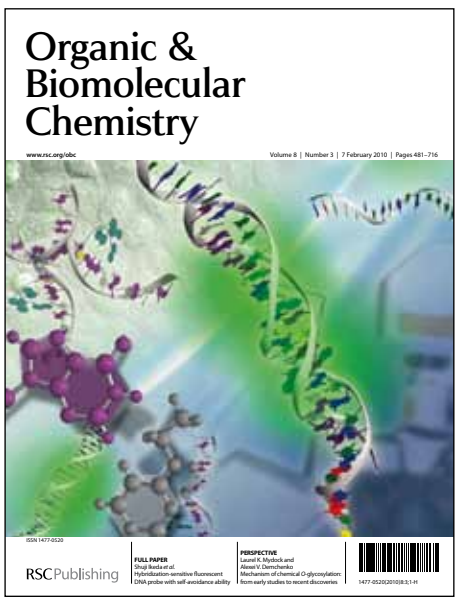
Organic & Biomolecular Chemistry

Accepted Manuscript



Cite this: DOI: 10.1039/c0xx00000x

www.rsc.org/xxxxxx

ARTICLE TYPE

Synthesis of Thioamides via One-Pot A^3-Coupling of Alkynyl Bromides, Amines, and Sodium Sulfide

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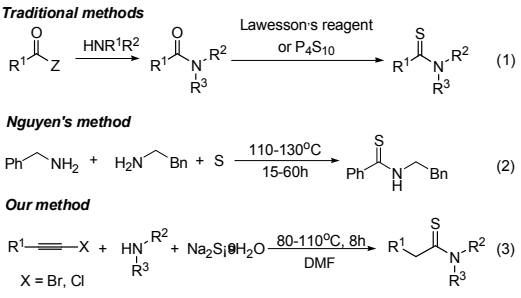
Received (in XXX, XXX) Xth XXXXXXXXX 200X, Accepted Xth XXXXXXXXX 200X

DOI: 10.1039/b000000x

We herein described a novel method for the synthesis of thioamides by three component condensation of alkynyl bromides, amines, and $Na_2S·9H_2O$. The developed method is applicable for a wide range of amines and alkynyl bromides bearing different functional groups furnishing the corresponding products in moderate to excellent yields.

Introduction

Thioamides are prevalent structural motifs that are found in many biologically active molecules[1] and synthetic intermediates.[2] They have attracted considerable attention in organic synthesis as versatile synthons due to their unique reactivity and wide availability.[3] For example, various important chemicals including nitriles, amides, amidines, and sulfur-containing heterocycles (e.g., thiazoles, thiazolins, and thiazolinons) have been synthesized from thioamides.[4] Compared with its analogue amides, the synthetic methods for the formation of thioamides are rather limited. Traditional methods for the preparation of thioamides usually involve the condensation of carboxyl derivatives and amines followed by thionation with the aid of P_4S_{10}, Lawesson's reagent, etc,[5] which often produce toxic chemical wastes and need tedious procedures (Scheme 1, eq. 1). And so far, the synthesis of thioamides in one-pot relies heavily on Willgerodt-Kindler reaction, starting from aryl alkyl ketones, elemental sulfur, and secondary amines such as morpholine.[6] Recently, Nguyen and coworkers developed a three-component reaction involving elemental sulfur and two different aliphatic primary amines for the synthesis of thioamides (Scheme 1, eq. 2).[7] However, this method has limited application because of the high reaction temperature and long reaction time that are typically required. As a consequence, the development of new methods for the practical synthesis of thioamides under mild reaction conditions is still highly desirable .



Scheme 1. Synthetic Approaches to Thioamides

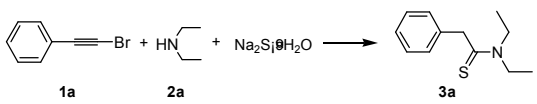
It has been demonstrated that haloalkynes are useful synthons in many organic transformations.[8] Our group has reported several nucleophilic additions, homocoupling reactions, and transition-metal-catalyzed bond formation reactions of haloalkynes.[9] As part of our continuing program on the functionalization of haloakynes, herein, we wish to report a highly efficient method for the thioamide synthesis from alkynyl bromides based on three-component reaction under convenient conditions.

On the basis of copper or iodine catalyzed reactions for the formation of C-N and C-S bonds[10, 11] and recent development of new reactions or synthetic sequences starting from ynamides,[12] we envisioned that the condensation of alkynyl bromides, amines and $Na_2S·9H_2O$ would provide thioamides.

Results and discussion

The first reaction of phenylethynyl bromide (0.30 mmol), diethylamine (0.45 mmol) and $Na_2S·9H_2O$ (0.45 mmol) was carried out in water (2.5 mL) at 100 °C and no desired thioamide could be detected. To our delight, when the reaction was performed in 1,4-dioxane, *N*,*N*-diethyl-2-phenylthioacetamide (**3a**) was obtained. This result prompted us to screen suitable reaction conditions (Table 1). It was found that the solvents played a critical role for the success of this process (entries 3−10). Among all the solvents tested, DMF gave the best result (entry 10), and was chosen as a standard solvent to optimize the other reaction parameters. Results of the examination of the reaction temperature and the reaction time indicated that 80 °C was the suitable reaction temperature and 8 h was the optimal reaction time for the synthesis of **3a** (entries 10−15).

Table 1. Optimization of Reaction Conditions for the Formation of Thioamide[a]



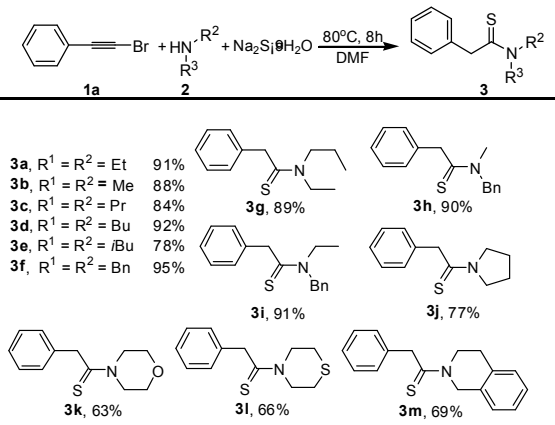
entry	solvent	temp (°C)	yield (%)[b]
1	H_2O	100	n.p.
2	1,4-dioxane	80	72

3	toluene	80	n.p.
4	CH_3CN	80	n.p.
5	ethanol	80	39
6	DMSO	80	36
7	DME	80	54
8	NMP	80	40
9	HMPA	80	trace
10	**DMF**	**80**	**91**
11	DMF	30	n.p.
12	DMF	60	41
13	DMF	100	87
14[c]	DMF	80	83
15[d]	DMF	80	91

[a] Unless otherwise noted, all reactions were carried out using phenylethynyl bromide 1a (0.30 mmol), diethylamine 2a (0.45 mmol), and $Na_2S{\cdot}9H_2O$ (0.45 mmol) in the indicated solvent (2.5 mL) at 80 °C for 8 h. n.p. = no product. [b] Determined by GC using dodecane as the internal standard. [c] Reaction time: 6h. [d] Reaction time: 10 h.

After optimized reaction conditions, we next conducted a survey of secondary amines with phenylethynyl bromide (**1a**) to explore the scope for this transformation. As shown in Table 1, the reactions appeared quite tolerant to the substrates of straight chain aliphatic secondary amines no matter if they are symmetrical or unsymmetrical. In all the cases, the transformations proceeded smoothly and afforded the desired products. Furthermore, some heterocyclic amines such as pyrrolidine, morpholine, thiomorpholine and 1,2,3,4-tetrahydroisoquinoline were also investigated. The results indicated that they were good partners for this transformation. Unfortunately, secondary arylamines were ineffective under the standard reaction conditions.

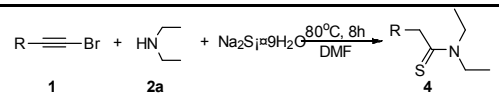
Table 1. The Scope of Secondary Amines[a]

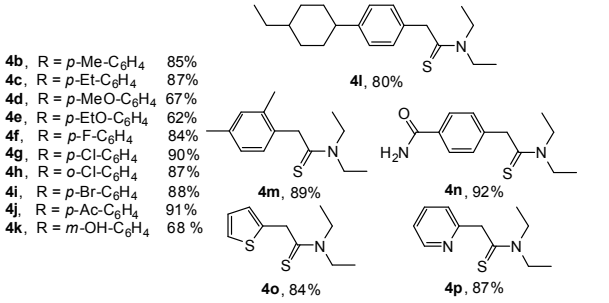


[a] Reactions were carried out using phenylethynyl bromide (1.0 mmol), amine (1.5 mmol) and $Na_2S{\cdot}9H_2O$ (1.5 mmol) in DMF (2.5 mL) at 80 °C for 8 h. Yields refer to the isolated yields.

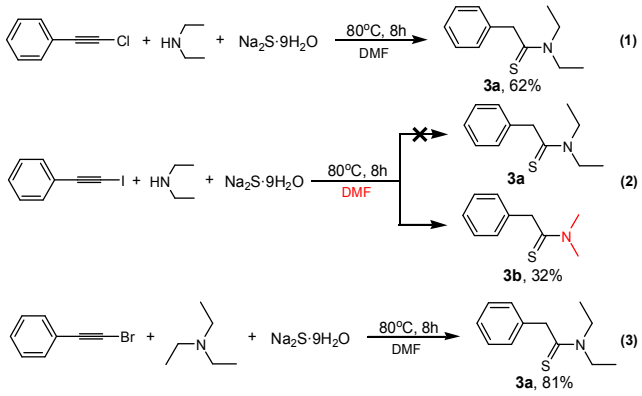
To expand the scope of this methodology, we also examined a series of alkynyl bromides. As summarized in Table 2, several different functional groups, including -CH_3 (**4b**), -C_2H_5 (**4c**), ether (**4d** and **4e**), fluoro (**4f**), chloro (**4g** and **4h**), bromo (**4i**), ketone (**4j**), hydroxy (**4k**) were tolerated under the optimized conditions and gave the corresponding thioamides in moderate to excellent yields. For the *para*-electron-rich substituted aromatic 1-bromoalkynes, the coupling yields gradually decreased from methoxyl to ethyoxyl (Table 3, **4d**–**4e**). Clearly, the electronic effects played an important role in this process. The presence of halo-substituents on the aromatic groups did not interfere with the formation of the thioamide bond, and these reactions afforded the corresponding products, which could be further functionalized by classical cross-coupling reactions (Table 3, **4f**–**4i**). Interestingly, the attempts to use 4-(bromoethynyl)benzonitrile led to the formation of 4-(2-(diethylamino)-2-thioxoethyl)benzamide (Table 2, **4n**), and this compound containing both amide and thioamide moieties was not easily prepared by traditional methods. Furthermore, other heterocyclic alkynyl bromides such as 2-(bromoethynyl)thiophene and 2-(bromoethynyl)pyridine were also investigated and found to form the desired products in good yields ranging from 84% to 87%. Moreover, we also tested some aliphatic alkynyl bromides such as 1-bromooct-1-yne, 1-bromo-3,3-dimethylbut-1-yne, (bromoethynyl)cyclohexane, (3-bromoprop-2-ynyloxy)benzene and (3-bromoprop-2-ynyloxy)benzene) instead of aromatic alkynyl bromides. However, no corresponding thioamide products could be detected under the optimized reaction conditions. Accordingly, we speculated the C_{sp}-Br bond of aliphatic alkynyl bromides were more stable than that of aromatic alkynyl bromides and are not easy to form new C_{sp}-N bond by the nucleophilic substitution reaction.

Table 2. The Scope of Alkynyl Bromides[a]





[a] Reactions were carried out using alkynyl bromide (1.0 mmol), diethylamine (1.5 mmol) and $Na_2S{\cdot}9H_2O$ (1.5 mmol) in DMF (2.5 mL) at 80 °C for 8 h. Yields refer to the isolated yields.

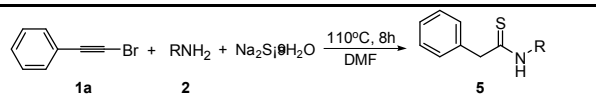


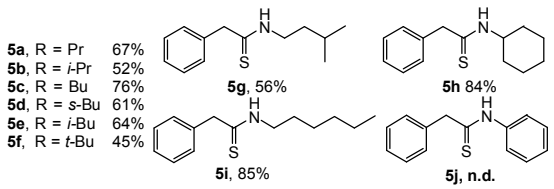
Scheme 2. Reaction of other Alkynyl Halides or Tertiary Amine

We also extended this reaction to phenylethynyl chloride and phenylethynyl iodide as substrates and found that the reaction occurred to give **3a** in 62% yield when phenylethynyl chloride was employed (Scheme 2, eq. 1). However, we were surprised that **3b** was formed in 32% yield instead of **3a** when phenylethynyl iodide was used, which presumably involved a radical process (Scheme 2, eq. 2). Furthermore, tertiary amine such as triethylamine also reacted well to afford **3a** in good yield (Scheme 2, eq. 3).

We then turned our attention to the coupling of primary amines, which under the optimized conditions gave poor conversion into products. Compared with secondary amines, primary amines proved to be a weaker match as a nucleophile for the phenylethynyl bromide. Taking account of this case, we increased the reaction temperature to 110 °C and were pleased to find that there was an obvious increase on the yield. With the new conditions established, a series of primary amines were employed to evaluate the scope of the reaction (Table 3). The reaction worked efficiently with aliphatic amines, affording the desired compounds in 45 − 85% yields. For the straight-chain primary amines, the coupling yields gradually increased from propylamine to hexylamine (**5a, 5c, 5h**). The butylamine was more reactive in this system than *sec*-butylamine, *iso*-butylamine, and *tert*-butylamine, which indicated the steric bulk of the primary amines had some impact on the reaction. Having screened a series of different aliphatic amines, we also examined some aromatic amines such as aniline. However, even at higher reaction temperature (150 °C) and with prolonged reaction time (20 h), the aniline was ineffective in the reaction.

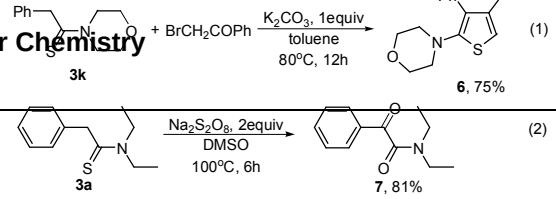
Table 3. The Scope of Primary Bromides[a]





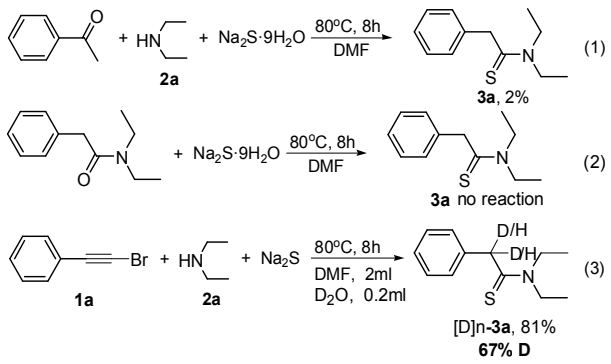
[a] Reactions were carried out using phenylethynyl bromide (1.0 mmol), amine (1.5 mmol), $Na_2S{\cdot}9H_2O$ (1.5 mmol), in DMF (2.5 mL) at 110 °C for 8 h. Yields refer to the isolated yields. n.d. = not detected

To demonstrate the synthetic utility of this protocol, some thioamides were employed for further transformations to prepare a series of functionalized products (Scheme 3). The [3 + 2] cyclization reactions of **3k** and 2-bromo-1-phenylethanone delivered substituted thiophene **6** in good yields (Scheme 3, eq. 1). Thioamide **3a** was successfully oxidized to *α*-ketoamide **7** by $Na_2S_2O_8$ (2 equiv) in 81% yield (Scheme 3, eq. 2).

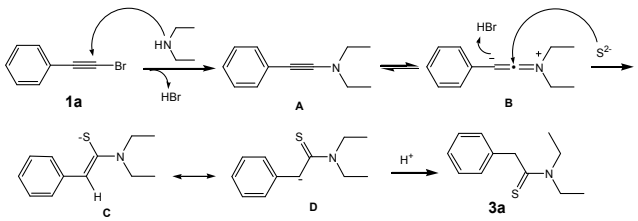


Scheme 3. Synthetic Transformations of the Thioamide Products

To further elucidate the reaction mechanism, several control experiments were conducted (Scheme 4). We first used acetophenone instead of alkynyl bromide to be the reaction partner (eq. 1) since a small amount of acetophenone derived from phenylethynyl bromide was detected during the reaction course. However, only a 2% GC yield of **3a** could be obtained under the optimized reaction conditions. Moreover, when using *N,N*-diethyl-2-phenylacetamide and $Na_2S{\cdot}9H_2O$ as the starting materials, the thionation reaction did not occur (eq. 2). On the basis of these results, we conclude that acetophenone and amide do not play a significant role in the formation of thioamide. The control experiment 3 suggested that deuterium product **$[D]_n$-3a** was obtained exclusively in 81% isolated yield, and the deuterium atom content (67% examined by ^1H NMR spectroscopy) was higher than theoretic 50%, which unraveled a H/D exchange occurred as the consequence of the enolization of target product and one hydrogen atom of methylene in **3a** came from liberated HBr, and the other hydrogen atom of methylene of **3a** came from water.



Scheme 4. Control Experiments



Scheme 5. Tentative Reaction Mechanism

According to the above observations, a tentative mechanism for the formation of thioamides was proposed. As shown in Scheme 5, in the first step, the coupling of alkynyl bromide with diethylamine provided ynamine **A**, which would be converted to its isomer **B**. Then, a nucleophilic addition reaction of **B** with sulfide occurred to afford intermediate **C**, which would be converted to its isomer **D**. Finally, protonation of **D** provided the target thioamide product.

Conclusions

In conclusion, an efficient thioamide synthesis based upon three-

component coupling of alkynyl bromides, amines, and $Na_2S·9H_2O$ has been developed. Both alkynyl bromides and amines were commercially available or easily prepared. The diverse substrate scope, catalyst-free and mild conditions, combined with an operationally simple procedure render it a powerful component to traditional approaches for the synthesis of biologically important compounds containing thioamide frameworks. Further expansion of the scope of the reaction is currently underway in our laboratory.

Experimental

Melting points were measured with a melting point instrument and were uncorrected. ^{1}H NMR and ^{13}C NMR spectra were recorded on Bruker Avance (400 and 100 MHz, respectively) instrument internally referenced to tetramethylsilane (TMS) or chloroform signals. IR spectra were obtained either as potassium bromide pellets or as liquid films between two potassium bromide pellets with a Bruker Vector 22 spectrometer. GC-MS was obtained using electron ionization (EI). High-resolution mass spectra were obtained with a LCMS-IT-TOF mass spectrometer. TLC was performed by using commercially prepared 100–400 mesh silica gel plates (GF_{254}) and visualization was effected at 254 nm. All reagents were obtained from commercial suppliers and used without further purification.

General procedure for the synthesis of products

A mixture of alkynyl halide (1.0 mmol), amine (1.5 mmol), and $Na_2S·9H_2O$ (1.5 mmol) in DMF (2.5 mL) was placed in a sealed tube (25 mL) equipped with a magnetic stirring bar. The mixture was stirred at 80 ^{o}C (or 110 ^{o}C) for 8h. After the reaction was completed, the mixture was washed with brine and extracted with ethyl acetate. The organic layer was dried with anhydrous $MgSO_4$, concentrated in vacuum and purified by flash silica gel chromatography using petroleum ether/ethyl acetate 15:1 to give the desired products.

***N,N*-Diethyl-2-phenylethanethioamide (3a)**:[13] yield: 91%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32 – 7.21 (m, 5H), 4.29 (s, 2H), 4.00 (q, *J* = 7.1 Hz, 2H), 3.48 (q, *J* = 7.2 Hz, 2H), 1.28 (t, *J* = 7.1 Hz, 3H), 1.10 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.9, 136.3, 128.7, 127.8, 126.8, 50.4, 47.6, 46.4, 13.1, 10.8. MS (EI) m/z: 207, 174, 145, 135, 116, 91. IR ν_{max}(KBr)/cm^{-1}: 2976, 2934, 1502, 1101, 748, 706.

***N,N*-Dimethyl-2-phenylethanethioamide (3b)**:[14] yield: 88%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.34 – 7.26 (m, 5H), 4.32 (s, 2H), 3.50 (s, 3H), 3.20 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.6, 135.6, 128.8, 128.0, 126.9, 50.9, 44.8, 42.2. MS (EI) m/z: 179, 146, 131, 116, 91, 88. IR ν_{max}(KBr)/cm^{-1}: 3026, 2931, 1520, 1102, 760, 714.

2-Phenyl-*N,N*-dipropylethanethioamide (3c):[15] yield: 84%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.23 – 7.15 (m, 5H), 4.21 (s, 2H), 3.81 – 3.77 (m, 2H), 3.30 – 3.26 (m, 2H), 1.74 – 1.64 (m, 2H), 1.50 – 1.40 (m, 2H), 0.84 (t, *J* = 7.4 Hz, 3H), 0.75 (t, *J* = 7.3 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 199.4, 136.3, 128.6, 127.7, 126.7, 54.8, 53.9, 50.6, 21.3, 18.8, 11.1, 11.0. MS (EI) m/z: 235, 202, 160, 144, 135, 91. IR ν_{max}(KBr)/cm^{-1}: 2964, 2874, 1499, 1107, 719.

***N,N*-Dibutyl-2-phenylethanethioamide (3d)**:[15] yield: 92%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.31 – 7.23 (m, 5H), 4.28 (s, 2H), 3.93 – 3.89 (m, 2H), 3.44 – 3.28 (m, 2H), 1.75 – 1.68 (m, 2H), 1.50 – 1.44 (m, 2H), 1.39 – 1.30 (m, 2H), 1.28 – 1.18 (m, 2H), 0.95 (t, *J* = 7.3 Hz, 3H), 0.87 (t, *J* = 7.3 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 199.1, 136.3, 128.6, 127.7, 126.7, 53.1, 52.2, 50.6, 30.1, 27.5, 20.0, 19.9, 13.7, 13.5. MS (EI) m/z: 263, 230, 220, 174, 172, 135, 91. IR ν_{max}(KBr)/cm^{-1}: 2958, 2868, 1499, 1111, 719.

***N,N*-Diisobutyl-2-phenylethanethioamide (3e)**:[16] yield: 78%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.27– 7.13 (m, 5H), 4.26 (s, 2H), 3.74 (d, *J* = 7.4 Hz, 2H), 3.22 (d, *J* = 7.6 Hz, 2H), 2.49– 2.39 (m, 1H), 2.05 – 1.95 (m, 1H), 0.83 (d, *J* = 6.6 Hz, 6H), 0.78 (d, *J* = 6.7 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 201.1, 136.3, 128.6, 127.9, 126.8, 60.6, 60.2, 51.0, 28.0, 25.3, 20.1, 20.0. MS (EI) m/z: 263, 231, 220, 175, 206, 135, 91. IR ν_{max}(KBr)/cm^{-1}:2960, 2871, 1495, 1113, 761, 720.

***N,N*-Dibenzyl-2-phenylethanethioamide (3f)**:[17] yield: 95%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.28 – 6.94 (m, 15H), 5.24 (d, *J* = 5.9 Hz, 2H), 4.52 (d, *J* = 5.7 Hz, 2H), 4.29 (d, *J* = 5.9 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 202.9, 135.8, 135.5, 134.7, 129.1, 128.8, 128.6, 128.0, 127.9, 127.9, 127.7, 127.1, 126.2, 55.4, 53.7, 50.9. MS (EI) m/z: 331, 240, 206, 178, 135, 91. IR ν_{max}(KBr)/cm^{-1}: 3028, 2924, 1490, 1152, 735, 697.

***N*-Ethyl-2-phenyl-*N*-propylethanethioamide (3g)**: yield: 89%, 1:1 mixture of rotamers. Yellow liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32 – 7.21 (m, 10H), 4.29 (d, *J* = 3.1 Hz, 4H), 4.01 (q, *J* = 7.0 Hz, 2H), 3.89 – 3.85 (m, 2H), 3.48 (q, *J* = 7.1 Hz, 2H), 3.38 – 3.34 (m, 2H), 1.83 – 1.73 (m, 2H), 1.57 – 1.48 (m, 2H), 1.27 (t, *J* = 7.0 Hz, 3H), 1.10 (t, *J* = 7.1 Hz, 3H), 0.93 (t, *J* = 7.4 Hz, 3H), 0.83 (t, *J* = 7.4 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 199.1, 199.0, 136.2, 136.2, 128.5, 128.5 127.7, 127.7, 126.7, 126.7, 54.3, 53.3, 50.4, 50.4, 47.9, 46.9, 21.3, 18.9, 13.0, 11.1, 10.9, 10.7. MS (EI) m/z: 221, 188, 146, 130, 118, 91. IR ν_{max}(KBr)/cm^{-1}: 2967, 2932, 1500, 1104, 795, 712. HRMS (ESI) Calcd for $C_{13}H_{19}NS$ $[M+H]^+$ 222.1311, found m/z 222.1324.

***N*-Benzyl-*N*-methyl-2-phenylethanethioamide (3h)**: yield: 90%, 1.1:1 mixture of rotamers. Yellow liquid. ^{1}H NMR (400 MHz, $CDCl_3$) (major rotamer) δ 7.39 – 6.99 (m, 10H), 5.33 (s, 2H), 4.37 (s, 2H), 3.05 (s, 3H);^{1}H NMR (400 MHz, $CDCl_3$) (minor rotamer) δ 7.39 – 6.99 (m, 10H), 4.72 (s, 2H), 4.35 (s, 2H), 3.41 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 201.7, 201.4, 135.9, 135.4, 135.4, 134.7, 129.0, 128.7, 128.7, 128.6, 128.0, 127.9, 127.9, 127.7, 127.7, 126.9, 126.9, 126.3, 58.5, 57.7, 51.0, 50.6, 42.8, 39.1. MS (EI) m/z:.255, 223, 182, 146, 135, 91 IR ν_{max}(KBr)/cm^{-1}: 3028, 2929, 1498, 1159, 728, 698. HRMS (ESI) Calcd for $C_{16}H_{17}NS$ $[M+H]^+$ 256.1154, found m/z 256.1146.

***N*-Benzyl-*N*-ethyl-2-phenylethanethioamide (3i)**: yield: 91%, 1.2:1 mixture of rotamers. Yellow liquid. ^{1}H NMR (400 MHz, $CDCl_3$) (major rotamer) δ 7.40 – 7.04 (m, 10H), 4.65 (s, 2H), 4.27 (s, 2H), 4.00 (q, *J* = 7.1 Hz, 2H), 1.24 (t, *J* = 7.1 Hz, 3H);^{1}H NMR (400 MHz, $CDCl_3$) (minor rotamer) δ 7.40 – 7.04 (m, 10H), 5.34 (s, 2H), 4.39 (s, 2H), 3.47 (q, *J* = 7.2 Hz, 2H), 1.06 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 201.3, 200.6, 136.0, 135.9, 135.7, 134.9, 128.9, 128.7, 128.6, 128.5, 128.0, 127.8, 127.7, 127.6, 127.5, 126.9, 126.8, 126.1, 54.8, 54.5, 50.8, 50.3,

48.5, 45.7, 12.8, 10.5. MS (EI) m/z: 269, 236, 206, 178, 135,91. IR ν_{max}(KBr)/cm^{-1}:3027, 2931, 1496, 1104, 728, 698. HRMS (ESI) Calcd for $C_{17}H_{19}NS$ $[M+H]^+$ 270.1311, found m/z 270.1324.

2-Phenyl-1-(pyrrolidin-1-yl)ethanethione (3j):[18] yield: 77%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.35 – 7.22 (m, 5H), 4.20 (s, 2H), 3.86 (t, *J* = 6.3 Hz, 2H), 3.52 (t, *J* = 6.3 Hz, 2H), 1.91 – 1.99 (m, 4H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 196.8, 135.4, 128.5, 128.3, 126.8, 54.0, 51.2, 50.8, 26.3, 24.2. MS (EI) m/z: 205, 172, 144, 114, 91. IR ν_{max}(KBr)/cm^{-1}: 2970, 2872, 1489, 1094, 759, 726.

1-Morpholino-2-phenylethanethione (3k):[19] yield: 63%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.23 (s, 4H), 7.17 (s, 1H), 4.27 (s, 4H), 3.64 (s, 2H), 3.53 (s, 2H), 3.30 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 199.7, 135.6, 128.7, 127.6, 126.9, 66.1, 65.9, 50.6, 50.4, 49.9. MS (EI) m/z: 221, 190, 162, 144, 135, 130, 91, 86, 77. IR ν_{max}(KBr)/cm^{-1}: 2967, 2855, 1488, 1111, 750, 707.

2-Phenyl-1-thiomorpholinoethanethione (3l): yield: 66%. Yellow solid. MP = 98 -100 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.34 – 7.26 (s, 5H), 4.62 – 4.57 (m, 2H), 4.35 (s, 2H), 3.95 – 3.90 (m, 2H), 2.76 – 2.71 (m, 2H), 2.26 – 2.21 (m, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 199.9, 135.6, 128.9, 127.8, 127.1, 53.0, 52.9, 51.0, 27.5, 26.9. MS (EI) m/z: 237, 204, 178, 144, 134, 91. IR ν_{max}(KBr)/cm^{-1}: 3022, 2924, 1489, 1152, 740, 712. HRMS (ESI) Calcd for $C_{12}H_{15}NNaS_2$ $[M+Na]^+$ 260.0538, found m/z 260.0541.

1-(3,4-Dihydroisoquinolin-2(1H)-yl)-2-phenylethanethione (3m): yield: 69%, 2:1 mixture of rotamers. Yellow liquid. ^{1}H NMR (400 MHz, $CDCl_3$) (major rotamer) δ 7.34 – 6.80 (m, 8H), 5.29 (s, 2H), 4.42 (s, 2H), 3.79 (t, *J* = 5.8 Hz, 2H), 2.61 (t, *J* = 5.8 Hz, 2H);^{1}H NMR (400 MHz, $CDCl_3$) (minor rotamer) δ 7.34 – 6.80 (m, 8H), 4.68 (s, 2H), 4.42 (s, 2H), 4.35 (t, *J* = 6.2 Hz, 2H), 2.97 (t, *J* = 6.2 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 199.4, 199.1, 135.6, 135.5, 134.9, 133.3, 132.3, 131.8, 128.7, 128.7, 128.0, 127.8, 127.8, 127.7, 127.4, 126.8, 126.8, 126.8, 126.7, 126.5, 126.4, 125.7, 52.7, 51.6, 50.9, 49.1, 47.9, 29.0, 27.9. MS (EI) m/z: 267, 252, 234, 176, 132, 91.. IR ν_{max}(KBr)/cm^{-1}: 3026, 2928, 1490, 1097, 740, 701. HRMS (ESI) Calcd for $C_{17}H_{17}NS$ $[M+H]^+$ 268.1154, found m/z 268.1147.

***N,N*-Diethyl-2-p-tolylethanethioamide (4b)**: yield: 85%. Yellow solid. MP = 62 - 64 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.20 (d, *J* = 7.9 Hz, 2H), 7.11 (d, *J* = 7.9 Hz, 2H), 4.23 (s, 2H), 3.99 (q, *J* = 7.1 Hz, 2H), 3.48 (q, *J* = 7.2 Hz, 2H), 2.32 (s, 3H), 1.27 (t, *J* = 7.1 Hz, 3H), 1.11 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 199.2, 136.3, 133.2, 129.3, 127.6, 50.0, 47.5, 46.4, 20.9, 13.1, 10.8. MS (EI) m/z: 221, 188, 174, 159, 134, 116, 88. IR ν_{max}(KBr)/cm^{-1}: 2975, 2930, 1506, 1097, 791. HRMS (ESI) Calcd for $C_{13}H_{19}NS$ $[M+H]^+$ 222.1311, found m/z 222.1314.

***N,N*-Diethyl-2-(4-ethylphenyl)ethanethioamide (4c)**: yield: 87%. Yellow liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.22 (d, *J* = 7.9 Hz, 2H), 7.14 (d, *J* = 8.0 Hz, 2H), 4.25 (s, 2H), 4.00 (q, *J* = 7.1 Hz, 2H), 3.48 (q, *J* = 7.2 Hz, 2H), 2.62 (q, *J* = 7.6 Hz, 2H), 1.28 (t, *J* = 7.1 Hz, 3H), 1.22 (t, *J* = 7.6 Hz, 3H), 1.11 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 199.2, 142.8, 133.4, 128.2, 127.7, 50.0, 47.6, 46.4, 28.4, 15.4, 13.2, 10.9. MS (EI) m/z: 235, 206, 202, 173, 135, 119, 116, 91. IR ν_{max}(KBr)/cm^{-1}:2968, 2931, 1505, 1097, 814. HRMS (ESI) Calcd for $C_{14}H_{21}NS$ $[M+H]^+$ 236.1467, found m/z 236.1476.

***N,N*-Diethyl-2-(4-methoxyphenyl)ethanethioamide (4d)**:[20] yield: 67%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.24 (d, *J* = 8.5 Hz, 2H), 6.85 (d, *J* = 8.6 Hz, 2H), 4.21 (s, 2H), 3.99 (q, *J* = 7.1 Hz, 2H), 3.78 (s, 3H), 3.49 (q, *J* = 7.1 Hz, 2H), 1.27 (t, *J* = 7.1 Hz, 3H), 1.11 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 199.4, 158.4, 128.8, 128.3, 114.1, 55.2, 49.6, 47.6, 46.3, 13.2, 10.8. MS (EI) m/z: 237, 204, 175, 164, 135, 121, 116, 91. IR ν_{max}(KBr)/cm^{-1}: 2933, 2835, 1507, 1243,1096, 1032, 815.

2-(4-Ethoxyphenyl)-*N,N*-diethylethanethioamide (4e): yield: 62%. Yellow liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.23 (d, *J* = 8.4 Hz, 2H), 6.84 (d, *J* = 8.5 Hz, 2H), 4.21 (s, 2H), 4.00 (p, *J* = 6.9 Hz, 4H), 3.49 (q, *J* = 7.2 Hz, 2H), 1.40 (t, *J* = 7.0 Hz, 3H), 1.27 (t, *J* = 7.0 Hz, 3H), 1.10 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 199.5, 157.9, 128.9, 128.1, 114.7, 63.4, 49.7, 47.6, 46.4, 14.8, 13.2, 10.9. MS (EI) m/z:251, 218, 189, 178, 160, 135, 116. IR ν_{max}(KBr)/cm^{-1}: 2977, 2931, 1507, 1238, 1095, 1046, 814. HRMS (ESI) Calcd for $C_{14}H_{21}NOS$ $[M+H]^+$ 252.1417, found m/z 252.1420.

***N,N*-Diethyl-2-(4-fluorophenyl)ethanethioamide (4f)**: yield: 84%. Yellow liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32 – 7.28 (m, 2H), 7.00 (t, *J* = 8.6 Hz, 2H), 4.23 (s, 2H), 3.99 (q, *J* = 7.0 Hz, 2H), 3.48 (q, *J* = 7.1 Hz, 2H), 1.27 (t, *J* = 7.0 Hz, 3H), 1.12 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.59, 161.6(d, *J* = 243.7 Hz), 131.9(d, *J* = 3.2 Hz), 129.3(d, *J* =7.8Hz), 115.4(d, *J* = 21.2Hz), 49.2, 47.5, 46.3, 13.1, 10.7. MS (EI) m/z: 225, 196, 192, 164, 153, 135, 116,109. IR ν_{max}(KBr)/cm^{-1}: 2976, 2934, 1506, 1226, 1102, 823. HRMS (ESI) Calcd for $C_{12}H_{16}FNS$ $[M+H]^+$ 226.1060, found m/z 226.1062.

2-(4-Chlorophenyl)-*N,N*-diethylethanethioamide (4g):[21] yield: 90%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.27 (s, 4H), 4.22 (s, 2H), 3.99 (q, *J* = 7.0 Hz, 2H), 3.47 (q, *J* = 7.1 Hz, 2H), 1.27 (t, *J* = 7.0 Hz, 3H), 1.13 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.3, 134.8, 132.6, 129.2, 128.7, 49.4, 47.6, 46.4, 13.2, 10.8. MS (EI) m/z: 241, 243, 208, 181, 168, 134, 125. IR ν_{max}(KBr)/cm^{-1}: 2976, 2933, 1498, 1093, 799.

2-(2-Chlorophenyl)-*N,N*-diethylethanethioamide (4h): yield: 87%. Yellow liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 – 7.34 (m, 2H), 7.24 – 7.17 (m, 2H), 4.28 (s, 2H), 4.02 (q, *J* = 7.1 Hz, 2H), 3.44 (q, *J* = 7.1 Hz, 2H), 1.29 (t, *J* = 7.1 Hz, 3H), 1.17 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.0, 134.3, 133.2, 129.1, 129.1, 128.0, 126.9, 47.5, 46.7, 46.4, 13.0, 10.7. MS (EI) m/z : 241, 206, 178, 158, 135, 125. IR ν_{max}(KBr)/cm^{-1}: 2976, 2933, 1503, 1099, 754. HRMS (ESI) Calcd for $C_{12}H_{16}ClNS$ $[M+H]^+$ 242.0765, found m/z 242.0764.

2-(4-Bromophenyl)-*N,N*-diethylethanethioamide (4i): yield: 88%. Yellow liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.44 (d, *J* = 8.4 Hz, 2H), 7.21 (d, *J* = 8.3 Hz, 2H), 4.21 (s, 2H), 3.99 (q, *J* = 7.1 Hz, 2H), 3.47 (q, *J* = 7.2 Hz, 2H), 1.27 (t, *J* = 7.1 Hz, 3H), 1.14 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.3, 135.3, 131.8, 129.7, 120.7, 49.6, 47.7, 46.5, 13.3, 10.9. MS (EI) m/z: 285, 287, 256, 252, 223, 168, 134, 116. IR ν_{max}(KBr)/cm^{-1}: 2974, 2931, 1504, 1101, 793. HRMS (ESI) Calcd for $C_{12}H_{16}BrNS$ $[M+H]^+$ 286.0260, found m/z 286.0257.

2-(4-Acetylphenyl)-*N,N*-diethylethanethioamide (4j): yield: 91%. Yellow liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92 (d, *J* = 8.3 Hz, 2H), 7.43 (d, *J* = 8.4 Hz, 2H), 4.32 (s, 2H), 4.01 (q, *J* = 7.1 Hz, 2H), 3.48 (q, *J* = 7.2 Hz, 2H), 2.59 (s, 3H), 1.29 (t, *J* = 7.1

Hz, 3H), 1.15 (t, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 197.9, 197.6, 141.9, 135.8, 128.7, 128.1, 50.0, 47.6, 46.5, 26.5, 13.3, 10.8. MS (EI) m/z: 249, 216, 160, 133, 116, 88. IR ν_{max}(KBr)/cm^{-1}: 2795, 2933, 1681, 1605, 1505, 1426, 1357, 1267, 1098, 810. HRMS (ESI) Calcd for $C_{14}H_{19}NNaOS$ $[M+Na]^+$ 272.1080, found m/z 272.1075.

***N,N*-diethyl-2-(3-hydroxyphenyl)ethanethioamide (4k)**: yield: 68%. Yellow liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.16 (t, J = 7.9 Hz, 1H), 6.90 (s, 1H), 6.82 (d, J = 7.6 Hz, 1H), 6.72 (dd, J = 8.1, 2.1 Hz, 1H), 4.23 (s, 2H), 3.99 (q, J = 7.1 Hz, 2H), 3.48 (q, J = 7.2 Hz, 2H), 1.29 (t, J = 7.1 Hz, 3H), 1.12 (t, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.7, 156.2, 137.8, 129.9, 120.2, 114.6, 114.0, 50.2, 47.7, 46.6, 13.2, 10.9. MS (EI) m/z: 223, 190, 162, 133, 116, 88, 77. IR ν_{max}(KBr)/cm^{-1}: 3300, 2976, 2933, 1591, 1512, 1453, 1287, 1232, 1099, 782. HRMS (ESI) Calcd for $C_{12}H_{17}NNaOS$ $[M+Na]^+$ 246.0923, found m/z 246.0919.

***N,N*-Diethyl-2-(4-(4-ethylcyclohexyl)phenyl)ethanethioamide (4l)**: yield: 80%. Yellow liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.22 (d, J = 8.0 Hz, 2H), 7.14 (d, J = 8.1 Hz, 2H), 4.24 (s, 2H), 3.99 (q, J = 7.1 Hz, 2H), 3.48 (q, J = 7.1 Hz, 2H), 2.43 (t, J = 12.2 Hz, 1H), 1.87 (d, J = 11.1 Hz, 4H), 1.47 – 1.38 (m, 2H), 1.30–1.23 (m, 6H), 1.10 (t, J = 7.2 Hz, 3H), 1.05 – 0.98 (m, 2H), 0.90 (t, J = 7.3 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 199.2, 146.4, 133.5, 127.6, 127.1, 50.0, 47.5, 46.4, 44.1, 39.0, 34.2, 33.1, 29.9, 13.1, 11.4, 10.9. MS (EI) m/z:317, 284, 255, 244, 215, 201, 173, 116, 72. IR ν_{max}(KBr)/cm^{-1}: 2922, 2850, 1505, 1099, 807. HRMS (ESI) Calcd for $C_{20}H_{31}NS$ $[M+H]^+$ 318.2250, found m/z 318.2264.

***N,N*-Diethyl-2-(2,4-dimethylphenyl)ethanethioamide (4m)**: yield: 89%. Yellow solid. MP = 72 - 74 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.04 (d, J = 7.7 Hz, 1H), 6.98 – 6.94 (m, 2H), 4.10 (s, 2H), 4.04 (q, J = 7.0 Hz, 2H), 3.39 (q, J = 7.1 Hz, 2H), 2.28 (s, 3H), 2.21 (s, 3H), 1.32 (t, J = 7.1 Hz, 3H), 1.18 (t, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 199.6, 136.0, 135.2, 131.7, 130.8, 126.8, 126.6, 47.4, 46.9, 46.3, 20.7, 19.3, 13.1, 10.7. MS (EI) m/z: 235, 220, 202, 172, 133, 116, 91. IR ν_{max}(KBr)/cm^{-1}: 2973, 2931, 1502, 1106, 928, 846, 719. HRMS (ESI) Calcd for $C_{14}H_{21}NS$ $[M+H]^+$ 236.1467, found m/z 236.1477.

4-((Diethylthiocarbamoyl)methyl)benzamide (4n): yield: 92%. Yellow solid. MP = 151 - 153 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.83 (d, J = 8.2 Hz, 2H), 7.73 (s, 1H), 7.40 (s, 1H), 7.34 (d, J = 8.2 Hz, 2H), 4.27 (s, 2H), 4.00 (q, J = 7.1 Hz, 2H), 3.47 (q, J = 7.2 Hz, 2H), 1.28 (t, J = 7.1 Hz, 3H), 1.18 (t, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 202.1, 197.9, 140.7, 137.7, 128.0, 127.4, 49.7, 47.8, 46.6, 13.4, 10.9. MS (EI) m/z: 250, 232, 199, 160, 143, 116, 88. IR ν_{max}(KBr)/cm^{-1}: 3337, 3283, 3176, 3007, 2975, 1629, 1519, 1424, 1232, 1090, 889. HRMS (ESI) Calcd for $C_{13}H_{18}N_2NaOS$ $[M+Na]^+$ 273.1032, found m/z 273.1027.

***N,N*-Diethyl-2-(thiophen-2-yl)ethanethioamide (4o)**: yield: 84%. Brown liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.18 (dd, J = 4.0, 2.4 Hz, 1H), 6.94 – 6.92 (m, 2H), 4.40 (s, 2H), 3.98 (q, J = 7.1 Hz, 2H), 3.57 (q, J = 7.2 Hz, 2H), 1.26 (t, J = 7.1 Hz, 3H), 1.18 (t, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 197.7, 138.2, 126.6, 125.2, 124.4, 47.7, 46.4, 45.0, 13.3, 10.7. MS (EI) m/z: 213, 180, 151, 140, 116, 88. IR ν_{max}(KBr)/cm^{-1}: 2975, 2932, 1507, 1467, 1289, 1229, 1097, 841, 700. HRMS (ESI) Calcd for $C_{10}H_{15}NNaS_2$ $[M+Na]^+$ 236.0538, found m/z 236.0534.

***N,N*-Diethyl-2-(pyridin-2-yl)ethanethioamide (4p)**: yield: 87%. Brown liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.51 (d, J = 4.8 Hz, 1H), 7.68 – 7.63 (m, 1H), 7.59 (d, J = 7.8 Hz, 1H), 7.19 – 7.16 (m, 1H), 4.44 (s, 2H), 4.00 (q, J = 7.1 Hz, 2H), 3.72 (q, J = 7.2 Hz, 2H), 1.26 (t, J = 7.1 Hz, 3H), 1.16 (t, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 197.6, 156.7, 149.1, 136.6, 123.0, 122.0, 52.9, 47.6, 46.7, 13.2, 10.8.MS (EI) m/z: 208, 175, 136, 119, 93, 72. IR ν_{max}(KBr)/cm^{-1}: 2974, 2932, 1588, 1507, 1472, 1429, 1290, 1212, 1103, 842, 751. HRMS (ESI) Calcd for $C_{11}H_{16}N_2NaS$ $[M+Na]^+$ 231.0926, found m/z 231.0924.

2-Phenyl-*N*-propylethanethioamide (5a):[22] yield: 67%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40 – 7.25 (m, 5H), 7.12 (s, 1H), 4.12 (s, 2H), 3.58 (q, J = 6.7Hz, 2H), 1.61 – 1.52 (m, 2H), 0.85 (t, J = 7.4 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 201.7, 134.8, 129.4, 129.1, 127.7, 53.0, 47.7, 21.0, 11.1. MS (EI) m/z: 193, 179, 160, 135, 102, 91. IR ν_{max}(KBr)/cm^{-1}: 3241, 2963, 2932, 1532, 1455, 1409, 1093, 705.

***N*-Isopropyl-2-phenylethanethioamide (5b)**:[23] yield: 52%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40 – 7.30 (m 3H), 7.24 (d, J = 7.1 Hz, 2H), 6.80 (s, 1H), 4.69 – 4.60 (m, 1H), 4.09 (s, 2H), 1.15 (d, J = 6.5 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.3, 134.9, 129.4, 129.2, 127.8, 53.3, 47.5, 21.1. MS (EI) m/z: 193, 160, 134, 118, 102, 91. IR ν_{max}(KBr)/cm^{-1}: 3238, 2971, 2929, 1527, 1455, 1411, 1093, 763, 707.

***N*-Butyl-2-phenylethanethioamide (5c)**:[13] yield: 76%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39 – 7.30 (m, 3H), 7.25 (d, J = 6.7 Hz, 2H), 7.10 (s, 1H), 4.12 (s, 2H), 3.61 (q, J = 6.7Hz, 2H), 1.55 – 1.48 (m, 2H), 1.31 – 1.21 (m, 2H), 0.87 (t, J = 7.4 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 201.6, 134.8, 129.4, 129.1, 127.7, 53.0, 45.8, 29.7, 19.9, 13.5. MS (EI) m/z: 207, 174, 135, 116, 91, . IR ν_{max}(KBr)/cm^{-1}: 3239, 2959, 2931, 1532, 1456, 1409, 1096, 769, 705.

***N-sec*-Butyl-2-phenylethanethioamide (5d)**:[23] 126.5 mg, yield: 61%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39 – 7.30 (m, 3H), 7.25 (d, J = 7.0 Hz, 2H), 6.83 (s, 1H), 4.54 – 4.48 (m, 1H), 4.11 (q, J = 16.4 Hz, 2H), 1.51 – 1.45 (m, 2H), 1.12 (d, J = 6.4 Hz, 3H), 0.80 (t, J = 7.3 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.6, 134.9, 129.3, 129.1, 127.7, 53.3, 52.6, 28.2, 18.5, 9.9. MS (EI) m/z: 207, 179, 152, 135, 116, 91. IR ν_{max}(KBr)/cm^{-1}: 3238, 2967, 2930, 1527, 1453, 1411, 1094, 761, 705.

***N*-Isobutyl-2-phenylethanethioamide (5e)**:[24] yield: 64%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40 – 7.30 (m, 3H), 7.26 (d, J = 7.0 Hz, 2H), 7.16 (s, 1H), 4.14 (s, 2H), 3.44 (t, J = 6.2 Hz, 2H), 1.93 – 1.83 (m, 1H), 0.82 (d, J = 6.7 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 201.7, 134.7, 129.4, 129.1, 127.8, 53.1, 53.0, 27.1, 19.9. MS (EI) m/z: 207, 192, 164, 135, 118, 91. IR ν_{max}(KBr)/cm^{-1}: 3245, 2959, 2927, 1532, 1459, 1410, 1101, 769, 705.

***N*-tert-Butyl-2-phenylethanethioamide (5f)**: yield: 45%. Yellow solid. MP = 71 - 73 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38 (t, J = 7.2 Hz, 2H), 7.32 (t, J = 7.3 Hz, 1H), 7.24 (d, J = 6.9 Hz, 2H), 6.80 (s, 1H), 4.06 (s, 2H), 1.45 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.6, 135.4, 129.4, 129.2, 127.7, 55.8, 55.7, 27.5. MS (EI) m/z: 207, 151, 134, 117, 92, 65. IR ν_{max}(KBr)/cm^{-1}: 3343, 2968, 2925, 1525, 1415, 1363, 1211, 1113, 748, 699. HRMS (ESI) Calcd for $C_{12}H_{17}NNaS$ $[M+Na]^+$ 230.0974, found m/z 230.0969.

***N*-Isopentyl-2-phenylethanethioamide (5g)**:[24] yield: 56%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40 – 7.31 (m, 3H), 7.24 (d, *J* = 6.9 Hz, 2H), 6.98 (s, 1H), 4.12 (s, 2H), 3.62 (q, *J* = 6.7 Hz, 2H), 1.56 – 1.46 (m, 1H), 1.40 (q, *J* = 7.2 Hz, 2H), 0.86 (d, *J* = 6.5 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 201.5, 134.8, 129.5, 129.2, 127.8, 53.1, 44.6, 36.5, 26.0, 22.3. MS (EI) m/z: 221, 178, 165, 135, 91. IR ν_{max}(KBr)/cm^{-1}: 3203, 3065, 2956, 1545, 1460, 1414, 1096, 764,708.

***N*-Cyclohexyl-2-phenylethanethioamide (5h)**:[25] yield: 84%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37 – 7.28 (m, 3H), 7.24 (d, *J* = 7.2 Hz, 1H), 7.11 (s, 1H), 4.40 – 4.32 (m, 1H), 4.07 (s, 2H), 1.97 – 1.93 (m, 2H), 1.61 – 1.56 (m, 3H), 1.39 – 1.30 (m, 2H), 1.19 – 1.08 (m, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 199.9, 134.9, 129.1, 128.9, 127.5, 53.9, 53.0, 30.9, 25.1, 24.1. MS (EI) m/z: 233, 200, 176, 152, 135, 98, 91. IR ν_{max}(KBr)/cm^{-1}: 3235, 2931, 2854, 1527, 1489, 1411, 1113, 769, 719.

***N*-Hexyl-2-phenylethanethioamide (5i)**:[25] 200.1 mg, yield: 85%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39 – 7.30 (m, 3H), 7.25 (d, *J* = 6.8 Hz, 2H), 7.11 (s, 1H), 4.12 (s, 2H), 3.60 (q, *J* = 6.7 Hz, 2H), 1.56 – 1.49 (m, 2H), 1.28 – 1.22 (m, 6H), 0.85 (t, *J* = 6.8 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 201.5, 134.8, 129.4, 129.1, 127.7, 53.0, 46.1, 31.1, 27.5, 26.3, 22.3, 13.8. MS (EI) m/z: 235, 202, 178, 165, 135, 118, 91. IR ν_{max}(KBr)/cm^{-1}: 3238, 2928, 2859, 1532, 1456, 1409, 1101, 768, 705.

4-(3,4-Diphenylthiophen-2-yl)morpholine (6):[26] yield: 75%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.27 – 7.16 (m, 8H), 7.10 – 7.06 (m, 2H), 6.85 (s, 1H), 3.66 – 3.64 (m, 4H), 2.87 – 2.85 (m, 4H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 154.8, 142.0, 137.3, 135.6, 130.3, 129.0, 128.3, 128.0, 127.9, 126.6, 126.4, 114.0, 66.8, 53.2. MS (EI) m/z: 321, 262, 248, 202, 130, 77.

***N*,*N*-Diethyl-2-oxo-2-phenylacetamide (7)**:[27] yield: 81%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.95 – 7.93 (m, 2H), 7.63 (t, *J* = 7.4 Hz, 1H), 7.51 (t, *J* = 7.7 Hz, 2H), 3.57 (q, *J* = 7.2 Hz, 2H), 3.25 (q, *J* = 7.1 Hz, 2H), 1.29 (t, *J* = 7.2 Hz, 3H), 1.16 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 191.5, 166.7, 134.5, 133.2, 129.6, 128.9, 42.1, 38.7, 14.1, 12.8. MS (EI) m/z: 205, 177, 148, 133, 100, 77.

Acknowledgment

We are grateful to the National Natural Science Foundation of China (20932002, 21172076 and 21202046), the National Basic Research Program of China (973 Program) (2011CB808600), the Guangdong Natural Science Foundation (10351064101000000 and S2012040007088), and China Postdoctoral Science Foundation (2012T50673).

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† Electronic Supplementary Information (ESI) available: Copies of ^{1}H and ^{13}C NMR spectra for selected compounds. See DOI: 10.1039/b000000x/

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