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Addition of a carbamoylsilane to *N*-sulfonylimines: direct synthesis of α-(*N*-sulfonyl)amino-*N*-methoxymethyl-*N*-methylamides

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ABSTRACT

N-Methoxymethyl-*N*-methylcarbamoyl(trimethyl)silane reacted with *N*-sulfonylimines in anhydrous benzene under catalyst-free conditions to afford α-(*N*-sulfonyl)amino-*N*-methoxymethyl-*N*-methylamides in good to excellent yields (71–95%). Furthermore, after acid hydrolysis at room temperature, the corresponding α-(*N*-sulfonyl)amino secondary amides can be formed.

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Introduction

α-Aminoamides are representatives of the smallest subunit of peptides and proteins, and found in a wide range of natural products and pharmaceuticals.[1] They have also been used as intermediates for the synthesis of different heterocycles.[2] Due to such interests, numerous methods for the synthesis of α-aminoamides have been developed. Among them, the Ugi reaction has been intensively studied over the past decades,[3] in which a multicomponent mixture of primary amine, carboxylic acid, aldehyde, and isocyanide affords an α-(*N*-acyl-*N*-alkyl amino)amide, whose various limitations are under continual improvement.[4] Recently, Mita et al. reported that the catalytic silylation of *N*-benzenesulfonylimines using a Cu-secondary diamine complex as catalyst, then carboxylation under a CO_2 atmosphere can afford α-aminoacids.[5] We have also used sulfonylimines as the reaction substrates to react with *N*,*N*-dimethylcarbamoyl(trimethyl)silane under catalyst-free conditions, successfully realized the formation of the α-(*N*-sulfonyl)aminoamides in a single step.[6] However, these results specifically address the formation of (tertiary) *N*,*N*-dimethylamides, for efficient application within these areas, the synthesis of α-amino secondary amides is required. To the best of our knowledge, carbamoylsilane has never been reported for the synthesis of α-amino secondary amides. We have tested this process using *N*-methoxymethyl-*N*-methylcarbamoyl(trimethyl)silane as a secondary amide source and reported here our results about the synthesis of α-(*N*-sulfonyl)amino-*N*-methoxymethyl-*N*-methyl amides (Scheme 1). *N*-Methoxymethyl group of α-(*N*-sulfonyl)amino-*N*-methoxymethyl-*N*-methyl amides **3** could be easily converted into hydrogen atom by acid hydrolysis, so this approach is an efficient method for synthesizing α-(*N*-sulfonyl)amino secondary amides.[7]

Results and discussion

N-Sulfonylimines **2** were easily prepared by the reaction of aldehydes and benzene sulfonicamide or *p*-methylbenzene sulfonicamide,[8] which reacted with *N*-methoxymethyl-*N*-methylcarbamoyl(trimethyl)silane **1** in a benzene solution under anhydrous conditions, good to excellent yields of α-(*N*-sulfonyl) aminoamides **3** were obtained. Results are displayed in Table 1. However, *N*-sulfinylimines as the C=N substrates did not react with carbamoylsilane **1**. This result may be from the weaker electron-withdrawing ability of sulfinyl, and may reflect that the electronic property of the substituents on the C=N bond plays a significant role.

In an initial attempt, we selected aliphatic *N*-sulfonylimines, such as propyl or isopropyl *N*-sulfonylimine to react with equimolar amounts of carbamoylsilane **1**. It was found that no desired products were obtained, and carbamoylsilane **1** was completely consumed. To our surprise, when *N*-sulfonylimine **2a** reacted with carbamoylsilane **1**, the compound **4**, an isomer of **2a**, was isolated in 94% yield after 16 h at 25 °C (Scheme 2). We speculate that the

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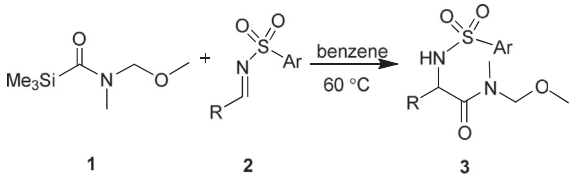
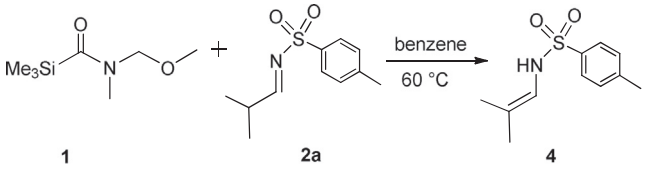
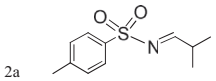
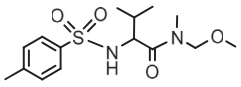
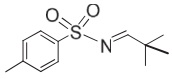
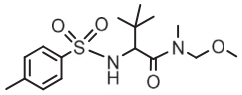
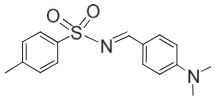
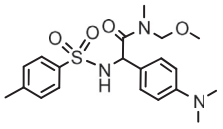
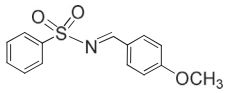
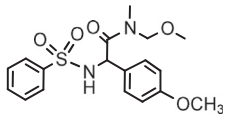
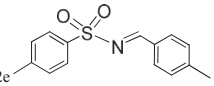
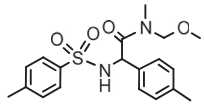
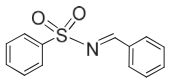
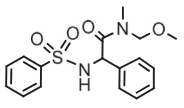
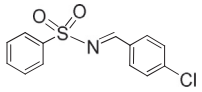
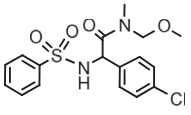
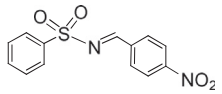
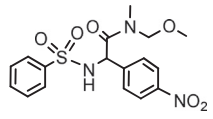
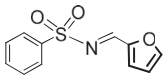
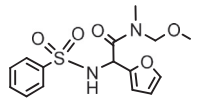
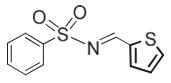
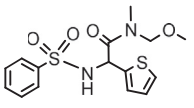
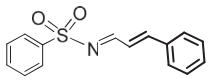
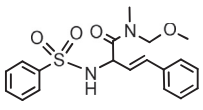


Scheme 1. The reaction of *N*-methoxymethyl-*N*-methylcarbamoyl(trimethyl)silane **1** with *N*-sulfonylimines **2**.

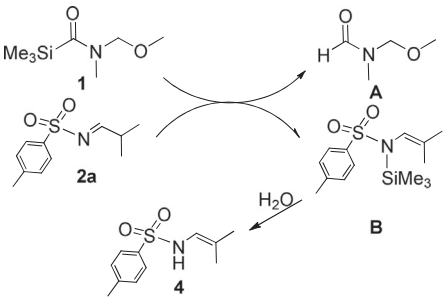


Scheme 2. The isomerization of *N*-sulfonylimine **2a**.

Table 1
α-(*N*-Sulfonyl)aminoamides **3** from *N*-sulfonylimines **2** and carbamoylsilane **1**

Entry	*N*-Sulfonylimine	Product	Time[a] (h)	Yield[b,c] (%)
1	 2a	 3a	16	0
2	 2b	 3b	14	71
3	 2c	 3c	18	71
4	 2d	 3d	23	84
5	 2e	 3e	24	77
6	 2f	 3f	20	81
7	 2g	 3g	21	86
8	 2h	 3h	14	95
9	 2i	 3i	20	83
10	 2j	 3j	23	84
11	 2k	 3k	15	79

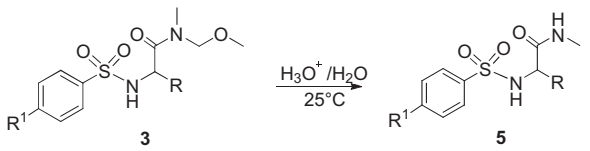
[a] To complete consumption of carbamoylsilane **1** in benzene at 60 °C.
[b] Isolated yield based on *N*-sulfonylimines. Characterization data are given.[12]
[c] 1:1.1 mol ratio of *N*-sulfonylimines and carbamoylsilane.



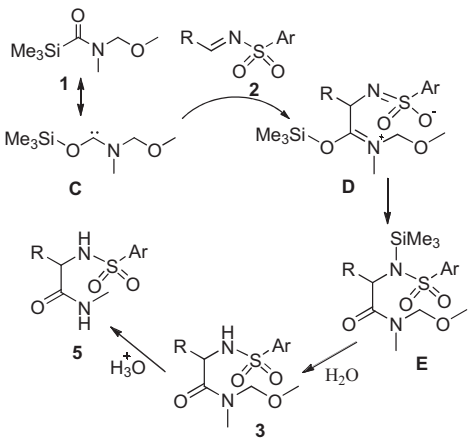
Scheme 3. The plausible mechanism of isomerization of *N*-sulfonylimine **2a**.

competitive protonolysis of carbamoylsilane **1** has occurred because the *N*-sulfonylimine **2a** contained enolizable α-hydrogens, led to the desilylative protonolysis of **1** into *N*-methoxymethyl-*N*-methylformamide **A** (Scheme 3), which have been isolated in reaction mixture.[12] Similar phenomenon was previously observed when iminium salts with enolizable α-hydrogens were used as substrates, where no products were obtained.[9] While *N*-sulfonylimine **2a** was converted to *N*-trimethylsilyl-*N*-sulfonyl-2-methyl-2-acrylic amine **B**, which was hydrolyzed in the separation process to give compound **4**.[10] However, the protonolysis of carbamoylsilane was not observed when isopropyl sulfonylimine reacted with *N*,*N*-dimethylcarbamoyl(trimethyl)silane.[6] **2b** possessing tertiary butyl in which there is not enolizable α-hydrogens gave desired addition products **3b** in good yields (Table 1, entry 2).

The common feature of all successful runs is the absence of 'alpha' hydrogens in the *N*-sulfonylimines, and the substituent on the C=N bond being either benzene sulfonyl or *p*-methylbenzene sulfonyl. To explore the scope of this reaction system, we tested the representative *N*-sulfonylimines bearing aryl, heteroaryl, and tertiary aliphatic substituents on the C=N bond (Table 1, entries 2–11). A comparison of the results obtained from **2c**–**h** indicates that the electronic consideration is an important factor in the addition reaction. Phenyl *N*-sulfonylimines possessing an electron-donating group on the aromatic ring, such as a dimethylamino or methyl group, gave slightly lower yields (entries 3 and 5). In contrast, substitution of an electron-withdrawing group on the aromatic ring, such as a nitro or chloro, led to higher yields (entries 7 and 8). While **2d** bearing methoxy afforded the addition product in good yields (entry 4), this result may be from the strong electron-withdrawing induction effect of methoxy. We conclude that, in general, electron-withdrawing to the phenyl substituent accelerates the reaction and leads to an improved yield, while an electron-donation group totally suppresses the reaction, aryl *N*-sulfonylimines possessing an electron-withdrawing group gave a better yield than those having an electron-donating group. In addition, *N*-sulfonylimines **2i** and **2j** containing an electron-rich heterocyclic ring, the furyl and thienyl, could also react with carbamoylsilane **1** to afford excellent yields of desired addition products **3i** and **3j** (entries 9 and 10). Reaction rate was similar to the rate of phenyl *N*-sulfonylimine **2f**. The less sterically demanding cinnamoyl *N*-sulfonylimine has proved more reactive toward reaction of **1** than most aryl *N*-sulfonylimines, since the reaction proceeded with faster rate in case of **2k** than in case of **2c**–**g**, and compound **3k**



Scheme 4. The formation of α-(*N*-sulfonyl)amino secondary amide **5** by acid hydrolysis of **3**.



Scheme 5. The proposed mechanism of the reaction.

corresponding to 1,2-addition product was exclusively obtained in good yield.

The α-(*N*-sulfonyl)aminoamides **3** can be easily hydrolyzed in a mixture of concentrated hydrochloric acid and dichloromethane at room temperature, led to the α-(*N*-sulfonyl)amino secondary amides **5** (Scheme 4). For example, α-(*N*-sulfonyl)aminoamide **3k** could be readily converted into α-(*N*-sulfonyl)amino-*N*-methyl amide **5k** in 97% yield.

Proposed reaction mechanism

A possible route to addition products **5** is presented in Scheme 5. Carbamoylsilane **1** can rearrange to its nucleophilic carbene form **C**,[11] which attacked the *N*-sulfonyl imines to produce an unstable intermediate **D**, followed by silyl group 1,4-migration to give the adducts **E**. The latter can be hydrolyzed in the separation process to form α-(*N*-sulfonyl)aminoamides **3**, which were hydrolyzed under acidic condition at room temperature to afford α-(*N*-sulfonyl)amino secondary amides **5**.

General procedure for the synthesis of α-(*N*-sulfonyl)amino-*N*-methoxymethyl-*N*-methyl amides 3

A Schlenk tube fitted with a Teflon vacuum stopcock and micro stirbar was flame heated under vacuum and refilled with Ar. *N*-Sulfonylimines **2** (0.50 mmol) and anhydrous benzene (1.5 mL) were added at ice bath temperature. After 20 min, carbamoylsilane **1** (0.55 mmol) was added. The sealed reaction mixture was stirred at 60 °C until no carbamoylsilane **1** could be detected by TLC. Volatiles were removed in vacuo to afford the crude product which was purified by column chromatography on silica gel (petroleum ether/ethyl acetate combination) to give amides **3**. **3c**: mp 151.5–153.0 °C. IR: 3194, 1652, 1614, 1379, 1169, 1094, 569 cm^{-1}. ^1H NMR (600 MHz, $CDCl_3$): δ 6.55–7.65 (m, 8H), 6.21, 6.19 (dd, J = 8.4 Hz, 1H), 5.23, 5.13 (dd, J = 8.4 Hz, 1H), 4.65, 4.64, 4.24, 4.22 (ssss, 2H), 3.07, 3.03 (ss, 3H), 2.93, 2.92 (ss, 6H), 2.85, 2.78 (ss, 3H), 2.38, 2.37 (ss, 3H). ^{13}C NMR (151 MHz, $CDCl_3$): δ 170.8, 170.9, 150.5, 148.8, 137.6, 137.5, 129.3, 129.3, 128.8, 128.6, 128.4, 127.3, 127.2, 123.3, 122.9, 112.5, 112.4, 80.5, 78.1, 57.4, 57.3, 55.7, 55.4, 40.4, 34.1, 32.8, 20.5, 20.4. Anal. Calcd for $C_{20}H_{27}N_3O_4S$: C, 59.24; H, 6.71; N, 10.36. Found: C, 59.43; H, 6.80; N, 10.41.

Procedure for acid hydrolysis of α-(*N*-sulfonyl)amino-*N*-methoxymethyl-*N*-methyl amides 3

Concentrated hydrochloric acid (15 mL) is added dropwise to a solution of **3** (100 mg) in dichloromethane (15 mL). After 24 h

stirring at room temperature, the organic layer was decanted and washed with sodium bicarbonate solution (45 mL). The aqueous phase was extracted with dichloromethane (3 × 15 mL). The combined organic layers were dried over $MgSO_4$ and evaporated to afford the crude product which was purified by column chromatography on silica gel (petroleum ether/ethyl acetate combination) to afford α-(*N*-sulfonyl)amino amides **5**.[12] **5k**: IR: 3334, 3255, 1646, 1450, 1342, 1169, 1089, 690 cm^{-1}. ^1H NMR (600 MHz, $CDCl_3$): δ 7.21–7.89 (m, 10H), 6.49 (d, *J* = 14.4 Hz, 1H), 6.04 (s, 1H), 5.96, 5.93 (dd, *J* = 7.8 Hz, 1H), 5.87 (d, *J* = 4.2 Hz, 1H), 2.80, 2.79 (ss, 3H). ^{13}C NMR (151 MHz, $CDCl_3$): δ 170.1, 169.9, 140.6, 140.4, 135.5, 135.3, 135.0, 134.3, 132.6, 132.5, 129.0, 128.9, 128.8, 128.6, 128.5, 128.4, 127.3, 127.2, 126.7, 123.6, 122.6, 80.6, 78.2, 34.5, 33.0. Anal. Calcd for $C_{17}H_{18}N_2O_3S$: C, 61.80; H, 5.49; N, 8.48. Found: C, 61.88; H, 5.56; N, 8.60.

Conclusions

We have successfully developed a novel and highly efficient synthetic method toward α-(*N*-sulfonyl)amino-*N*-methoxymethyl-*N*-methylamides by the additions of *N*-methoxymethyl-*N*-methylcarbamoyl(trimethyl)silane to *N*-sulfonylimines. The reaction in general provides good yields of the products under mild reaction conditions. This approach is an efficient synthesis method of α-(*N*-sulfonyl)amino secondary amides because of the acid hydrolysis of α-(*N*-sulfonyl)amino-*N*-methoxymethyl-*N*-methylamides **3** at room temperature leading to corresponding α-(*N*-sulfonyl)amino secondary amides **5**. The mild and no catalyst conditions, simple procedure, and impressive yield provide a valuable method for the preparation of various α-(*N*-sulfonyl)amino secondary amides. We believe that the current methodology will find applications in organic and medicinal chemistry.

Acknowledgments

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Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.tetlet.2015.09.022.

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12. *Characterization data for compounds* ***3***, ***4***, ***A***, *and* ***5***. All NMR spectra were obtained in $CDCl_3$ unless otherwise indicated. **3b**: mp 126.5–128.0 °C. IR: 3245, 1656, 1390, 1338, 1160, 1092, 566 cm^{-1}. ^1H NMR: δ 7.27–7.23 (m, 4H), 5.53–5.58 (m, 1H), 3.90–4.65 (m, 3H), 3.16, 3.08 (ss, 3H), 2.79, 2.73 (ss, 3H), 2.42 (s, 3H), 1.00, 0.96 (ss, 9H). ^{13}C NMR: δ 172.0, 171.5, 143.7, 143.4, 136.9, 129.4, 129.3, 127.3, 127.2, 81.2, 77.8, 59.4, 59.3, 56.1, 55.6, 35.7, 35.6, 34.0, 33.4, 26.5, 26.3, 21.5. Anal. Calcd for $C_{16}H_{26}N_2O_4S$: C, 56.12; H, 7.65; N, 8.18. Found: C, 56.35; H, 7.46; N, 8.16. **3d**: mp 111.5–113.0 °C. IR: 3222, 1656, 1510, 1164, 1084, 1023, 578 cm^{-1}. ^1H NMR: δ 6.73–7.73 (m, 9H), 6.54, 6.49 (dd, *J* = 8.4 Hz, 1H), 5.28, 5.19 (dd, *J* = 8.4 Hz, 1H), 4.22–4.66 (m, 2H), 3.73 (s, 3H), 3.03, 2.99 (ss, 3H), 2.82, 2.74 (ss, 3H). ^{13}C NMR: δ 170.4, 170.0, 159.7, 140.5, 140.3, 132.3, 132.2, 129.1, 129.0, 128.7, 128.1, 127.2, 127.1, 127.0, 114.4, 80.5, 78.1, 57.3, 57.1, 55.8, 55.4, 55.3, 34.3, 32.9. Anal. Calcd for $C_{18}H_{22}N_2O_5S$: C, 57.13; H, 5.86; N, 7.40. Found: C, 57.34; H, 5.93; N, 7.14. **3e**: mp 133.0–134.0 °C. IR: 3264, 1652, 1347, 1164, 1098, 681 cm^{-1}. ^1H NMR: δ 7.04–7.7.64 (m, 8H), 6.34, 6.30 (dd, *J* = 8.4 Hz, 1H), 5.27, 5.17 (dd, *J* = 8.4 Hz, 1H), 4.22–4.66 (m, 2H), 3.05, 3.00 (ss, 3H), 2.85, 2.75 (ss, 3H), 2.38, 2.36 (ss, 3H), 2.29 (s, 3H). ^{13}C NMR: δ 170.4, 170.0, 143.1, 143.0, 138.6, 138.5, 137.4, 137.3, 133.2, 132.4, 129.7, 129.3, 129.2, 127.8, 127.6, 127.3, 127.1, 80.5, 78.1, 57.5, 57.3, 55.7, 55.4, 34.3, 32.9, 21.5, 21.4, 21.1. Anal. Calcd for $C_{19}H_{24}N_2O_4S$: C, 60.61; H, 6.43; N, 7.44. Found: C, 60.52; H, 6.68; N, 7.47. **3f**: IR: 3235, 1656, 1450, 1333, 1159, 1093, 723 cm^{-1}. ^1H NMR: δ 7.24–7.95 (m, 10H), 6.44, 6.40 (dd, *J* = 7.8 Hz, 1H), 5.40, 5.25 (dd, *J* = 7.8 Hz, 1H), 4.24–4.68 (m, 2H), 3.06, 3.02 (ss, 3H), 2.86, 2.77 (ss, 3H). ^{13}C NMR: δ 170.2, 169.8, 140.3, 140.2, 136.0, 135.2, 132.6, 132.4, 132.3, 129.1, 128.7, 128.6, 127.9, 127.7, 127.2, 127.0, 126.4, 80.5, 78.2, 57.8, 57.6, 55.9, 55.5, 34.3, 32.9. Anal. Calcd for $C_{17}H_{20}N_2O_4S$: C, 58.60; H, 5.79; N, 8.04. Found: C, 58.71; H, 5.74; N, 8.25. **3g**: IR: 3231, 1656, 1445, 1333, 1164, 1093, 723 cm^{-1}. ^1H NMR: δ 7.16–7.73 (m, 9H), 6.75, 6.70 (dd, *J* = 8.4 Hz, 1H), 5.33, 5.24 (dd, *J* = 8.4 Hz, 1H), 4.29–4.66 (m, 2H), 3.05, 3.04, 2.99, 2.98 (ssss, 3H), 2.84, 2.75 (ss, 3H). ^{13}C NMR: δ 169.9, 169.7, 140.3, 140.2, 134.7, 134.6, 134.5, 133.9, 132.5, 132.4, 129.3, 129.2, 129.1, 128.8, 127.1, 126.9, 126.3, 80.6, 78.2, 57.0, 56.8, 55.9, 55.5, 34.7, 33.0. Anal. Calcd for $C_{17}H_{19}N_2O_4SCl$: C, 53.33; H, 5.00; N, 7.32. Found: C, 53.42; H, 5.11; N, 7.38. **3h**: mp 114.5–116.0 °C. IR: 3264, 1652, 1515, 1352, 1169, 1098, 719 cm^{-1}. ^1H NMR: δ 7.35–8.07 (m, 9H), 6.74, 6.72 (dd, *J* = 7.8 Hz, 1H), 5.47, 5.37 (dd, *J* = 7.8 Hz, 1H), 4.43–4.66 (m, 2H), 3.10, 3.02 (ss, 3H), 2.90, 2.80 (ss, 3H). ^{13}C NMR: δ 169.2, 169.1, 150.6, 147.8, 147.7, 143.1, 142.3, 140.0, 139.9, 132.8, 128.9, 128.8, 128.7, 127.1, 126.9, 124.2, 124.0, 122.9, 80.9, 76.4, 56.9, 56.6, 56.0, 55.7, 35.2, 35.1. Anal. Calcd for $C_{17}H_{19}N_3O_6S$: C, 51.90; H, 4.87; N, 10.68. Found: C, 51.84; H, 4.91; N, 10.74. **3i**: IR: 3226, 1665, 1450, 1337, 1164, 1089, 752 cm^{-1}. ^1H NMR: δ 7.19–7.77 (m, 6H), 6.54, 6.52 (dd, *J* = 7.8 Hz, 1H), 6.19–6.23 (m, 2H), 5.47, 5.40 (dd, *J* = 7.8 Hz, 1H), 4.36–4.72 (m, 2H), 3.03–3.07 (m, 3H), 2.82–2.86 (m, 3H). ^{13}C NMR: δ 168.0, 167.7, 148.7, 148.1, 143.0, 142.9, 140.1, 140.0, 132.5, 128.8, 128.7, 127.1, 127.0, 110.7, 109.4, 109.1, 80.5, 78.2, 55.8, 55.4, 51.7, 51.5, 34.4, 32.8. Anal. Calcd for $C_{15}H_{18}N_2O_5S$: C, 53.24; H, 5.36; N, 8.28. Found: C, 53.33; H, 5.49; N, 8.33. **3j**: IR: 3230, 1660, 1445, 1333, 1164, 1088, 723 cm^{-1}. ^1H NMR: δ 6.84–7.79 (m, 8H), 6.51, 6.46 (dd, *J* = 8.4 Hz, 1H), 5.62, 5.54 (dd, *J* = 8.4 Hz, 1H), 4.36–4.72 (m, 2H), 3.11, 3.06 (ss, 3H), 2.87, 2.86 (ss, 3H). ^{13}C NMR: δ 169.6, 169.3, 140.3, 140.2, 138.7, 137.9, 132.6, 128.9, 128.8, 127.3, 127.2, 127.0, 126.9, 126.8, 126.7, 80.8, 78.2, 56.0, 55.5, 53.0, 52.8, 34.5, 33.0. Anal. Calcd for $C_{15}H_{18}N_2O_4S_2$: C, 50.83; H, 5.12; N, 7.90. Found: C, 50.97; H, 5.22; N, 7.99. **3k**: IR: 3222, 1656, 1445, 1333, 1164, 1094, 691 cm^{-1}. ^1H NMR: δ 7.21–7.86 (m, 10H), 6.62, 6.56 (dd, *J* = 15.6 Hz, 1H), 6.27, 5.24 (dd, *J* = 8.4 Hz, 1H), 6.00, 5.97, 5.93, 5.90 (dddd, *J* = 7.2 Hz, 1H), 5.03, 4.95 (tt, *J* = 7.2 Hz, 1H), 4.52–4.94 (m, 2H), 3.19, 3.09 (ss, 3H), 2.98, 2.90 (ss, 3H). ^{13}C NMR: δ 170.1, 169.9, 140.6, 140.4, 135.5, 135.3, 135.0, 134.3, 132.6, 132.5, 129.0, 128.9, 128.8, 128.6, 128.5, 128.4, 127.3, 127.2, 126.7, 123.6, 122.6, 80.6, 78.2, 55.9, 55.8, 55.6, 55.5, 34.5, 33.0. Anal. Calcd for $C_{19}H_{22}N_2O_4S$: C, 60.94; H, 5.92; N, 7.48. Found: C, 60.83; H, 5.99; N, 7.61. **4**:[10] mp 114.0–115.5 °C. ^1H NMR: δ 7.28–7.77 (m, 4H), 6.31 (d, *J* = 9.6 Hz, 1H), 5.81–5.83 (m, 1H), 2.44 (s, 3H), 1.63 (s, 3H), 1.47 (s, 3H). ^{13}C NMR: δ 143.5, 137.2, 129.7, 126.9, 120.3, 116.7, 22.2, 21.6, 16.2. **A**: ^1H NMR: δ 8.14 (s, 1H), 4.72, 4.58 (ss, 2H), 3.24, 3.20 (ss, 3H), 2.93, 2.87 (ss, 3H). ^{13}C NMR: δ 163.3, 162.7, 81.1, 74.4, 55.3, 54.2, 32.5, 28.3. **5b**: mp 196.0–197.0 °C. IR: 3443, 3204, 1644, 1401, 1333, 1160, 1072 cm^{-1}. ^1H NMR: δ 7.77 (d, *J* = 7.8 Hz, 2H), 7.29 (d, *J* = 8.4 Hz, 2H), 5.39 (d, *J* = 9.0 Hz, 1H), 5.28 (s, 1H), 3.29 (d, *J* = 9.6 Hz, 1H), 2.52, 2.51 (ss, 3H), 2.43(s, 3H), 0.96 (s, 9H). ^{13}C NMR: δ 170.0, 143.6, 136.6, 129.5, 127.5, 65.4, 53.5, 34.4, 26.5, 26.0, 21.5. Anal. Calcd for $C_{14}H_{22}N_2O_3S$: C, 56.35; H, 7.43; N, 9.39. Found: C, 56.48; H, 7.24; N, 9.52. **5c**: mp 218.5–220.0 °C. IR: 3340, 3257, 1644, 1327, 1167, 1088 cm^{-1}. ^1H NMR: δ 7.62 (d, *J* = 8.4 Hz, 2H), 7.28 (d, *J* = 8.4 Hz, 2H), 6.70 (d, *J* = 8.4 Hz, 2H), 6.57 (d, *J* = 8.4 Hz, 2H), 5.81 (d, *J* = 3.6 Hz, 1H), 5.75 (d, *J* = 3.6 Hz, 1H), 4.61, 4.60 (ss, 1H), 2.94 (s, 6H), 2.76, 2.75 (ss, 3H), 2.41 (s, 3H). ^{13}C NMR: δ 170.2, 150.7, 143.2, 136.6, 129.4, 128.7, 127.4, 123.7, 112.5, 60.4, 40.4, 26.7, 21.5. Anal. Calcd for $C_{18}H_{23}N_3O_3S$: C, 59.81; H, 6.41; N, 11.63. Found: C, 59.62; H, 6.13; N, 11.45. **5d**: mp 113.0–114.0 °C. IR: 3340, 3265, 1651, 1509, 1333, 1156, 1088 cm^{-1}. ^1H NMR: δ 7.72–7.41 (m, 5H), 7.05 (d, *J* = 8.4 Hz, 2H), 6.77 (d, *J* = 8.4 Hz, 2H), 5.98 (s, 1H), 5.67 (s, 1H), 4.72, 4.71 (ss, 1H), 3.86, 3.78 (ss, 3H), 2.76, 2.75 (ss, 3H). ^{13}C NMR: δ 169.7, 159.8, 139.7, 132.6, 128.9, 128.4, 127.2, 114.4, 60.1, 55.3, 26.7. Anal. Calcd for $C_{16}H_{18}N_2O_4S$: C, 57.47; H, 5.43; N, 8.38. Found: C, 57.50; H, 5.26; N, 8.10. **5e**: mp 174.0–175.5 °C. IR: 3423, 3256, 1656, 1401, 1342, 1167, 1088 cm^{-1}. ^1H NMR: δ 7.62 (d, *J* = 8.4 Hz, 2H), 7.22 (d, *J* = 8.4 Hz, 2H), 7.07 (d, *J* = 8.4 Hz, 2H), 7.02 (d, *J* = 8.4 Hz, 2H), 5.93 (d, *J* = 3.6 Hz, 1H), 5.79 (d, *J* = 3.6 Hz, 1H), 4.68, 4.67 (ss, 1H), 2.74, 2.73 (ss, 3H), 2.42 (s, 3H), 2.32 (s, 3H). ^{13}C NMR: δ 169.6, 143.5, 138.7, 136.5, 133.7, 129.7, 129.5, 127.6, 127.3, 60.4, 26.7, 21.5, 21.1. Anal. Calcd for $C_{17}H_{20}N_2O_3S$: C, 61.42; H, 6.06; N, 8.43. Found: C, 61.15; H, 6.13; N, 8.18. **5f**: mp 182.0–183.0 °C. IR: 3434, 3276, 1640, 1401, 1342, 1171, 1076 cm^{-1}. ^1H

NMR: δ 7.72–7.13 (m, 10H), 6.07 (s, 1H), 5.74 (s, 1H), 4.79 (s, 1H), 2.75, 2.74 (ss, 3H). ^{13}C NMR: δ 169.3, 139.6, 136.4, 132.7, 129.1, 128.9, 128.8, 127.7, 127.2, 60.6, 26.8. Anal. Calcd for $C_{15}H_{16}N_2O_3S$: C, 59.19; H, 5.30; N, 9.20. Found: C, 59.12; H, 5.34; N, 9.11. **5g**: mp 160.5–162.0 °C. IR: 3434, 3250, 1640, 1446, 1327, 1160, 1083 cm^{-1}. ^{1}H NMR: δ 7.71–7.08 (m, 9H), 6.08 (s, 1H), 5.66 (s, 1H), 4.77, 4.76 (ss, 1H), 2.76, 2.75 (ss, 3H). ^{13}C NMR: δ 169.1, 139.6, 134.9, 134.7, 132.8, 129.1, 129.0, 127.1, 59.9, 26.7. Anal. Calcd for $C_{15}H_{15}ClN_2O_3S$: C, 53.17; H, 4.46; N, 8.27. Found: C, 53.02; H, 4.35; N, 8.14. **5h**: mp 168.5–170.0 °C. IR: 3439, 3235, 1645, 1401, 1342, 1167, 1025 cm^{-1}. ^{1}H NMR: δ 8.11 (d, J = 8.4 Hz, 2H), 7.73 (d, J = 8.4 Hz, 2H), 7.56–7.28 (m, 5H), 6.22 (s, 1H), 5.72 (s, 1H), 4.91 (s, 1H), 2.77, 2.76 (ss, 3H). ^{13}C NMR: δ 167.9, 148.0, 143.4, 139.4, 133.1, 129.1, 128.6, 127.1, 124.1, 59.8, 27.0. Anal. Calcd for $C_{15}H_{15}N_3O_5S$: C, 51.57; H, 4.33; N, 12.03. Found: C, 51.36; H, 4.13; N, 11.94. **5i**: mp 78.5–80.0 °C. IR: 3393, 3313, 1634, 1401, 1254, 1160, 1072 cm^{-1}. ^{1}H NMR: δ 8.16–7.54 (m, 8H), 6.29 (d, J = 3.0 Hz, 1H), 4.84 (s, 1H), 2.97, 2.96 (ss, 3H). ^{13}C NMR: δ 172.5, 161.6, 161.2, 148.6, 132.8, 129.3, 129.2, 126.6, 110.5, 25.9, 14.3. Anal. Calcd for $C_{13}H_{14}N_2O_4S$: C, 53.05; H, 4.79; N, 9.52. Found: C, 53.24; H, 4.59; N, 9.77%. **5j**: mp 116.5–118.0 °C. IR: 3412, 3250, 1660, 1401, 1333, 1160, 1092 cm^{-1}. ^{1}H NMR: δ 7.77–6.82 (m, 8H), 6.38 (s, 1H), 6.33 (d, J = 6.0 Hz, 1H), 5.19 (d, J = 6.0 Hz, 1H), 2.72, 2.71 (ss, 3H). ^{13}C NMR: δ 168.8, 139.5, 138.9, 132.8, 129.0, 127.2, 127.1, 126.8, 126.7, 56.2, 26.7. Anal. Calcd for $C_{13}H_{14}N_2O_3S_2$: C, 50.30; H, 4.55; N, 9.03. Found: C, 50.18; H, 4.29; N, 8.86.