An efficient procedure for cleavage of aziridines with various thiols promoted by $ZnCl_2$

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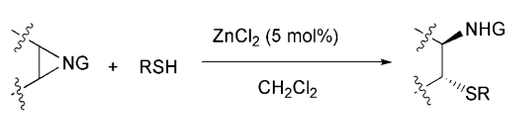
The ring-opening reaction of aziridines with various thiophenols and thiols catalyzed by $ZnCl_2$ provides β-amino sulfides in high yield.

Currently, there is significant interest in the synthesis and reactions of aziridines and their N-activated analogs.[1] Due to their very high reactivity and ability to function as carbon electrophiles, aziridine derivatives are versatile synthetic intermediates for the synthesis of biologically important compounds. Procedures for the synthesis of aziridines have been well developed and thus aziridines are as readily available as epoxides,[2] and significant progress has been made in the ring-opening reactions of activated and unactivated aziridines.

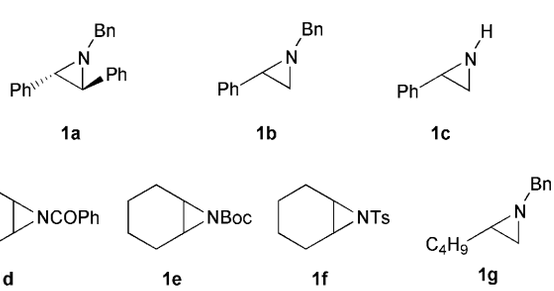
β-Amino sulfides are compounds of undoubted synthetic interest in organic chemistry.[3] The most straightforward route to β-amino sulfides involves the regioselective ring-opening reaction of aziridines with thiols, and several procedures have appeared in the literature.[4–6] Boron trifluoride promoted the ring-opening reaction of aziridines with thiols but more than a stoichiometric amount of $BF_3{\cdot}OEt_2$ and an excess of thiophenol were needed.[4e–i] Thiophenolates seem to be effective reagents; however, the reaction should proceed under basic reaction conditions.[4a–d] Triethylamine was also used when *N*-nosylaziridines were the substrates.[4j] Very recently, ring-opening reactions of *N*-[(*S*)-(−)-α-methylbenzyl]aziridine-2-methanol derivatives with 3.0 equivalents of a thiol were reported by Lee.[5] When butane-1-thiol was used as the nucleophile, the reaction was complete after 42 h under reflux. Uneyama reported that the ring-opening reaction of *N*-benzyl-2-(trifluoromethyl)aziridine with thiophenol (20 equiv.) at 90 °C for 3 h afforded the desired product (85% yield) in the presence of CF_3SO_3H.[6] Although there are precedents for ring-opening reactions of aziridines by thiols or thiophenolates, to date there is no general and efficient method for the reaction because of possible complexity in the structure of the substrate aziridine. As part of a programme aimed at the synthesis of epoxides and aziridines and their applications in organic synthesis,[7] we have studied the ring-opening reactions of these small heterocyclic compounds.[8,9] It was found that $ZnCl_2$ was an efficient catalyst in the ring opening of epoxides with thiols.[8c] Thus we tried to use this catalyst in the ring-opening reaction of aziridine and thiophenol. Herein we would like to report a general and effective procedure for the ring-opening reaction of aziridines with various thiols promoted by Lewis acids (Scheme 1).



Scheme 1

Results and discussion

At the outset, the reaction was carried out by using (2*S*,3*S*)-*N*-benzyl-2,3-diphenylaziridine **1a** and thiophenol **2a** and only 8% of the corresponding product was obtained after 24 hours at room temperature in the absence of $ZnCl_2$. We thought that if Lewis acids were used, the substrate would be activated and the reaction could proceed smoothly. Thus, we carried out the reaction of *N*-benzyl-2,3-diphenylaziridine **1a** and thiophenol **2a** in the presence of $ZnCl_2$ (10 mol%) in dichloromethane at room temperature. The reaction was finished in 5 minutes and the corresponding product **3aa** was obtained in 85% yield. We also screened other Lewis acids (10 mol%) in this reaction at room temperature and the following results were obtained $Zn(OTf)_2$ (80% yield after 5 min), $Cu(OTf)_2$ (72% yield after 10 h), $Ti(O^iPr)_4$ (11% yield after 24 h), and $Yb(OTf)_3$ (70% yield after 24 h). It seems that when 'softer' Lewis acids are used the results are better. Although $Yb(OTf)_3$ gave 70% yield the reaction time was longer. The reaction could proceed even in the presence of 5 mol% of $ZnCl_2$ to furnish the corresponding product in 82% yield (Table 1). It was found that the ring-opening reaction of the *N*-Boc-cyclohexanoaziridine **1e** with thiophenol could proceed without Lewis acid, the yield being 48% after eight hours. However, when a catalytic amount of $ZnCl_2$ (5 mol%) was used, the desired product **3ea** was provided in 81% yield, and the reaction time was less than 5 minutes. We also carried out the above reaction using catalytic amounts (5 mol%) of $Yb(OTf)_3$ (78% yield) and $Cu(OTf)_2$ (71% yield). To show the scope of the reaction, we extended it to a variety of thiols and aziridines using $ZnCl_2$ (5 mol%) as catalyst. In all cases, a very clean reaction was observed and the corresponding product was obtained in high yield (Table 1).



From Table 1, it can be seen that all reactions proceeded smoothly under mild conditions to afford the desired β-amino sulfides in high yields. All reactions were carried out at room temperature and most of them were finished in less than

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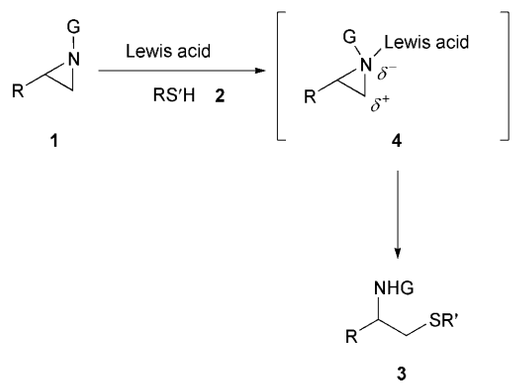
Table 1 Ring opening of aziridines with various thiols promoted by $ZnCl_2$ [a]

Entry	Aziridine	Thiol		Product	Yield (%) [b]
1	**1a**	PhSH	**2a**	**3aa**	82
2	**1a**	*p*-$CH_3C_6H_4SH$	**2b**	**3ab**	88
3	**1a**	*p*-ClC_6H_4SH	**2c**	**3ac**	81
4	**1a**	BnSH	**2e**	**3ae**	85
5	**1b**	PhSH	**2a**	**3ba**	81
6	**1b**	*p*-$CH_3C_6H_4SH$	**2b**	**3bb**	82
7	**1b**	*p*-ClC_6H_4SH	**2c**	**3bc**	84
8	**1b**	*p*-$(CH_3)_3CC_6H_4SH$	**2d**	**3bd**	91
9	**1b**	BnSH	**2e**	**3be**	71
10	**1b**	^{n}BuSH	**2f**	**3bf**	79
11	**1c**	PhSH	**2a**	**3ca**	83
12	**1c**	*p*-ClC_6H_4SH	**2c**	**3cc**	61
13	**1c**	*p*-$(CH_3)_3CC_6H_4SH$	**2d**	**3cd**	78
14	**1c**	BnSH	**2e**	**3ce**	78
15	**1d**	PhSH	**2a**	**3da**	72
16	**1e**	PhSH	**2a**	**3ea**	81
17	**1e**	*p*-$CH_3C_6H_4SH$	**2b**	**3eb**	83
18	**1e**	*p*-ClC_6H_4SH	**2c**	**3ec**	90
19	**1e**	*p*-$(CH_3)_3CC_6H_4SH$	**2d**	**3ed**	74
20	**1e**	BnSH	**2e**	**3ee**	69
21 [c]	**1f**	PhSH	**2a**	**3fa**	67
22	**1g**	*p*-$(CH_3)_3CC_6H_4SH$	**2d**	**3gd**	95

[a] Reaction conditions: aziridine (1.0 mmol), thiol (1.0 mmol), $ZnCl_2$ (5 mol%) in CH_2Cl_2 (3.0 mL) at room temperature. [b] Isolated yield based on aziridine. [c] $Zn(OTf)_2$ (5 mol%) as the catalyst.

5 minutes. The worthy feature of the reaction is that not only the activated aziridines but also the unactivated aziridines are suitable substrates in this reaction. Also, nucleophiles are not limited to thiophenols: thiols such as toluene-α-thiol **2e** and butane-1-thiol **2f** are efficient too. As previously observed in other metal salt-promoted reactions,[8b] the $ZnCl_2$-catalyzed reaction are completely *anti*-stereoselective. In the case of *mono*-substituted aziridines, the nucleophile attacked the terminal aziridine carbon regioselectively.

Coordination of the Lewis acid is the major criterion for the reaction. It seems that the generation of a highly reactive Lewis acid-coordinated aziridine **4** is essential for the ring-opening reaction (Scheme 2). Some aziridines, especially



Scheme 2

those containing electron-withdrawing groups, are known to be reactive toward nucleophiles.[2,9,10] However, when the aziridine **1f** was used as the substrate, a 67% yield of the product **3fa** was obtained after 20 hours at room temperature by using zinc triflate as the catalyst. The result might be due to the low coordinating ability of the lone pair on the nitrogen atom of the *N*-tosylcyclohexanoaziridine **1f** toward Lewis acids.

In conclusion, we have developed an efficient and convenient method for the ring-opening reactions of aziridines with thiols. It provides a simple and general access to β-amino sulfides from aziridines because of its efficiency and simplicity. Studies toward an asymmetric version of this reaction are underway.

Experimental

All reactions were performed under a nitrogen atmosphere using oven-dried glassware. Solvents were purified prior to use according to the standard method. The commercially available reagents were used as received without further purification. Mps are uncorrected. ^{1}H NMR spectra were recorded on a Bruker AMX-300 (300 MHz). IR spectra were recorded in KBr and mesured in cm^{-1}, using a Shimadzu IR-440 infrared spectrophotometer. Mass spectra and high-resolution mass spectra were taken using HP5989A and Finnigan MAT mass spectrometers, respectively. Elemental analyses were performed on a Foss-Heraeus Vario EL instrument. Optical rotations were measured using a Perkin-Elmer 241 MC polarimeter with a thermally jacketed 10 cm cell. $[a]_D$-Values are given in units of 10^{-1} deg cm^2 g^{-1}.

General procedure

To a stirred solution of anhydrous zinc(II) chloride (18 mg, 0.05 mmol) in CH_2Cl_2 (3.0 mL) was added an aziridine **1** (1.0 mmol) and a thiol **2** (1.0 mmol) under nitrogen and the resulting mixture was stirred at ambient temperature until complete consumption of the aziridine (monitored by TLC). The reaction mixture was then diluted with 10 mL of diethyl ether, washed subsequently with saturated aq. NH_4Cl (20 mL) and water (10 mL), and dried ($MgSO_4$). The solvent was removed *in vacuo* to give an oil, which was purified by flash column chromatography to obtain the corresponding β-amino sulfides.

***N*-[(1*S*,2*R*)-1,2-Diphenyl-2-(phenylthio)ethyl]benzenemethanamine 3aa.** 82% Yield, white solid, mp 96–98 °C; $[a]_D^{20}$ −80.3 (*c* 1.35, $CHCl_3$); IR (neat) ν_{max} 3250, 1600 cm^{-1}; ^{1}H NMR ($CDCl_3$; TMS) δ 1.50–2.30 (br, 1H), 3.35 (d, *J* 13.6 Hz, 1H), 3.60 (d, *J* 13.6 Hz, 1H), 4.05 (d, *J* 7.5 Hz, 1H), 4.40 (d, *J* 7.5 Hz, 1H), 7.00–7.30 (m, 20H); EIMS (relative intensity) 395 (M, 7%), 289 (22), 196 (99), 91 (100); HRMS: Calc. for $C_{27}H_{25}NS$: *M*, 395.1707. Found: M^+, 395.1663.

***N*-[(1*S*,2*R*)-2-(4-Methylphenylthio)-1,2-diphenylethyl]benzenemethanamine 3ab.** 88% Yield, white solid, mp 82–84 °C; $[a]_D^{20}$ −95.2 (*c* 0.9, $CHCl_3$); IR (neat) ν_{max} 3300, 1599 cm^{-1}; ^{1}H NMR ($CDCl_3$; TMS) δ 2.15 (s, 3H), 2.20–2.30 (m, 1H), 3.30 (d,

J 13.6 Hz, 1H), 3.65 (d, *J* 13.8 Hz, 1H), 3.95 (d, *J* 7.4 Hz, 1H), 4.30 (d, *J* 6.2 Hz, 1H), 6.80–7.40 (m, 19H); EIMS (relative intensity) 409 (M^+, 0.35%), 302 (3), 196 (56), 91 (100) (Calc. for $C_{28}H_{27}NS$: C, 82.15; H, 6.60; N, 3.42. Found: C, 82.46; H, 6.64; N, 3.34%).

***N*-[(1*S*,2*R*)-2-(4-Chlorophenylthio)-1,2-diphenylethyl]-benzenemethanamine 3ac.** 81% Yield, white solid, mp 88–90 °C; $[\alpha]_D^{20}$ −93.9 (*c* 0.7, $CHCl_3$); IR (neat) ν_{max} 3311, 1602 cm^{-1}; ^1H NMR ($CDCl_3$; TMS) δ 1.50–2.50 (br, 1H), 3.30 (d, *J* 13.7 Hz, 1H), 3.60 (d, *J* 13.9 Hz, 1H), 4.05 (d, *J* 7.8 Hz, 1H), 4.35 (d, *J* 6.5 Hz, 1H), 6.90–7.50 (m, 19H); EIMS (relative intensity) 432 (MH^+, 3%, ^{37}Cl), 431 (M^+, 3, ^{37}Cl), 430 (MH^+, 8, ^{35}Cl), 429 (M^+, 1, ^{35}Cl), 322 (20), 286 (17), 196 (91), 91 (100) (Calc. for $C_{27}H_{24}ClNS$: C, 75.44; H, 5.58; N, 3.26. Found: C, 75.76; H, 5.67; N, 3.14%).

***N*-[(1*S*,2*R*)-1,2-Diphenyl-2-(phenylmethylthio)ethyl]benzene-methanamine 3ae.** 85% Yield, white solid, mp 110–112 °C; $[\alpha]_D^{20}$ −69.7 (*c* 0.75, $CHCl_3$); IR (neat) ν_{max} 3274, 1600 cm^{-1}; ^1H NMR ($CDCl_3$; TMS) δ 1.25–2.00 (br, 1H), 3.20 (s, 2H), 3.25–3.40 (m, 1H), 3.50–3.75 (m, 1H), 3.80–4.10 (m, 2H), 6.90–7.50 (m, 20H); EIMS (relative intensity) 409 (M^+, 1%), 302 (2), 196 (73), 91 (100) (Calc. for $C_{28}H_{27}NS$: C, 82.15; H, 6.60; N, 3.42. Found: C, 82.24; H, 6.55; N, 3.27%).

***N*-[1-Phenyl-2-(phenylthio)ethyl]benzenemethanamine 3ba.** 81% Yield, colorless liquid; IR (neat) ν_{max} 3327, 1601 cm^{-1}; ^1H NMR ($CDCl_3$; TMS) δ 1.90 (br s, 1H), 3.10 (d, *J* 7.3 Hz, 2H), 3.80 (s, 2H), 4.40 (t, *J* 7.3 Hz, 1H), 7.10–7.40 (m, 15H); EIMS (relative intensity) 320 (MH^+, 3%), 319 (M^+, 0.25), 210 (1), 120 (83), 91 (100); HRMS: Calc. for $C_{21}H_{21}NS$: *M*, 319.1422. Found: M^+, 319.1408.

***N*-[2-(4-Methylphenylthio)-1-phenylethyl]benzenemethan-amine 3bb.** 82% Yield, colorless liquid; IR (neat) ν_{max} 3320, 1600 cm^{-1}; ^1H NMR ($CDCl_3$; TMS) δ 1.90 (br s, 1H), 2.30 (s, 3H), 3.10 (d, *J* 7.3 Hz, 2H), 3.80 (s, 2H), 4.30 (t, *J* 7.3 Hz, 1H), 7.00 (d, *J* 8.4 Hz, 2H), 7.10 (d, *J* 8.1 Hz, 2H), 7.15–7.40 (m, 10H); EIMS (relative intensity) 334 (MH^+, 10%), 210 (7), 120 (78), 91 (100); HRMS: Calc. for $C_{22}H_{23}NS$: *M*, 333.1524. Found: M^+, 333.1538.

***N*-[2-(4-Chlorophenylthio)-1-phenylethyl]benzenemethan-amine 3bc.** 84% Yield, colorless liquid; IR (neat) ν_{max} 3320, 1602 cm^{-1}; ^1H NMR ($CDCl_3$; TMS) δ 2.10–2.40 (br s, 1H), 3.10 (d, *J* 7.3 Hz, 2H), 3.80 (s, 2H), 4.30 (t, *J* 7.3 Hz, 1H), 7.10–7.40 (m, 14H); EIMS (relative intensity) 354 (MH^+, 0.25%), 353 (M^+, 0.11), 120 (65), 91 (100); HRMS: Calc. for $C_{21}H_{20}ClNS$: *M*, 353.0975. Found: M^+, 353.0990.

***N*-[2-(4-*tert*-Butylphenylthio)-1-phenylethyl]benzenemethan-amine 3bd.** 91% Yield, colorless liquid; IR (neat) ν_{max} 3322, 1601 cm^{-1}; ^1H NMR ($CDCl_3$; TMS) δ 1.30 (s, 9H), 1.90 (br s, 1H), 3.10 (d, *J* 7.3 Hz, 2H), 3.80 (s, 2H), 4.35 (t, *J* 7.3 Hz, 1H), 7.15–7.40 (m, 14H); EIMS (relative intensity) 376 (MH^+, 100%), 210 (15), 120 (35), 91 (61); HRMS: Calc. for $C_{25}H_{29}NS$: *M*, 375.1978. Found: M^+, 375.1999.

***N*-[1-Phenyl-2-(phenylmethylthio)ethyl]benzenemethanamine 3be.** 71% Yield, colorless liquid; IR (neat) ν_{max} 3321, 1601 cm^{-1}; ^1H NMR ($CDCl_3$; TMS) δ 1.90 (br s, 1H), 3.00 (d, *J* 7.4 Hz, 2H), 3.47 (d, *J* 13.4 Hz, 1H), 3.58 (d, *J* 13.4 Hz, 1H), 3.70 (s, 2H), 3.90 (t, *J* 7.4 Hz, 1H), 7.20–7.40 (m, 15H); EIMS (relative intensity) 334 (MH^+, 26%), 210 (12), 120 (60), 91 (100); HRMS: Calc. for $C_{22}H_{23}NS$: *M*, 333.1515. Found: M^+, 333.1533.

***N*-[2-(Butylthio)-1-phenylethyl]benzenemethanamine 3bf.** 79% Yield, colorless liquid; IR (neat) ν_{max} 3322, 1601 cm^{-1}; ^1H NMR ($CDCl_3$; TMS) δ 0.85 (t, *J* 7.3 Hz, 3H), 1.20–1.60 (m, 4H), 2.10 (br, 1H), 2.30 (m, 2H), 3.00 (d, *J* 7.4 Hz, 2H), 3.80 (s, 2H), 4.00 (t, *J* 7.4 Hz, 1H), 7.15–7.45 (m, 10H). EIMS (relative intensity) 300 (MH^+, 0.84%), 120 (85), 91 (100); HRMS: Calc. for $C_{19}H_{25}NS$: *M*, 299.1697. Found: M^+, 299.1702.

1-Phenyl-2-(phenylthio)ethanamine 3ca. 83% Yield, colorless liquid; IR (neat) ν_{max} 3373, 1583 cm^{-1}; ^1H NMR ($CDCl_3$; TMS) δ 1.50 (s, 2H), 3.15 (d, *J* 6.8 Hz, 2H), 4.15 (t, *J* 6.9 Hz, 1H), 7.10–7.40 (m, 10H); EIMS (relative intensity) 230 (MH^+, 7%), 229 (M^+, 9), 213 (34), 199 (100), 165 (18), 120 (38); HRMS: Calc. for $C_{14}H_{15}NS$: *M*, 229.0891. Found: M^+, 229.0908.

2-(4-Chlorophenylthio)-1-phenylethanamine 3cc. 61% Yield, colorless liquid; IR (neat) ν_{max} 3376, 1600 cm^{-1}; ^1H NMR ($CDCl_3$; TMS) δ 1.55 (s, 2H), 3.10 (d, *J* 7.0 Hz, 2H), 4.10 (t, *J* 7.0 Hz, 1H), 7.10–7.40 (m, 9H); EIMS (relative intensity) 265 (M^+, 1%, ^{37}Cl), 263 (M^+, 3, ^{35}Cl), 197 (33), 120 (100), 91 (76); HRMS: Calc. for $C_{14}H_{14}ClNS$: *M*, 263.0538. Found: M^+, 263.0537.

2-(4-*tert*-Butylphenylthio)-1-phenylethanamine 3cd. 78% Yield, colorless liquid; IR (neat) ν_{max} 3376, 1599 cm^{-1}; ^1H NMR ($CDCl_3$; TMS) δ 1.30 (s, 9H), 1.60 (s, 2H), 3.15 (d, *J* 6.9 Hz, 2H), 4.15 (t, *J* 6.9 Hz, 1H), 7.20–7.30 (m, 9H); EIMS (relative intensity) 285 (M^+, 3%), 255 (100), 241 (13), 199 (17), 120 (65), 91 (48); HRMS: Calc. for $C_{18}H_{23}NS$: *M*, 285.1559. Found: M^+, 285.1555.

1-Phenyl-2-(phenylmethylthio)ethanamine 3ce. 78% Yield, colorless liquid; IR (neat) ν_{max} 3374, 1601 cm^{-1}; ^1H NMR ($CDCl_3$; TMS) δ 1.45 (s, 2H), 3.00 (d, *J* 6.9 Hz, 2H), 3.48 (d, *J* 13.4 Hz, 1H), 3.60 (d, *J* 13.4 Hz, 1H), 3.67 (t, *J* 7.0 Hz, 1H), 7.20–7.50 (m, 10H); EIMS (relative intensity) 244 (MH^+, 7%), 227 (15), 213 (28), 121 (38), 91 (100); HRMS: Calc. for $C_{15}H_{17}NS$: *M*, 243.1066. Found: M^+, 243.1074.

***N*-[2-(Phenylthio)cyclohexyl]benzamide 3da.** 72% Yield, white solid; mp 126–128 °C; IR (neat) ν_{max} 3302, 2933, 1637, 1554 cm^{-1}; ^1H NMR ($CDCl_3$; TMS) δ 1.10–1.50 (m, 4H), 1.60–1.75 (m, 2H), 2.05–2.20 (m, 1H), 2.25–2.40 (m, 1H), 2.90–3.10 (m, 1H), 3.75–3.90 (m, 1H), 6.20 (d, *J* 6.6 Hz, 1H), 7.10–7.50 (m, 8H), 7.60 (d, *J* 8.6 Hz, 2H); EIMS (relative intensity) 311 (M^+, 0.54%), 273 (6), 210 (27), 190 (100), 155 (23), 105 (98), 91 (81) (Calc. for $C_{19}H_{21}NOS$: C, 73.31; H, 6.75; N, 4.50. Found: C, 73.16; H, 6.87; N, 4.33%).

***N*-Boc-2-(Phenylthio)cyclohexylamine 3ea.** 81% Yield, white solid; mp 108–110 °C; IR (neat) ν_{max} 3346, 2932, 1686, 1532 cm^{-1}; ^1H NMR ($CDCl_3$; TMS) δ 1.10–1.30 (m, 3H), 1.40 (s, 9H), 1.50–1.75 (m, 3H), 1.95–2.05 (m, 1H), 2.05–2.20 (m, 1H), 2.85 (dt, *J* 10.3, 3.7 Hz, 1H), 3.30–3.40 (m, 1H), 4.62 (d, *J* 7.3 Hz, 1H), 7.10–7.30 (m, 3H), 7.30–7.50 (m, 2H); EIMS (relative intensity) 307 (M^+, 2.4%), 252 (2), 190 (23), 57 (100); HRMS: Calc. for $C_{17}H_{25}NO_2S$: *M*, 307.1564. Found: M^+, 307.1585.

***N*-Boc-2-(4-Methylphenylthio)cyclohexylamine 3eb.** 83% Yield, white solid; mp 82–84 °C; IR (neat) ν_{max} 3373, 2939, 1687, 1520 cm^{-1}; ^1H NMR ($CDCl_3$; TMS) δ 1.10–1.50 (m, 3H), 1.40 (s, 9H), 1.60–1.80 (m, 3H), 2.00–2.10 (m, 1H), 2.10–2.25 (m, 1H), 2.35 (s, 3H), 2.80 (dt, *J* 10.4, 3.7 Hz, 1H), 3.20–3.40 (m, 1H), 4.60–4.80 (m, 1H), 7.10 (d, *J* 7.8 Hz, 2H), 7.40 (d, *J* 8.1 Hz, 2H); EIMS (relative intensity) 321 (M^+, 11%), 204 (98), 57 (100); HRMS: Calc. for $C_{18}H_{27}NO_2S$: *M*, 321.1718; Found: M^+, 321.1740.

***N*-Boc-2-(4-Chlorophenylthio)cyclohexylamine 3ec.** 90% Yield, white solid; mp 109–111 °C; IR (neat) ν_{max} 3369, 2936, 1687, 1523 cm^{-1}; ^1H NMR ($CDCl_3$; TMS) δ 1.10–1.50 (m, 3H), 1.40

(s, 9H), 1.50–1.75 (m, 3H), 2.00–2.10 (m, 1H), 2.10–2.25 (m, 1H), 2.80 (dt, *J* 10.3, 3.4 Hz, 1H), 3.30–3.40 (m, 1H), 4.65 (d, *J* 8.8 Hz, 1H), 7.20–7.30 (m, 2H), 7.40 (d, *J* 8.1 Hz, 2H); EIMS (relative intensity) 344 (MH^+, 1%, ^{37}Cl), 343 (M^+, 6, ^{37}Cl), 342 (MH^+, 4, ^{35}Cl), 341 (M^+, 14, ^{35}Cl), 286 (6), 224 (56), 57 (100) (Calc. for $C_{17}H_{24}ClNO_2S$: C, 59.74; H, 7.03; N, 4.10. Found: C, 59.91; H, 7.11; N, 4.20%).

***N*-Boc-2-(4-*tert*-Butylphenylthio)cyclohexylamine 3ed.** 74% Yield, white solid; mp 100–102 °C; IR (neat) ν_{max} 3351, 2936, 1678, 1533 cm^{-1}; ^1H NMR ($CDCl_3$; TMS) δ 1.10–1.35 (m, 12H), 1.45 (s, 9H), 1.60–1.80 (m, 3H), 2.00–2.10 (m, 1H), 2.10–2.25 (m, 1H), 2.80 (dt, *J* 10.7, 3.8 Hz, 1H), 3.30–3.45 (m, 1H), 4.70 (d, *J* 6.6 Hz, 1H), 7.30 (d, *J* 8.4 Hz, 2H), 7.40 (d, *J* 8.4 Hz, 2H); EIMS (relative intensity) 364 (MH^+, 4%), 363 (M^+, 15), 307 (2), 246 (100), 231 (19) (Calc. for $C_{21}H_{33}NO_2S$: C, 69.42; H, 9.09; N, 3.86. Found: C, 69.46; H, 9.15; N, 3.89%).

***N*-Boc-2-(Phenylmethylthio)cyclohexylamine 3ee.** 69% Yield, white solid; mp 69–71 °C; IR (neat) ν_{max} 3356, 2938, 1684, 1531 cm^{-1}; ^1H NMR ($CDCl_3$; TMS) δ 1.10–1.90 (m, 6H), 1.40 (s, 9H), 2.00–2.30 (m, 2H), 2.40 (dt, *J* 10.1, 3.6 Hz, 1H), 3.40–3.60 (m, 1H), 3.60–3.80 (m, 2H), 4.50–4.70 (m, 1H), 7.20–7.40 (m, 5H); EIMS (relative intensity) 321 (M^+, 0.11%), 265 (8), 204 (31), 57 (100); HRMS: Calc. for $C_{18}H_{27}NO_2S$: *M*, 321.1748. Found: M^+, 321.1755.

4-Methyl-*N*-[2-(phenylthio)cyclohexyl]benzenesulfonamide 3fa. 67% Yield, white solid; mp 130–131 °C; IR (film) ν_{max} 3265 cm^{-1}; ^1H NMR ($CDCl_3$; TMS) δ 1.20–1.50 (m, 4H), 1.50–1.75 (m, 2H), 2.00–2.10 (m, 1H), 2.20–2.30 (m, 1H), 2.45 (s, 3H), 2.80–3.00 (m, 2H), 5.10–5.20 (d, *J* 3.6 Hz, 1H), 7.20–7.40 (m, 7H), 7.75 (d, *J* 8.3 Hz, 2H); EIMS (relative intensity) 361 (M^+, 7%), 252 (13), 206 (76), 190 (83), 91 (100) (Calc. for $C_{19}H_{23}NO_2S_2$: C, 63.13; H, 6.41; N, 3.87. Found: C, 63.07; H, 6.48; N, 3.91%).

***N*-[1-(4-*tert*-Butylphenylthiomethyl)pentyl]benzenemethanamine 3gd.** 95% Yield, colorless liquid; IR (neat) ν_{max} 3320, 1602 cm^{-1}; ^1H NMR ($CDCl_3$; TMS) δ 0.85 (t, *J* 7.0 Hz, 3H), 1.20–1.40 (m, 13H), 1.50–1.70 (m, 2H), 2.00–2.40 (br, 1H), 2.70–2.80 (m, 1H), 2.98 (dd, *J* 13.1, 6.5 Hz, 1H), 3.10 (dd, *J* 13.1, 6.5 Hz, 1H), 3.75 (s, 2H), 7.20–7.40 (m, 9H); EIMS (relative intensity) 356 (MH^+, 8%), 298 (1), 176 (100), 91 (97); HRMS: Calc. for $C_{23}H_{33}NS$: *M*, 355.2359. Found: M^+, 355.2346.

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