 210.0761, found: 210.0755.

General procedure for synthesis of oxiranes 4f and 4g

To a cold mixture of 40% w/w aqueous sodium hydroxide (50 mL), alcohol (30 mmol), and tetrabutylammonium bromide (1.5 mmol, 484 mg) was added epichlorohydrin (120 mmol, 11.1 g) slowly. The reaction progress was monitored by thin layer chromatography (TLC) with dichloromethane as eluent. After completion of the reaction, the mixture was extracted twice with diethyl ether. The combined organic phase was dried over magnesium sulfate, filtered, and evaporated to dryness. The residue was purified by column chromatography (silica gel, PE-AcOEt, 100:1, v/v) to oxirane **4**. The analytical data of known oxiranes **4f** and **4g** are identical to those reported previously.[23]

General procedure for the synthesis of oxiranes 4i and 4n

Dimethylsulfonium methylide was prepared under nitrogen from sodium hydride and trimethylsulfonium iodide (**1b**) in DMSO and THF. Sodium hydride (0.95 g, 24 mmol, 60% mineral oil dispersion) was washed with petroleum ether (3 X 5 mL). The residual petroleum ether was removed under vacuum. Under atmosphere of nitrogen, dry THF (11 mL) and dry DMSO (11 mL) were added and the reaction mixture was cooled in an ice bath. A solution of trimethylsulfonium iodide (**1b**) (4.90 g, 24 mmol) in DMSO (4 mL) was added. After addition, phenylacetaldehyde (1.44 g, 12 mmol) or 4-phenylbutan-2-one (1.78 g, 12 mmol) was added in one portion. The reaction mixture was stirred at 0 °C for 30 min and at room temperature for an additional 12 h. The reaction mixture was slowly quenched with a mixture of water and ice (20 mL) and extracted with methylene chloride (3 X 10 mL). The combined organic extracts were washed with brine (2 X 30 mL), dried over potassium carbonate, filtered. The residue was purified by column chromatography (silica gel, PE) to give colorless oil **4i** or **4n**. Their analytical data are identical to those reported previously.[24]

General procedure for the synthesis of thiiranes 2

A solution of oxirane **4** (24.0 mmol) and KSCN (9.31 g, 96.0 mmol) in water (30.0 mL) was heated to 40 °C and stirred for 24 h at the same temperature. The resulting mixture was diluted with EtOAc and washed with brine. The organic phase was dried (Na_2SO_4) and concentrated in vacuo. The residue was purified by column chromatography (silica gel, PE) to give thiirane **2**. The analytical data of known thiiranes are identical to those reported previously.[19,20b]

Phenoxymethylthiirane (2a)

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Colorless oil, 2.91 g, yield 88%, R_f = 0.62 (PE/EA = 10:1, *v*/*v*). ^{1}H NMR ($CDCl_3$, 400 MHz) (*δ*, ppm) = 7.29 (t, *J* = 7.9 Hz, 2H, ArH), 6.97 (t, *J* = 7.6 Hz, 1H, ArH), 6.91 (d, *J* = 8.4 Hz, 2H, ArH), 4.22 (dd, *J* = 10.2, 5.4 Hz, 1H in CH_2O), 3.90 (dd, *J* = 10.2, 7.2 Hz, 1H in CH_2O), 3.30–3.24 (m, 1H, CHS), 2.61 (d, *J* = 6.0, Hz, 1H in CH_2S), 2.33 (d, *J* = 5.2, Hz, 1H in CH_2S). ^{13}C NMR (101 MHz, $CDCl_3$) (*δ*, ppm) = 158.4, 129.5, 121.2, 114.7, 72.5, 31.4, 24.0. GC-MS (EI) *m/z* = 166 $(M)^+$ for $C_9H_{10}OS$.

(4-Methylphenoxy)methylthiirane (2b)

Colorless oil, 2.00 g, yield 56%, R_f = 0.91 (PE/EA = 5:1, *v*/*v*). ^{1}H NMR ($CDCl_3$, 400 MHz) (*δ*, ppm) = 7.07 (d, *J* = 8.4 Hz, 2H, ArH), 6.80 (d, *J* = 8.4 Hz, 2H, ArH), 4.18 (dd, *J* = 10.2, 5.6 Hz, 1H in CH_2O), 3.85 (dd, *J* = 10.2, 7.2 Hz, 1H in CH_2O), 3.27–3.21 (m, 1H, CHS), 2.58 (d, *J* = 6.4 Hz, 1H in CH_2S), 2.31–2.78 (m, 4H, 1H in CH_2O & CH_3). ^{13}C NMR (101 MHz, $CDCl_3$) (*δ*, ppm) = 156.3, 130.5, 129.9, 114.6, 72.8, 31.4, 24.0, 20.4. GC-MS (EI) *m/z* = 180 $(M)^+$ for $C_{10}H_{12}OS$.

(3-Methylphenoxy)methylthiirane (2c)

Colorless oil, 1.79 g, yield 50%, R_f = 0.62 (PE/EA = 10:1, *v*/*v*). ^{1}H NMR ($CDCl_3$, 400 MHz) (*δ*, ppm) = 7.08 (t, *J* = 7.6 Hz, 1H, ArH), 6.70 (d, *J* = 7.6 Hz, 1H, ArH), 6.65–6.61 (m, 2H, ArH), 4.11 (dd, *J* = 10.4, 5.6 Hz, 1H in CH_2O), 3.79 (dd, *J* = 10.4, 7.2 Hz, 1H in CH_2O), 3.20–3.14 (m, 1H, CHS), 2.51 (d, *J* = 6.4 Hz, 1H in CH_2S), 2.24 (s, 3H, CH_3), 2.23 (d, *J* = 5.6 Hz, 1H in CH_2S). ^{13}C NMR (101 MHz, $CDCl_3$) (*δ*, ppm) = 158.4, 139.5, 129.2, 122.0, 115.5, 111.5, 72.4, 31.4, 23.9, 21.5. GC-MS (EI) *m/z* = 180 $(M)^+$ for $C_{10}H_{12}OS$.

(4-Methoxyphenoxy)methylthiirane (2d)

White solid, 65–66 °C, 2.35 g, yield 60%, R_f = 0.75 (PE/EA = 3:1, *v*/*v*). ^{1}H NMR ($CDCl_3$, 400 MHz) (*δ*, ppm) = 6.89–6.82 (m, 4H, ArH), 4.16 (dd, *J* = 10.4, 5.6 Hz, 1H in CH_2O), 3.86 (dd, *J* = 10.0, 6.8 Hz, 1H in CH_2O), 3.77 (s, 3H, CH_3), 3.24 (dt, *J* = 6.8, 5.5 Hz, 1H, SCH), 2.59 (d, *J* = 6.0 Hz, 1H in SCH_2), 2.30 (dd, *J* = 5.2, 1.2 Hz, 1H in SCH_2). ^{13}C NMR (101 MHz, $CDCl_3$) (*δ*, ppm) = 154.2, 152.5, 115.8, 114.6, 73.4, 55.6, 31.5, 23.9. GC-MS (EI) *m/z* = 196 $(M)^+$ for $C_{10}H_{12}O_2S$.

(4-Chlorophenoxy)methylthiirane (2e)

Colorless oil, 1.89 g, yield 47%, R_f = 0.56 (PE/EA = 10:1, *v*/*v*). ^{1}H NMR ($CDCl_3$, 400 MHz) (*δ*, ppm) = 7.15 (d, *J* = 8.4 Hz, 2H, ArH), 6.77 (d, *J* = 8.4 Hz, 2H, ArH), 4.13 (dd, *J* = 10.8, 2.0 Hz, 1H in CH_2O), 3.82 (dd, *J* = 10.8, 5.6 Hz, 1H in CH_2O), 3.28–3.24 (m, 1H, CHS), 2.82 (t, *J* = 4.4 Hz, 1H in CH_2S), 2.67–2.66 (m, 1H in CH_2S). ^{13}C NMR (101 MHz, $CDCl_3$) (*δ*, ppm) = 157.0, 129.3, 126.1, 115.9, 69.0, 50.0, 44.5. GC-MS (EI) *m/z* = 200 $(M)^+$ for C_9H_9ClOS.

(2-Phenylethyl)oxymethylthiirane (2f)

Colorless oil, 1.30 g, yield 29%, R_f = 0.38 (PE/EA = 20:1, *v*/*v*). ^{1}H NMR ($CDCl_3$, 400 MHz) (*δ*, ppm) = 7.28 (t, *J* = 7.6 Hz, 2H, ArH), 7.22–7.17 (m, 3H, ArH), 3.70 (t, *J* = 7.2 Hz, 2H, CH_2O), 3.63 (dd, *J* = 10.8, 5.6 Hz, 1H in OCH_2), 3.43 (dd, *J* = 10.8, 6.8 Hz, 1H in OCH_2), 3.06–3.00 (m, 1H, SCH), 2.89 (t, *J* = 7.2 Hz, 2H, $ArCH_2$), 2.47 (d, *J* = 6.0 Hz, 1H in SCH_2), 2.16 (d, *J* = 5.2Hz, 1H in SCH_2). ^{13}C NMR (101 MHz, $CDCl_3$) (*δ*, ppm) = 138.5, 128.8, 128.2, 126.1, 75.3, 72.0, 36.2, 32.0, 23.6. GC-MS (EI) *m/z* = 194 $(M)^+$ for $C_{11}H_{14}OS$.

Benzyloxymethylthiirane (2g)

Colorless oil, 2.56 g, yield 68%, R_f = 0.39 (PE/EA = 10:1, *v*/*v*). ^{1}H NMR ($CDCl_3$, 400 MHz) (*δ*, ppm) = 7.35-7.26 (m, 5H, ArH), 4.60 (d, *J* = 10.8 Hz, 1H in $ArCH_2$), 4.56 (d, *J* = 10.8 Hz, 1H in $ArCH_2$), 3.68 (dd, *J* = 10.4, 5.6 Hz, 1H, OC*H*HCH), 3.48 (dd, *J* = 10.4, 6.8 Hz, 1H, OCH*H*CH), 3.13-3.07 (m, 1H, SCH), 2.51 (d, *J* = 6.0 Hz, 1H in SCH_2), 2.20 (dd, *J* = 5.2, 1.2 Hz, 1H in SCH_2). ^{13}C NMR (101 MHz, $CDCl_3$) (*δ*, ppm) = 137.8, 128.4, 127.8, 127.7, 74.6, 73.1, 32.1, 23.8. GC-MS (EI) *m/z* = 180 $(M)^+$ for $C_{11}H_{12}OS$.

(4-Chlorophenylthio)methylthiirane (2h)

Colorless oil, 780 mg, yield 15%, R_f = 0.77 (PE/EA = 10:1, *v*/*v*). IR (KBr): *v* = 2921, 2849, 1643, 1573, 816 cm^{-1}. ^{1}H NMR ($CDCl_3$, 400 MHz) (*δ*, ppm) = 7.29 (t, *J* = 2.8 Hz, 1H, ArH), 7.27 (t, *J* = 2.4 Hz, 1H, ArH), 7.21 (t, *J* = 2.8 Hz, 1H, ArH), 7.18 (t, *J* = 2.0 Hz, 1H, ArH), 3.30 (dd, *J* = 13.6, 5.2 Hz, 1H in $ArSCH_2$), 2.99 (ddt, *J* = 10.0, 8.4, 5.2 Hz, 1H, SCH), 2.73 (dd, *J* = 13.6, 8.4 Hz, 1H in $ArSCH_2$), 2.40 (d, *J* = 5.2 Hz, 1H in SCH_2), 2.02 (dd, *J* = 5.2, 1.2 Hz, 1H in SCH_2). ^{13}C NMR (101 MHz, $CDCl_3$) (*δ*, ppm) = 133.5, 133.1, 132.3, 129.2, 41.3, 33.3, 25.9. GC-MS (EI) *m/z* = 216 $(M)^+$ for $C_9H_9ClS_2$.

Benzylthiirane (2i)

Colorless oil, 600 mg, yield 44%, R_f = 0.30 (PE/DCM = 10:1, *v*/*v*). ^{1}H NMR ($CDCl_3$, 400 MHz) (*δ*, ppm) = 7.34–7.23 (m, 5H, ArH), 3.12–3.06 (m, 1H, CHS), 2.96 (dd, *J* = 14.4, 6.0 Hz, 1H in $ArCH_2$), 2.92 (dd, *J* = 14.4, 7.2 Hz, 1H in $ArCH_2$), 2.55 (d, *J* = 5.8 Hz, 1H in CH_2S), 2.28 (d, *J* = 5.8 Hz, 1H in CH_2S). ^{13}C NMR (101 MHz, $CDCl_3$) (*δ*, ppm) = 139.2, 128.6, 128.5, 126.6, 42.6, 35.7, 25.6. GC-MS (EI) *m/z* = 150 $(M)^+$ for $C_9H_{10}S$.

***n*-Hexylthiirane (2j)**

Colorless oil, 1.10 g, yield 38%, R_f = 0.85 (PE/EA = 10:1, *v*/*v*). ^{1}H NMR ($CDCl_3$, 400 MHz) (*δ*, ppm) = 2.91-2.84 (m, 1H, SCH), 2.49 (d, *J* = 6.0 Hz, 1H in SCH_2), 2.14 (dd, *J* = 6.0, 0.8 Hz, 1H in SCH_2), 1.86-1.78 (m, 1H, SCHC*H*H), 1.53-1.45 (m, 5H, 1H in CH_2, & $2CH_2$), 1.45-1.23 (m, 4H, $2CH_2$), 0.89 (t, *J* = 6.4 Hz, 3H, CH_3). ^{13}C NMR (101 MHz, $CDCl_3$) (*δ*, ppm) = 36.6, 36.0, 31.7, 29.3, 28.9, 25.9, 22.5, 14.0. GC-MS (EI) *m/z* = 144 $(M)^+$ for $C_8H_{16}S$.

2-Methyl-2-[(4-methylphenoxy)methyl]thiirane (2k)

Colorless oil, 534 mg from **4k** (1.00 g, 5.61 mmol), yield 49%, R_f = 0.84 (PE/EA = 10:1, *v*/*v*). IR (KBr): *v* = 3030, 2983, 2923, 1613, 1585, 1458, 817 cm^{-1}. ^{1}H NMR ($CDCl_3$, 400 MHz) (*δ*, ppm) = 7.08 (d, *J* = 8.0 Hz, 2H, ArH), 6.82 (d, *J* = 8.0 Hz, 2H, ArH), 4.14 (d, *J* = 9.6 Hz, 1H in OCH_2), 3.86 (d, *J* = 9.6 Hz, 1H in OCH_2), 2.52 (s, 1H in SCH_2), 2.47 (s, 1H in SCH_2), 2.29 (s, 3H, $ArCH_3$), 1.75 (s, 3H, $SCCH_3$). ^{13}C NMR (101 MHz, $CDCl_3$) (*δ*, ppm) = 156.6, 130.4, 129.9, 114.6, 76.3, 42.5, 32.7, 23.5, 20.5. GC-MS (EI) *m/z* = 194 $(M)^+$ for $C_{11}H_{14}OS$.

2-Methyl-2-[(3-methylphenoxy)methyl]thiirane (2l)

Colorless oil, 1.02 g from **4l** (1.47 g, 8.00 mmol, yield 57%, R_f = 0.73 (PE/EA = 10:1, *v*/*v*). IR (KBr): *v* = 3038, 2983, 2923, 1601, 1585, 1458, 770, 690 cm^{-1}. ^1H NMR ($CDCl_3$, 400 MHz) (*δ*, ppm) = 7.16 (t, *J* = 7.6 Hz, 1H, ArH), 6.78 (d, *J* = 7.2 Hz, 1H, ArH), 6.73-6.68 (m, 2H, ArH), 4.15 (d, *J* = 9.6 Hz, 1H in OCH_2), 3.86 (d, *J* = 9.6 Hz, 1H in OCH_2), 2.52 (d, *J* = 1.0 Hz, 1H in SCH_2), 2.46 (t, *J* = 1.0 Hz, 1H in SCH_2), 2.32 (s, 3H, $ArCH_3$), 1.74 (s, 3H, $SCCH_3$). ^{13}C NMR (101 MHz, $CDCl_3$) (*δ*, ppm) = 158.7, 139.6 129.2, 121.9, 115.6, 111.5, 76.0, 42.4, 32.7, 23.4, 21.5. GC-MS (EI) *m/z* = 180 $(M)^+$ for $C_{10}H_{12}OS$.

2-Methyl-2-[(4-nitrophenoxy)methyl]thiirane (2m)

Yellowish oil, 562 mg from **4m** (1.00 g, 4.78 mmol), yield 52%, R_f = 0.29 (PE/EA = 10:1, *v*/*v*). IR (KBr): *v* = 3113, 2985, 2929, 1608, 1454, 844 cm^{-1}. ^1H NMR ($CDCl_3$, 400 MHz) (*δ*, ppm) = 8.19 (d, *J* = 9.2 Hz, 2H, ArH), 6.96 (d, *J* = 9.2 Hz, 2H, ArH), 4.21 (dd, *J* = 9.6, 1.2 Hz, 1H in OCH_2), 4.03 (d, *J* = 9.6 Hz, 1H in OCH_2), 2.55 (d, *J* = 1.2 Hz, 1H in SCH_2), 2.51 (t, *J* = 1.2 Hz, 1H in SCH_2), 1.76 (s, 3H, CH_3). ^{13}C NMR (101 MHz, $CDCl_3$) (*δ*, ppm) = 163.4, 141.6, 125.8, 114.5, 76.6, 41.5, 32.2, 23.2. GC-MS (EI) *m/z* = 225 $(M)^+$ for $C_{10}H_{11}NO_3S$.

2-Methyl-2-(2-phenylethyl)thiirane (2n)

Colorless oil, 50 mg, yield 52%, R_f = 0.50 (PE/DCM = 10:1, *v*/*v*). ^1H NMR ($CDCl_3$, 400 MHz) (*δ*, ppm) = 7.29-7.25 (m, 2H, ArH), 7.20-7.17 (m, 3H, ArH), 2.89-2.75 (m, 2H, $ArCH_2$), 2.37 (s, 2H, SCH_2), 2.18 (ddd, *J* = 13.7, 10.6, 6.1 Hz, 1H in CH_2), 1.86 (ddd, *J* = 13.7, 11.0, 5.5 Hz, 1H in CH_2), 1.65 (s, 3H, CH_3). ^{13}C NMR (101 MHz, $CDCl_3$) (*δ*, ppm) = 141.5, 128.4, 128.3, 125.9, 46.0, 43.6, 34.8, 34.2, 25.8. GC-MS (EI) *m/z* = 178 $(M)^+$ for $C_{11}H_{14}S$.

General procedure for the synthesis of thietanes 3

To a stirred suspension of NaH (62 mg, 1.5 mmol) in THF (6.0 mL) was added trimethyloxosulfonium iodide (**1a**, 330 mg, 1.5 mmol). The mixture was further stirred at 40 °C for 3 h. Then a thiirane **2** (0.5 mmol) followed by DMSO (0.1 mL) were added. The mixture was stirred in air at 40 °C for the indicated time until complete consumption of thiirane **2** (TLC and GC-MS monitoring). After cooling and addition of water (20 mL), the mixture was extracted with DCM, and the combined extracts were washed with brine, dried over anhydrous sodium sulfate, and concentrated in vacuo, and the resulting residue was purified by silica gel column chromatography (silica gel buffered by 3% Et_3N, 200–300 mesh, petroleum ether-dichloromethane (PE-DCM), 10:1, v/v) to afford thietane **3**.

For thiiranes **2i**, **2j**, and **2n**, to a stirred suspension of NaH (83 mg, 2.0 mmol) in THF (6.0 mL) was added trimethyloxosulfonium iodide (**1a**, 440 mg, 2.0 mmol). The mixture was further stirred at 40 °C for 3 h. Then thiirane **2** (0.5 mmol) followed by DMSO (0.5 mL) were added.

2-(Phenoxymethyl)thietane (3a)

Colorless liquid, 56 mg, yield 62%, R_f = 0.37 (PE/DCM = 10:1, *v/v*). IR (KBr): *v* = 2923, 2853, 1600, 1496, 1456, 752, 690 cm^{-1}. ^1H NMR ($CDCl_3$, 400 MHz) (*δ*, ppm) = 7.30–7.26 (m, 2H, ArH), 6.97–6.90 (m, 3H, ArH), 4.25 (dd, *J* = 9.6, 7.2 Hz, 1H in CH_2O), 4.14 (dd, *J* = 9.6, 6.4 Hz, 1H in CH_2O), 3.99–3.92 (m, 1H, CHS), 3.26–3.13 (m, 2H, SCH_2), 3.09 (dddd, *J* = 12.0, 6.4, 2.8 Hz, 1H in CH_2), 2.75 (dddd, *J* = 12.0, 8.8, 6.0, 6.0 Hz, 1H in CH_2). ^{13}C NMR (101 MHz, $CDCl_3$) (*δ*, ppm) = 158.6, 129.5, 121.0, 114.7, 72.9, 38.6, 30.1, 22.3. GC-MS (EI) *m/z* = 180 $(M)^+$ for $C_{10}H_{12}OS$. HR-MS (ESI) *m/z* $[M+H]^+$ calcd for $C_{10}H_{13}O_2S^+$: 197.0631, found: 197.0626. Under ESI condition, thietane always generates the corresponding thietane S-oxide. Thus, mass spectrum was determined under EI conditions for comfirmation of structures.

2-(4-Methylphenyloxymethyl)thietane (3b)

Colorless liquid, 73 mg, yield 75%, R_f = 0.33 (PE/DCM = 10:1, *v*/*v*). IR (KBr): *v* = 2923, 2854, 1612, 1585, 1510, 1458, 817 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) (*δ*, ppm) = 7.07 (d, *J* = 8.0 Hz, 2H, ArH), 6.80 (d, *J* = 8.0 Hz, 2H, ArH), 4.24–4.20 (m, 1H in CH_2O), 4.11 (dd, *J* = 10.0, 6.4 Hz, 1H in CH_2O), 4.03–3.86 (m, 1H, SCH), 3.20–3.04 (m, 3H, 1H in CH_2S & CH_2S), 2.78–2.70 (m, 1H in SCH_2), 2.28 (s, 3H, CH_3). ^{13}C NMR (101 MHz, $CDCl_3$) (*δ*, ppm) = 156.5, 130.2, 129.9, 114.6, 73.2, 38.6, 30.1, 22.3, 20.5. GC-MS (EI) *m/z* = 194 $(M)^+$ for $C_{11}H_{14}OS$.

2-(3-Methylphenyloxymethyl)thietane (3c)

Colorless liquid, 61 mg, yield 63%, R_f = 0.34 (PE/DCM = 10:1, *v*/*v*). IR (KBr): *v* = 2957, 2931, 2872, 1629, 1510, 1441, 798, 748 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) (*δ*, ppm) = 7.16 (t, *J* = 7.8 Hz, 1H, ArH), 6.77 (d, *J* = 7.6 Hz, 1H, ArH), 6.75-6.73 (m, 2H, ArH), 4.23 (dd, *J* = 9.6, 7.4 Hz, 1H in OCH_2), 4.12 (dd, *J* = 9.5, 6.3 Hz, 1H in OCH_2), 3.98–3.91 (m, 1H, SCH), 3.25–3.10 (m, 1H in SCH_2), 3.10–3.02 (m, 2H, SCH_2), 2.75-2.70 (m, 1H in SCH_2), 2.32 (s, 3H, CH_3). ^{13}C NMR (101 MHz, $CDCl_3$) (*δ*, ppm) = 158.7, 139.5, 129.2, 121.8, 115.5, 111.5, 72.9, 38.6, 30.1, 22.3, 21.5. GC-MS (EI) *m/z* = 194 $(M)^+$ for $C_{11}H_{14}OS$.

2-(4-Methoxyphenyloxymethyl)thietane (3d)

Colorless liquid, 61 mg, yield 59%, R_f = 0.18 (PE/DCM = 10:1, *v*/*v*). IR (KBr): *v* = 2921, 2850, 1508, 1466, 824 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) (*δ*, ppm) = 6.86–6.81 (m, 4H, ArH), 4.20 (dd, *J* = 9.6, 7.2 Hz, 1H in OCH_2), 4.08 (dd, *J* = 9.6, 6.4 Hz, 1H in OCH_2), 3.97–3.90 (m, 1H, CHS), 3.77 (s, 3H, OCH_3), 3.25–3.10 (m, 2H, SCH_2), 3.10–3.03 (m, 1H in SCH), 2.74-2.70 (m, 1H in CH_2). ^{13}C NMR (101 MHz, $CDCl_3$) (*δ*, ppm) = 154.0, 152.8, 115.8, 114.6, 73.9, 55.7, 38.7, 30.0, 22.3. GC-MS (EI) *m/z* = 210 $(M)^+$ for $C_{11}H_{14}O_2S$.

2-(4-Chlorophenyloxymethyl)thietane (3e)

Colorless liquid, 40 mg, yield 38%, R_f = 0.41 (PE/DCM = 10:1, *v*/*v*). IR (KBr): *v* = 2927, 2860, 1595, 1580, 1491, 1455, 823 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) (*δ*, ppm) = 7.23 (d, *J* = 7.9 Hz, 2H, ArH), 6.83 (d, *J* = 8.0 Hz, 2H, ArH), 4.23–4.19 (m, 1H in OCH_2), 4.12–4.08 (m 1H in OCH_2), 3.97–3.91 (m, 1H, SCH), 3.26–3.07 (m, 2H, SCH_2), 3.07–3.00 (m, 1H in SCH_2), 2.76-2.70 (m, 1H in SCH_2). ^{13}C NMR (101 MHz, $CDCl_3$) (*δ*, ppm) = 157.3, 129.3, 125.9, 115.9, 73.3, 38.4, 29.9, 22.3. GC-MS (EI) *m/z* = 214 $(M)^+$ for $C_{10}H_{11}ClOS$.

2-(2-Phenylethoxymethyl)thietane (3f)

Colorless liquid, 77 mg, yield 74%, R_f = 0.17 (PE/DCM = 10:1, *v*/*v*). IR (KBr): *v* = 2026, 2933, 1604, 1508, 748, 699 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) (*δ*, ppm) = 7.30–7.27 (m, 2H, ArH), 7.22–7.18 (m, 3H, ArH), 3.82–3.73 (m, 1H, SCH), 3.73 (dd, *J* = 15.2, 6.8 Hz, 1H, $ArCH_2CH_2OCHH$), 3.69 (t, *J* = 7.2 Hz, 2H, $ArCH_2CH_2O$), 3.61 (dd, *J* = 9.6, 6.4 Hz, 1H, $ArCH_2CH_2OCHH$), 3.21–3.15 (m, 1H in SCH_2), 3.07 (dt, *J* = 5.6, 9.2 Hz, 1H in SCH_2), 2.99–2.91 (m, 1H in CH_2), 2.89 (t, *J* = 7.2 Hz, 2H, CH_2), 2.67-2.55 (m, 1H in CH_2). ^{13}C NMR (101 MHz, $CDCl_3$) (*δ*, ppm) = 138.8, 128.9, 128.3, 126.2, 76.3, 72.2, 39.4, 36.2, 30.1, 22.2. GC-MS (EI) *m/z* = 208 $(M)^+$ for $C_{12}H_{16}OS$.

2-(Benzyloxymethyl)thietane (3g)

Colorless liquid, 73 mg, yield 75%, R_f = 0.17 (PE/DCM = 10:1, *v*/*v*). IR (KBr): *v* = 3028, 2823, 2850, 1497, 1452, 735, 696 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) (*δ*, ppm) = 7.37-7.27 (m, 5H, ArH), 4.56 (s, 2H, $ArCH_2$), 3.87-3.80 (m, 1H, SCH), 3.75 (dd, *J* = 9.8, 6.8 Hz, 1H in CH_2O), 3.64 (dd, *J* = 9.8, 6.8 Hz, 1H in CH_2O), 3.19 (dt, *J* = 6.8, 9.2 Hz, 1H in SCH_2), 3.08 (dt, *J* = 5.2, 9.2 Hz, 1H in SCH_2), 3.02-2.96, (m, 1H in CH_2), 2.70-2.60 (m, 1H in CH_2). ^{13}C NMR (101 MHz, $CDCl_3$) (*δ*, ppm) = 138.1, 128.4, 128.3, 127.7, 75.5, 73.2, 39.4, 30.1, 22.3. GC-MS (EI) *m/z* = 194 $(M)^+$ for $C_{11}H_{14}OS$.

2-(4-Chlorophenylthiomethyl)thietane (3h)

Colorless liquid, 21 mg, yield 18%, R_f = 0.41 (PE/DCM = 10:1, *v*/*v*). IR (KBr): *v* = 2923, 2860, 1601, 1585, 1491 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) (*δ*, ppm) = 7.31-7.24 (m, 4H, ArH), 3.77-3.69 (m, 1H, $ArSCH_2CH$), 3.27 (dddd, *J* = 13.6, 8.4 Hz, 1H in $ArSCH_2$), 3.22-3.15 (m, 2H, $ArSCHHCHSCHH$), 3.03-2.90 (m, 2H, $SCHHCHH$), 2.65 (dddd, *J* = 10.8, 8.8, 8.8, 4.4 Hz, 1 H, SCH_2CHH). ^{13}C NMR (101 MHz, $CDCl_3$) (*δ*, ppm) = 133.6, 132.8, 131.9, 129.1, 43.0, 39.5, 32.6, 21.3. GC-MS (EI) *m/z* = 230 $(M)^+$ for $C_{10}H_{11}ClS_2$.

2-Benzylthietane (3i)[25]

Colorless liquid, 54 mg, yield 66%, R_f = 0.48 (PE/DCM = 10:1, *v*/*v*). IR (KBr): *v* = 2924, 2854, 1495, 1454, 721, 698 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) (*δ*, ppm) = 7.28 (t, *J* = 7.5 Hz, 2H, ArH), 7.22–7.15 (m, 3H, ArH), 4.00–3.93 (m, 1H, SCH), 3.22 (dd, *J* = 16.8, 8.4 Hz, 1H in $ArCH_2$), 3.09–2.84 (m, 3H, 1H in $ArCH_2$ & SCH_2), 2.92–2.84 (m, 1H, SCH_2CHH), 2.77–2.68 (m, 1H, SCH_2CHH). ^{13}C NMR (101 MHz, $CDCl_3$) (*δ*, ppm) = 138.6, 128.6, 128.4, 126.4, 45.4, 42.9, 33.3, 21.5. GC-MS (EI) *m/z* = 164 $(M)^+$ for $C_{10}H_{12}S$.

2-Hexylthietane (3j)[26]

Colorless liquid, 57 mg, yield 72%, R_f = 0.74 (PE/DCM = 10:1, *v*/*v*). IR (KBr): *v* = 2955, 2925, 2853 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) (*δ*, ppm) = 3.77-3.70 (m, 1H, SCH), 3.23 (dd, *J* = 16.8, 8.4 Hz, 1H in SCH_2), 2.98-2.85 (m, 2H in SCH_2CH_2), 2.66-2.56 (m, 1H in CH_2), 1.80-1.66 (m, 2H, CH_2), 1.71-1.31 (m, 8H, $4CH_2$), 0.88 (t, *J* = 6.8 Hz, 3H, CH_3). ^{13}C NMR (101 MHz, $CDCl_3$) (*δ*, ppm) = 42.9, 39.5, 33.9, 31.8, 28.9, 26.4, 22.6, 21.8, 14.1. GC-MS (EI) *m/z* = 158 $(M)^+$ for $C_9H_{18}S$.

2-Methyl-2-(4-methylphenyloxymethyl)thietane (3k)

Colorless liquid, 95 mg, yield 91%, R_f = 0.45 (PE/DCM = 10:1, *v*/*v*). IR (KBr): *v* = 3030, 2923, 2860, 1613, 1585, 1501, 1452, 1377, 817 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) (*δ*, ppm) = 7.08 (d, *J* = 8.8 Hz, 2H, ArH), 6.83 (d, *J* = 8.8 Hz, 2H, ArH), 4.21 (d, *J* = 9.2 Hz, 1H in OCH_2), 3.95 (d, *J* = 9.2 Hz, 1H in OCH_2), 3.14 (dt, *J* = 7.2, 8.8 Hz, 1H in SCH_2), 3.04 (dt, *J* = 5.2, 9.2 Hz, 1H in SCH_2), 2.88-2.72 (m, 2H, CH_2), 2.29 (s, 3H, CH_3Ar), 1.62 (s, 3H, $SCCH_3$). ^{13}C NMR (101 MHz, $CDCl_3$) (*δ*, ppm) = 157.0, 130.1, 129.8, 114.5, 76.4, 48.1, 36.4, 28.0, 20.4, 18.8. GC-MS (EI) *m/z* = 208 $(M)^+$ for $C_{12}H_{16}OS$.

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2-Methyl-2-(3-methylphenyloxymethyl)thietane (3l)

Colorless liquid, 96 mg, yield 92%, R_f = 0.31 (PE/DCM = 10:1, *v*/*v*). IR (KBr): *v* = 3037, 2955, 2922, 2860, 1601, 1585, 1489, 1450, 770, 690 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) (*δ*, ppm) = 7.17 (t, *J* = 8.0 Hz, 1H, ArH), 6.78-6.73 (m, 3H, ArH), 4.22 (d, *J* = 9.2 Hz, 1H in OCH_2), 3.97 (d, *J* = 9.2 Hz, 1H in OCH_2), 3.18-3.12 (m, 1H in SCH_2), 3.04-3.00 (m, 1H in SCH_2), 2.88-2.72 (m, 2H, CH_2), 2.33 (s, 3H, CH_3Ar), 1.62 (s, 3H, $SCCH_3$). ^{13}C NMR (101 MHz, $CDCl_3$) (*δ*, ppm) = 159.0, 139.5, 129.2, 121.7, 115.5, 111.5, 76.1, 48.1, 36.4, 28.0, 21.5, 18.8. GC-MS (EI) *m/z* = 208 $(M)^+$ for $C_{12}H_{16}OS$.

2-Methyl-2-(4-nitrophenyloxymethyl)thietane (3m)

Colorless liquid, 20 mg, yield 17%, R_f = 0.40 (PE/DCM = 10:1, *v*/*v*). IR (KBr): *v* = 2929, 2850, 1618, 1592, 1555, 1500, 1384, 843 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) (*δ*, ppm) = 8.22 (d, *J* = 9.2 Hz, 2H, ArH), 7.00 (d, *J* = 9.2 Hz, 2H, ArH), 4.31 (d, *J* = 9.2 Hz, 1H in OCH_2), 4.10 (d, *J* = 9.2 Hz, 1H in OCH_2), 3.20-3.14 (m, 1H in SCH_2), 3.08 (dt, *J* = 5.2, 8.8 Hz, 1H in SCH_2), 2.8-2.80 (m, 2H, CH_2), 1.65 (s, 3H, CCH_3). ^{13}C NMR (101 MHz, $CDCl_3$) (*δ*, ppm) = 163.9, 141.7, 125.9, 114.6, 76.7, 47.4, 36.2, 27.8, 18.7. GC-MS (EI) *m/z* = 239 $(M)^+$ for $C_{11}H_{13}NO_3S$.

2-Methyl-2-phenethylthietane (3n)

Colorless liquid, 50 mg, yield 52%, R_f = 0.50 (PE/DCM = 10:1, *v*/*v*). IR (KBr): *v* = 3061, 2922, 1603, 1497, 747, 698 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) (*δ*, ppm) = 7.31–7.16 (m, 5H, ArH), 3.20-3.07 (m, 1H in $ArCH_2$), 3.07-2.98 (m, 1H in $ArCH_2$), 2.79–2.70 (m, 2H, SCH_2), 2.70-2.60 (m, 2H, CH_2), 2.16 (ddd, *J* = 13.5, 11.3, 5.5 Hz, 1H in CH_2), 2.00 (ddd, *J* = 13.5, 11.1, 6.0 Hz, 1H in CH_2), 1.61 (s, 3H, CH_3). ^{13}C NMR (101 MHz, $CDCl_3$) *δ* = 142.1, 128.39, 128.37, 125.8, 51.2, 47.0, 40.0, 31.4, 30.2, 18.4. GC-MS (EI) *m/z* = 192 $(M)^+$ for $C_{12}H_{16}S$.

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