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Amination of Diazocarbonyl Compounds: N−H Insertion under Metal-Free Conditions

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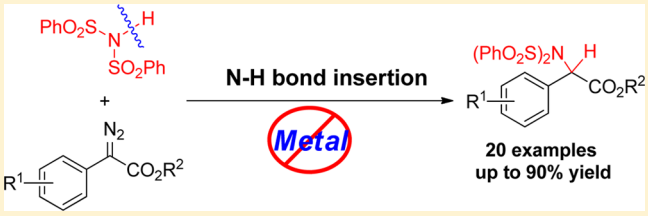
Supporting Information

ABSTRACT: Transition-metal-free intermolecular N−H insertion of α-diazocarbonyl compounds is reported. Among the series of nitrogen sources examined, dibenzenesulfonimide was found to be the choice in terms of the yields and the reaction time. Primary mechanistic experiments suggest that a pathway involving a sequence of protonation and nucleophilic substitution was preferred.

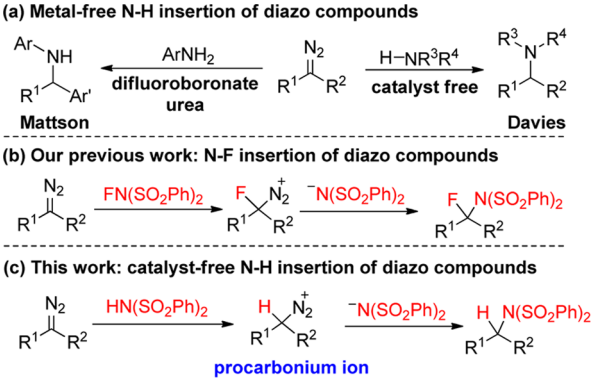


INTRODUCTION

Donor/acceptor (D/A) carbenoids generated from aryl diazoesters are versatile reaction intermediates. They can undergo various transformations including three-membered ring (cyclopropane, cyclopropene) formation, X−H bond insertion (X = C, N, O, S, etc.), ylide generation and cross-coupling reactions.[1,2] Of particular interest, N−H bond insertion has received considerable attention due to its facile construction of nitrogen-containing molecules, such as α-amino esters/ketones and N-heterocycles,[3,4] which are precursors for α-amino acids and pharmaceutically useful compounds.

Thus, it is not surprising that significant advances have been achieved toward transition-metal (mainly Cu, Rh, Pd) catalyzed N−H insertion reactions.[3] As for metal-free process,[4,5] Mattson and co-workers developed a difluoroboronate urea type catalyst, which can serve as a strong hydrogen bond donor to activate α-nitro-α-diazo esters, hence achieving an organocatalytic approach to N−H insertion reactions (Scheme 1a, left).[4b−d] Among all these catalytic transformations, aniline derivatives or carbamates were employed as the nitrogen sources. Recently, the research group of Davies disclosed a catalyst-free, thermal induced N−H insertion of donor/acceptor carbenes (Scheme 1a, right).[4a] This protocol was operationally simple, and more importantly, a broad range of nitrogen sources including primary amines, secondary amines, and aniline derivatives could be inserted. During our recent study on aminofluorination of diazo compounds (Scheme 1b),[6] we have observed small amount of amination product, when water was employed as the reaction media. Replacement of *N*-fluorobenzenesulfonimide (NFSI) with dibenzenesulfonimide resulted in a rapid formation of α-amino-ester derivative (Scheme 1c). Although the reaction of diazo compounds with acids, such as carboxylic acids,[7] hydrogen halides[8] and sulfonic acids[9] are known in the literature, to our knowledge, insertion of D/A carbenoid precusors to imides has not been realized to date. Considering the ubiquitous motif of sulfonamides in pharmaceutical chemistry,[10] we decided to explore this metal-free N−H insertion reactions systematically, and reported our preliminary results on this topic.[11]

Scheme 1. N−H Bonds Insertion of Diazo Compounds



RESULTS AND DISCUSSION

At the outset, dibenzenesulfonimide was selected as nitrogen source as its structure is similar to that of NFSI. To our delight, upon addition of ethyl diazophenylacetate **1a**[12] to a solution of dibenzenesulfonimide **2** in 1,2-dichloroethane (DCE) at room temperature, bubbles were generated immediately. The orange solution was changed to colorless within half an hour. The desired product **3a** was obtained in 74% yield upon isolation (Table 1, entry 1). Reaction temperature had little affects on the yields of **3a** (Table 1, entries 2−4). Besides DCE, other solvents were also examined. Dichloromethane (DCM), acetonitrile (MeCN), tetrahydrofuran (THF) or toluene

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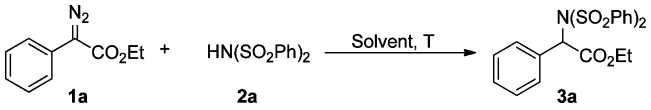
Table 1. Optimization of the Reaction Conditions



1a 2a 3a

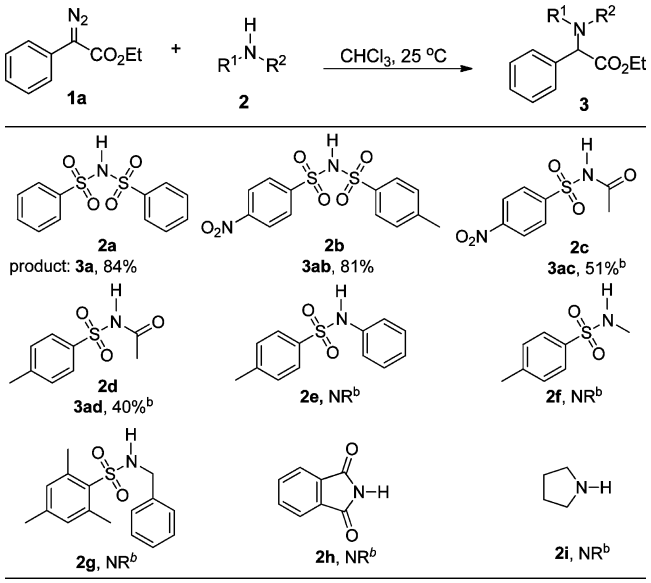
entry[a]	solvent	T/°C	yield[b]
1	DCE	60	75
2	DCE	80	74
3	DCE	40	75
4	DCE	25	74
5	CH_2Cl_2	25	34
6	$CHCl_3$	25	84
7	MeCN	25	28
8	THF	25	18
9	PhMe	25	33
10	$PhCF_3$	25	38
11[c]	H_2O	25	70

[a]**1a** (0.3 mmol) and **2a** (0.6 mmol) were stirred in solvent (3 mL) at room temperature for 0.5 h. [b]Isolated yield. [c]15 h was needed to complete the reaction.

(PhMe) gave low to moderate yields (Table 1, entries 5 and 7−9). When trifluorotoluene ($PhCF_3$), which is the best choice for the thermal induced N−H insertion reactions,[4a] was used, only moderate yield of **3a** was obtained (Table 1, entry 10). Chloroform ($CHCl_3$) was proved to be optimal, giving **3a** in 84% isolated yield (Table 1, entry 6). Notably, the reaction can also be performed in water, and a relatively longer reaction time (15 h) was required (Table 1, entry 11). It is worthwhile to mention that slow addition of **1a** was not necessary for the current N−H insertion reaction.

Besides dibenzenesulfonimide, the effects of other nitrogen sources were also evaluated. 4-Methyl-*N*-((4-nitrophenyl)-sulfonyl)benzenesulfonamide (**2b**) gave similar yield of desired product **3ab** (Table 2, 81%). Replacing either sulfonyl group in **2b** with acetyl group led to lower reactivity, presumably because of the lower acidity of the corresponding imides (Table 2, **2c** and **2d**). Thus, an elevated reaction temperature and extended

Table 2. Reaction Scope of Sulfonamides[a]

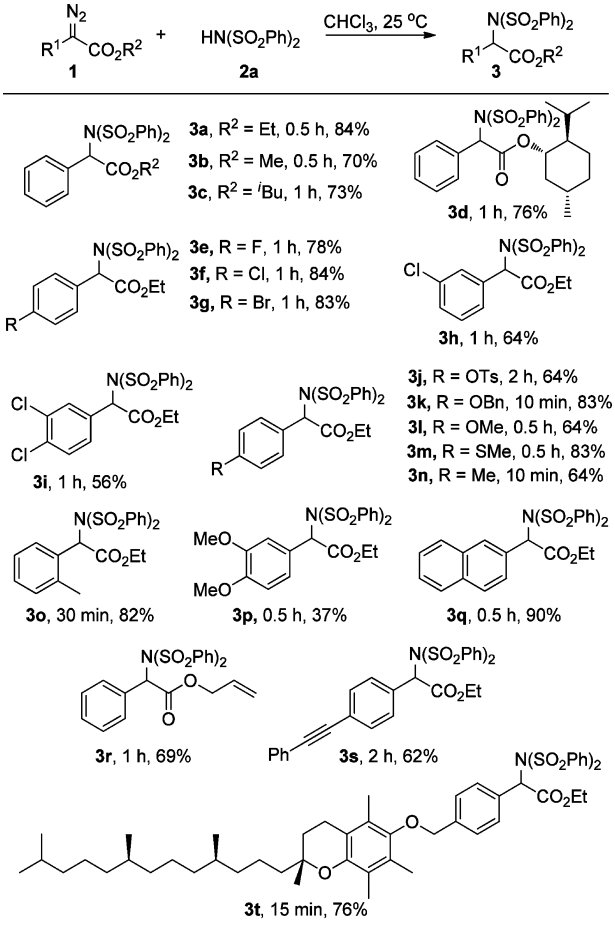


[a]NR = No Reaction. [b]Reactions were carried out at 60 °C for 12 h.

reaction time were required, giving 3ac and **3ad** in moderate yields. Phthalimide **2h** (pK_a 8.3) could not be inserted even at elevated temperature. Phenyl, methyl or benzyl substituted sulfonamides (pK_a around 16) proved to unreactive under current system (Table 2, **2e−2g**). As expected, pyrrolidine **2i** (pK_a 44) could not react with **1a** either. This reaction phenomenon indicates that a pathway involving a sequence of protonation and nucleophilic substitution is likely (vide infra).

The generality and limitation regarding diazo compounds for the reactions with dibenzenesulfonimide were examined (Table 3). Most of the diazo compounds listed in Table 3 reacted with

Table 3. Reaction Scope of Diazo Compounds



[a]All reactions were carried out in 0.30 mmol scale at room temperature, [**1**] = 0.1 M, isolated yield.

dibenzenesulfonimide smoothly to give the corresponding products in moderate to good yields. Increasing the sizes of the ester groups (R^2) has no big influence on the reaction (Table 3, **2a−d**). Methyl, isobutyl, or even more bulky menthol group gave similar yields of corresponding products (Table 3, **3a−d**). Notably, a pair of diastereoisomers **3d** was obtained in a ratio of 1:1 with (+)-menthol as the chiral auxiliary. The effects of substituents on the phenyl ring have also been examined. Both electron-withdrawing (fluoro, chloro, bromo) and electron-donating groups (methoxyl, methylthio, methyl) on the aromatic ring of **1** were tolerated under the standard conditions, and the corresponding products were obtained in moderate to good yields (Table 3, **3e−3o**). Furthermore,

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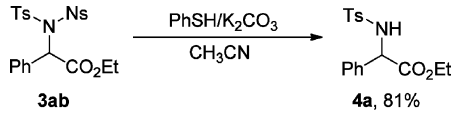
phenyl ring bearing substituted groups at the *ortho-*, *meta-* and *para-* positions had no obvious impacts on the yields of the products (Table 3, **3e**−**3o**). The reaction of diazoacetates possessing two substituents on the aromatic ring showed lower efficiency (Table 3, **3i** and **3p**). Naphthyl acetate derived diazo compound was also viable reaction partner (Table 3, **3q**). Of note, functional groups containing vinyl or alkynyl moiety remained intact (Table 3, **3r** and **3s**). Interestingly, tocopherol derived diazoacetate could also undergo the reaction, giving the desired product in good yield (Table 3, **3t**). Notably, the reaction could be scaled up to gram scale without sacrificing the yield of **3a** (5 mmol scale, 1.80 g **3a** was obtained with 78% yield). It is also should be mentioned that when diazo compounds aliphatic carboxylic acid were employed, no formation of aminated products were observed.

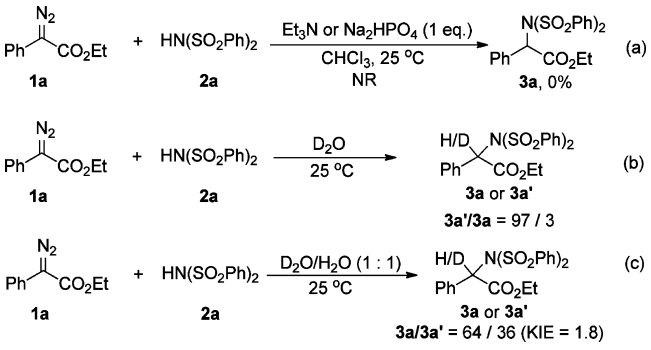
It is worthy to mention that the sulfonamide groups on **3ab** could be easily removed according to the literature procedures (Scheme 2).[13] Deprotection of 4-nitrobenzenesulfonyl group was achieved by treatment with $PhSH/K_2CO_3$[13a] in MeCN, giving **4a** in 81% yield.

Scheme 2. Desulfonylation of 3ab



Having uncovered an efficient method for the N−H bond insertion of disulfonimides, we sought to gain more insights into the reaction mechanism. Thus, a series of additional experiments were carried out subsequently. In the presence of 1 equiv organic base (Et_3N) or inorganic base (Na_2HPO_4), the reaction did not take place at all (Scheme 3a). Using D_2O as

Scheme 3. Preliminary Mechanistic Studies



solvent, 97% of deuterium was incorporated into the final product (Scheme 3b). Kinetic isotope effect (KIE) for the N−H insertion reaction was found to be 1.8 using a mixture of D_2O/H_2O (1:1) as solvent (Scheme 3c), suggesting that protonation of the diazo compounds was the rate determined step.[14] Fitted the relative rates by Hammett equation, a fairly linear correlation between $\log(k_X/k_H)$ and σ was obtained with a reaction constant of $\rho = -2.39$ (Figure 1). The large negative ρ value also suggests that a positive charge reaction center was developed during the reaction progress and formation of the procarbonium ion is a rate determined step.[15]

On the basis of previous reports[7−9] and our own observations, a plausible mechanism for the catalyst-free N−H insertion reaction between diazo compounds and dibenzenesulfonimide is proposed (Scheme 4). Dibenzenesulfonimide **2a** is known as a weak acid with pK_a of 1.45,[16] which may be

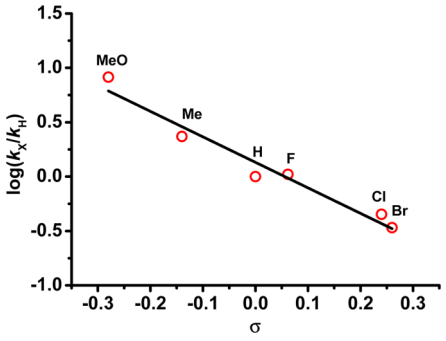
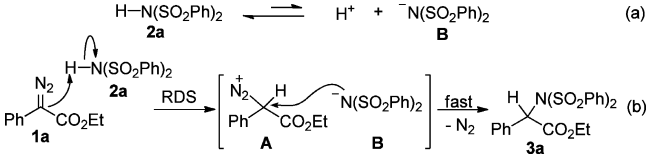


Figure 1. Hammett plot of $\log(k_X/k_H)$ vs σ for the reaction of dibenzenesulfonimide with *para*-substituted diazophenylacetate **1** in $CHCl_3$ at room temperature, [**1**] = 0.15 M, [dibenzenesulfonimide] = 0.10 M, slope = −2.39, *y*-intercept = 0.114, r^2 = 0.945.

Scheme 4. Proposed Mechanism for the N−H Bond Insertion



partially ionized to generate a proton ion and a dibenzenesulfonimide anion (Scheme 4a). The major species in chloroform may still be dibenzenesulfonimide **2a**. So that the reaction mechanism should be similar to that of X−H (X = Cl, F) bonds insertion.[1b] Protonation of the mild nucleophilic diazo carbon leads to a tight ion pair of diazonium ion **A** and dibezenesulfonimide anion **B**. Displacement of nitrogen on **A** by dibezenesulfonimide anion **B** furnishes the final product **3a** (Scheme 4b).[6]

CONCLUSION

In conclusion, we have developed an efficient catalyst-free N−H bonds insertion of α-diazo compounds under mild conditions. This method provides a facile approach for inserting diazo compounds into the N−H bonds of sulfonimides. Mechanistic studies reveal that the N−H insertion undergoes protonation of diazo compounds to generate a procarbonium ion, followed by displacement of dinitrogen by benzenesulfonimide anion via S_N2 type reaction to furnish the final products.

EXPERIMENTAL SECTION

General Information. Unless otherwise indicated, all glassware was dried before use and the experimental reactions were performed under an atmosphere of air. All diazocarbonyls were synthesized according to known procedures reported in the literature.[12b−e] All solvents were distilled from appropriate drying agents prior to use. Reaction progress was monitored by thin layer chromatography (TLC). Visualization was achieved by ultraviolet light at 254 nm or by staining using triketohydrindene hydrate. Flash column chromatography was performed using silica gel 60 (200−300 mesh). Pressed KBr disks for infrared spectra were recorded using a FT-IR spectrometer. Wavelengths (ν) are reported in cm^{-1}. Melting points were recorded using a melting point thermometer. All ^1H NMR and ^{13}C NMR spectra were recorded in $CDCl_3$. Chemical shifts were given in parts per million (ppm, δ) referenced to the peak of tetramethylsilane,

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defined at δ = 0.00 (^{1}H NMR) or the solvent peak of $CDCl_3$ defined at δ = 7.26 (^{1}H NMR); the solvent peak of $CDCl_3$, defined at δ = 77.0 (^{13}C NMR); Coupling constants are quoted in Hz (*J*). ^{1}H NMR spectroscopy splitting patterns are designated as singlet (s), doublet (d), triplet (t), quartet (q). Splitting patterns that could not be interpreted or easily visualized were designated as multiplet (m) or broad (br). High-resolution mass spectra were obtained using a high-resolution ESI-TOF mass spectrometer.

Caution! *Even though we have noted no explosive tendencies of the diazo compounds, it is strongly recommended that they should be handled with great care and proper protection.*

General Procedure for Preparation of Diazoesters. *Method A.* According to a known procedure,[12b,d,e] to the solution of ethyl phenylacetate (5 mmol) and *p*-toluenesulfonylazide (TsN_3) (1.24 g, 6 mmol) in anhydrous CH_3CN or THF (40 mL) was added 1,8-diazabicyclo-[5.4.0]-undec-7-ene (DBU) (1.14 g, 7.5 mmol) slowly at room temperature. Then the reaction mixture was stirred at room temperature for 15 h. After water (40 mL) was added, the resulting mixture was extracted with diethyl ether (3 × 40 mL). The combined organic layer was washed with brine (20 mL) and dried over anhydrous Na_2SO_4. After removing the solvent under reduced pressure, the residual was purified by column chromatography on silica gel to give **1a**−**1r**.

Method B. According to a known procedure,[12c] $Pd(PPh_3)_4$ (144 mg, 5 mol %), NaOH (300.0 mg, 7.5 mmol) were suspended in ethanol (10.0 mL) and stirred for 30 min under argon. Then aryl iodide (2.5 mmol) and ethyl 2-diazo-3-oxobutanoate (468 mg, 3.0 mmol) was added. The resulting solution was stirred at room temperature for 5 h. The mixture was filtered through a short path of silica gel with ethyl acetate as eluent. After removing the solvent under reduced pressure, the residual was purified by column chromatography on silica gel to give the products **1s** and **1t**.

General Procedure for the N−H Insertion of Diazoesters. The mixture of diazoesters **1** (0.3 mmol) and dibenzenesulfonimide (0.6 mmol, 178 mg) in 3 mL of $CHCl_3$ was stirred until disappearing of diazoesters **1** (monitored by TLC). After removing the solvent under reduced pressure, the residual was purified by column chromatography on silica gel to give **3**.

^{1}H and ^{13}C NMR Spectra Data for the Prepared Substrates. *Ethyl 2-diazo-2-phenylacetate (**1a**).* ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48 (d, *J* = 7.6 Hz, 2H), 7.38 (t, *J* = 7.6 Hz, 2H), 7.17 (t, *J* = 7.6 Hz, 1H), 4.34 (q, *J* = 7.1 Hz, 2H), 1.34 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.2, 128.9, 125.7, 125.6, 123.9, 60.9, 14.4.

*Methyl 2-diazo-2-phenylacetate (**1b**).* ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48 (d, *J* = 7.5 Hz, 2H), 7.38 (t, *J* = 7.5 Hz, 2H), 7.18 (t, *J* = 7.5 Hz, 1H), 3.86 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.6, 128.9, 125.8, 125.4, 123.9, 51.9.

*Isobutyl 2-diazo-2-phenylacetate (**1c**).* ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48 (d, *J* = 7.5 Hz, 2H), 7.38 (t, *J* = 7.5 Hz, 2H), 7.17 (t, *J* = 7.5 Hz, 1H), 4.06 (d, *J* = 6.6 Hz, 2H), 2.07−1.94 (m, 1H), 0.97 (d, *J* = 6.6 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.2, 128.9, 125.7, 125.6, 123.9, 70.9, 27.87, 19.0.

*(1S,2R,5S)-2-Isopropyl-5-methylcyclohexyl 2-diazo-2-phenylacetate (**1d**).* ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 (d, *J* = 7.6 Hz, 2H), 7.36 (t, *J* = 7.6 Hz, 2H), 7.15 (t, *J* = 7.6 Hz, 1H), 4.91−4.85 (m,1H), 2.14−2.10 (m, 1H), 1.96−1.88(m, 1H), 1.73−1.67 (m, 2H),1.54−1.48(m, 1H), 1.44−1.41(m, 1H), 1.15−1.02(m, 2H), 0.93−0.90(m, 6H), 0.88−0.84(m, 1H), 0.81 (d, *J* = 7.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.6, 128.8, 125.7, 125.5, 123.8, 74.9, 47.1, 41.3, 34.2, 31.4, 26.5, 23.6, 21.9, 20.6, 16.5.

*Ethyl 2-diazo-2-(4-fluorophenyl)acetate (**1e**).* ^{1}H NMR (400 MHz, $CDCl_3$)δ 7.45−7.41 (m, 2H), 7.09−7.05 (m, 2H), 4.31 (q, *J* = 7.1 Hz, 2H), 1.33 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.1, 160.8 (d, J_{C-F} = 245 Hz), 125.7 (d, J_{C-F} = 7.9 Hz), 121.3 (d, J_{C-F}= 3.2 Hz), 115.8 (d, J_{C-F} = 21.8 Hz), 60.9, 14.3.

*Ethyl 2-(4-chlorophenyl)-2-diazoacetate (**1f**).* ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 (d, *J* = 8.7 Hz, 2H),7.32 (d, *J* = 8.7 Hz, 2H),4.32(q, *J* = 7.1 Hz, 2H),1.33 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.8, 131.3, 129.0, 125.0, 124.2, 61.1, 14.4.

*Ethyl 2-(4-bromophenyl)-2-diazoacetate (**1g**).* ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 (d, *J* = 8.7 Hz, 2H), 7.36 (d, *J* = 8.7 Hz, 2H),4.33(q, *J* = 7.1 Hz, 2H),1.34 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.8, 131.9, 125.3, 124.8, 119.2, 61.1, 14.4.

*Ethyl 2-(3-chlorophenyl)-2-diazoacetate (**1h**).* ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.55 (s, 1H), 7.34−7.27 (m,2H),7.14 (d, *J* = 7.4 Hz, 1H),4.34(q, *J* = 7.1 Hz, 2H),1.34 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.6, 135.0, 130.0, 127.8, 125.6, 123.6, 121.5, 61.2, 14.4.

*Ethyl 2-diazo-2-(3,4-dichlorophenyl)acetate (**1i**).* ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65 (d, *J* = 2.2 Hz, 1H), 7.42 (d, *J* = 8.5 Hz, 1H),7.28 (dd, *J* = 8.5 Hz, *J* = 2.2 Hz, 1H), 4.34 (q, *J* = 7.1 Hz, 2H), 1.34 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.3, 133.1, 130.6, 129.2, 126.1, 125.1, 122.5, 61.3, 14.4.

*Ethyl 2-diazo-2-(4-(tosyloxy)phenyl)acetate (**1j**).* ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.70 (d, *J* = 7.6 Hz, 2H), 7.40 (d, *J* = 8.0 Hz, 2H), δ 7.31 (d, *J* = 7.6 Hz, 2H), 6.98 (d, *J* = 8.0 Hz, 2H), 4.32 (q, *J* = 6.8 Hz, 2H), 2.45 (s, 3H), 1.33 (t, *J* = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.8, 147.2, 145.4, 132.2, 129.8, 128.5, 124.9, 124.7, 122.9, 61.1, 21.7, 14.4.

*Ethyl 2-(4-(benzyloxy)phenyl)-2-diazoacetate (**1k**).* ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42 (d, *J* = 7.0 Hz, 2H), 7.40−7.37 (m, 4H), 7.34−7.30 (m, 1H), 5.06 (s, 2H), 4.31 (q, *J* = 7.1 Hz, 2H), 1.33 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.7, 157.1, 136.8, 128.6, 128.0, 127.4, 125.9, 117.4, 115.6, 70.1, 60.9, 14.5.

*Ethyl 2-diazo-2-(4-methoxyphenyl)acetate (**1l**).* ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37 (d, *J* = 8.9 Hz, 2H), 6.93 (d, *J* = 8.9 Hz, 2H), 4.30 (q, *J* = 7.1 Hz, 2H), 3.78 (s, 3H), 1.32 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.6, 157.9, 125.7, 116.9, 114.4, 60.8, 55.2, 14.4.

*Ethyl 2-diazo-2-(4-(methylthio)phenyl)acetate (**1m**).* ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40 (d, *J* = 8.8 Hz, 2H), 7.27 (d, *J* = 8.8 Hz, 2H), 7.32 (q, *J* = 6.8 Hz, 4H), 2.48 (s, 3H), 1.36 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.2, 135.9, 127.3, 124.4, 122.2, 61.0, 16.0, 14.5.

*Ethyl 2-diazo-2-(3,4-dimethylphenyl)acetate (**1n**).* ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36 (d, *J* = 8.2 Hz, 2H), 7.18 (d, *J* = 8.2 Hz, 2H), 4.31(q, *J* = 7.1 Hz, 2H), 2.33 (s, 3H), 1.33 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.4, 135.5, 129.6, 124.0, 122.2, 60.8, 20.9, 14.4.

*Ethyl 2-diazo-2-(o-tolyl)acetate (**1o**).* ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40−7.38 (m, 1H), 7.26−7.25 (m, 3H), 4.30 (q, *J* = 7.2 Hz, 2H), 2.31 (s, 3H), 1.31 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.1, 137.6, 130.8, 130.8, 128.8, 126.3, 124.2, 61.1, 19.9, 14.5.

*Ethyl 2-diazo-2-(4-methoxyphenyl)acetate (**1p**).* ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.20 (d, *J* = 1.5 Hz, 1H), 6.91−6.85 (m, 2H), 4.32 (q, *J* = 7.1 Hz, 2H), 3.90 (s, 3H), 3.88 (s, 3H), 1.34 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.7, 149.4, 147.2, 117.5, 116.3, 111.6, 108.2, 60.9, 55.9, 55.8, 14.5.

*Ethyl 2-diazo-2-(naphthalen-2-yl)acetate (**1q**).* ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 (s, 1H), 7.85 (d, *J* = 8.5 Hz, 1H), 7.80 (d, *J* = 7.3 Hz, 2H), 7.54 (d, *J* = 8.3 Hz, 1H), 7.50−7.42 (m, 2H), 4.38 (q, *J* = 6.8 Hz, 2H), 1.38 (t, *J* = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.3, 133.6, 131.4, 128.6, 127.6, 127.5, 126.6, 125.7, 122.8, 122.5, 121.9, 61.0, 14.5.

*Vinyl 2-diazo-2-phenylacetate (**1r**).* ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48 (d, *J* = 7.6 Hz, 2H), 7.38 (t, *J* = 8.0 Hz, 2H), 7.18 (t, *J* = 8.0 Hz, 1H), 6.02−5.93 (m, 1H), 5.40 (dd, *J* = 17.2 Hz, *J* = 1.2 Hz, 1H), 5.27 (d, *J* = 10.4 Hz, 1H), 4.76 (d, J = 5.2 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.7, 132.0, 128.8, 125.7, 125.3, 123.9, 118.2, 65.3.

*Vinyl 2-diazo-2-phenylacetate (**1s**).* ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.54−7.52 (m, 4H), 7.47−7.45 (m, 2H), 7.33−7.32 (m, 3H), 4.33 (q, *J* = 7.1 Hz, 2H), 1.34 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.8,132.1, 131.5, 128.3,128.2, 125.7, 123.4, 123.2, 120.3, 89.6, 89.1, 61.1, 14.4.

*Ethyl 2-diazo-2-(4-((((R)-2,5,7,8-tetramethyl-2-((4R,8R)-4,8,12-trimethyltridecyl)chroman-6-yl)oxy)methyl)phenyl)acetate (**1t**).* ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 (s, 4H), 4.66 (s, 2H), 4.32 (q, *J* = 7.2 Hz, 2H), 2.57 (t, *J* = 6.4 Hz, 2H), 2.20 (s, 3H), 2.15 (s, 3H), 2.10 (s,

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3H), 1.85−1.71 (m, 2H), 1.60−1.47 (m, 3H), 1.45−1.38 (m, 3H), 1.35−1.31 (m, 5H), 1.29−1.24 (m, 10H), 1.16−0.97 (m, 6 H), 0.87−0.84 (m, 12H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.2, 148.2, 148.0, 135.7, 128.4, 127.9, 125.9, 125.1, 124.0, 123.0, 117.6, 74.8, 74.3, 61.0, 40.1, 39.5, 37.7−37.4 (m), 32.9−32.8 (m), 31.4, 28.1, 24.9, 24.5, 23.9, 22.8, 21.1, 20.8, 19.8−19.7 (m), 14.6, 13.0, 12.1, 11.9.

^{1}H and ^{13}C NMR Spectra Data for the Prepared Products. *Ethyl 2-phenyl-2-(N-(phenylsulfonyl)phenylsulfonamido)acetate (**3a**).* Compound **3a** was obtained as a white solid in 84% yield, 115.7 mg, R_f = 0.39 (petroleum ether:ethyl acetate = 5:1); mp 137−138 °C; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.66 (t, J = 8.0 Hz, 6H), 7.55 (t, J = 7.2 Hz, 2H), 7.41−7.34 (m, 7H), 6.12 (s, 1H), 4.17−4.09 (m, 1H), 3.90−3.82 (m, 1H), 0.97 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.0, 138.9, 133.6, 133.0, 131.1, 128.6, 128.52, 128.50, 128.1, 64.2, 61.9, 13.6; IR (KBr) 3060, 2950, 1738, 1498, 1354, 1331, 1081, 1017, 777, 751, 546 cm^{-1}; HRMS-(DART) (m/z) (M + H)$^+$ calcd for $C_{22}H_{22}NO_6S_2$, 460.0889, found 460.0882.

*Methyl 2-phenyl-2-(N-(phenylsulfonyl)phenylsulfonamido)-acetate (**3b**).* Compound **3b** was obtained as a white solid in 70% yield, 93 mg, R_f = 0.33 (petroleum ether:ethyl acetate = 10:1); mp 162−163 °C; ^{1}H NMR (400 MHz, $CDCl_3$, 7.26) δ 7.68 (d, J = 8.0 Hz, 4H), 7.61−7.55 (m, 4H), 7.41 (t, J = 7.6 Hz, 4H), 7.38−7.32 (m, 3H), 6.13 (s, 1H), 3.50 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.6, 139.7, 133.6, 132.8, 131.1, 128.7, 128.5, 128.2, 64.2, 52.5; IR (KBr) 3061, 2947, 1738, 1583, 1331, 1284, 1169, 915, 895, 778, 546 cm^{-1}; HRMS-(DART) (m/z) (M + NH_4)$^+$ calcd for $C_{21}H_{23}N_2O_6S_2$, 463.0998, found 463.0992.

*Isobutyl 2-phenyl-2-(N-(phenylsulfonyl)phenylsulfonamido)-acetate (**3c**).* Compound **3c** was obtained as a white solid in 73% yield, 106 mg, R_f = 0.39 (petroleum ether:ethyl acetate = 10:1); mp 101−102 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.67 (d, J = 7.6 Hz, 4H), 7.61 (d, J = 6.8 Hz, 2H), 7.56 (t, J = 7.6 Hz, 2H), 7.42−7.34 (m, 7H), 6.18 (s, 1H), 4.00−3.95 (m, 1H), 3.55−3.50 (m, 1H), 1.65−1.58 (m, 1H), 0.79 (t, J = 7.2 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.3, 139.9, 133.6, 133.1, 131.2, 128.6, 128.5, 128.1, 72.3, 64.5, 27.4, 19.0; IR (KBr) 3064, 2959, 2847, 1738, 1359, 1224, 1050, 683, 581, 544 cm^{-1}; HRMS-(DART) (m/z) (M + NH_4)$^+$ calcd for $C_{24}H_{29}N_2O_6S_2$, 505.1467, found 505.1462.

*(1S,2R,5S)-2-Isopropyl-5-methylcyclohexyl 2-phenyl-2-(N-(phenylsulfonyl)phenylsulfonamido)acetate (**3d**).* Compound **3d** was obtained as a white solid in 76% yield, 129 mg, R_f = 0.41 (petroleum ether:ethyl acetate = 5:1); mp 53−54 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.71−7.62 (m, 6H) 7.55−7.54 (m, 2H), 7.42−7.31 (m, 7H), 6.12 (s, 0.5H), 6.03 (s, 0.5H), 4.74−4.64 (m, 1H), 1.89 (d, J = 9.6 Hz, 1H), 1.60 (t, J = 12 Hz, 1H), 1.38 (br, 1H), 1.03−0.93 (m, 2H), 0.87 (t, J = 6.8 Hz, 4H), 0.78 (m, 4H), 0.69 (dd, J_1 = 22.0 Hz, J = 6.8 Hz, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.73, 166.69, 139.9, 133.5, 133.2, 133.0, 131.4, 131.3, 128.56, 128.52, 128.49, 128.1, 128.0,76.7, 64.6, 64.5, 46.4, 46.0, 40.2, 49.9, 34.0, 31.32, 31.35, 25.5, 25.2, 22.7, 22.5, 22.0, 20.9, 20.7, 15.6, 15.5; IR (KBr) 3064, 2951, 1740, 1583, 1217, 1167, 1080, 1065, 616, 581 cm^{-1}; HRMS-(DART) (m/z) (M + NH_4)$^+$ calcd for $C_{30}H_{39}N_2O_6S_2$, 587.2250, found 587.2244.

*Ethyl 2-(4-fluorophenyl)-2-(N-(phenylsulfonyl)phenylsulfon-amido)acetate (**3e**).* Compound **3e** was obtained as a white solid in 78% yield, 111 mg, R_f = 0.25 (petroleum ether:ethyl acetate = 10:1); mp 120−121 °C; ^{1}H NMR (400 MHz, $CDCl_3$, 7.26) δ 7.71 (d, J = 7.6 Hz, 4H), 7.68−7.65 (m, 2H), 7.58 (t, J = 7.2 Hz, 2H), 7.43 (t, J = 8.0 Hz, 4H), 7.04 (t, J = 8.4 Hz, 2H), 6.07 (s, 1H), 4.17−4.09 (m, 1H), 3.89−3.81 (m, 1H), 0.96 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.9, 162.7 (d, J_{C-F} = 247.7 Hz), 139.7, 133.7, 133.2 (d, J_{C-F} = 8.2 Hz), 129.0 (d, J_{C-F} = 3.4 Hz), 128.6, 128.5, 115.0 (d, J_{C-F} = 21.4 Hz), 63.4, 62.0, 13.5; IR (KBr) 3066, 2996, 2899, 1733, 1381, 1354, 1289, 1224, 1022, 616, 544 cm^{-1}; HRMS-(DART) (m/z) (M + NH_4)$^+$ calcd for $C_{22}H_{24}FN_2O_6S_2$, 495.1060, found 495.1054.

*Ethyl 2-(4-chlorophenyl)-2-(N-(phenylsulfonyl)phenylsulfon-amido)acetate (**3f**).* Compound **3f** was obtained as a white solid in 84% yield, 124 mg, R_f = 0.39 (petroleum ether:ethyl acetate = 5:1); mp 137−138 °C; ^{1}H NMR (400 MHz, $CDCl_3$, 7.26) δ 7.71 (d, J = 8.0 Hz, 4H), 7.61−7.57 (m, 4H), 7.43 (t, J = 8.0 Hz, 4H), 7.31 (d, J = 8.8 Hz, 2H), 6.05 (s, 1H), 4.17−4.09 (m, 1H), 3.89−3.81 (m, 1H), 0.96 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.7, 139.7 134.7, 133.7, 132.5, 131.6, 128.6, 128.5, 128.2, 63.4, 62.1, 13.5; IR (KBr) 3066, 2984, 1488, 1374, 1214, 1169, 1090, 1012, 614, 579, 546 cm^{-1}; HRMS-(DART) (m/z) (M + NH_4)$^+$ calcd for $C_{22}H_{24}ClN_2O_6S_2$, 511.0764, found 511.0759.

*Ethyl 2-(4-bromophenyl)-2-(N-(phenylsulfonyl)phenylsulfon-amido)acetate (**3g**).* Compound **3g** was obtained as a white solid in 83% yield, 134 mg, R_f = 0.34 (petroleum ether:ethyl acetate = 10:1); mp 144−145 °C; ^{1}H NMR (400 MHz, $CDCl_3$, 7.26) δ 7.71 (d, J = 7.6 Hz, 4H), 7.59 (t, J = 7.2 Hz, 2H), 7.53 (d, J = 8.4 Hz, 2H), 7.48−7.42 (m, 6H), 6.03 (s, 1H), 4.17−4.09 (m, 1H), 3.89−3.81 (m, 1H), 0.96 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.7, 139.6, 133.7, 132.8, 132.1, 131.2, 128.6, 128.5, 123.0, 63.4, 62.1, 13.5; IR (KBr) 3064, 2986, 1740, 1586, 1488, 1351, 1209, 1167, 683, 616, 544 cm^{-1}; HRMS-(EI) (m/z) (M + NH_4)$^+$ calcd for $C_{22}H_{24}BrN_2O_6S_2$, 555.0259, found 555.0254.

*Ethyl 2-(3-chlorophenyl)-2-(N-(phenylsulfonyl)phenylsulfon-amido)acetate (**3h**).* Compound **3h** was obtained as a white solid in 64% yield, 95 mg, R_f = 0.29 (petroleum ether:ethyl acetate = 10:1); mp 86−87 °C; ^{1}H NMR (400 MHz, $CDCl_3$, 7.26) δ 7.70 (d, J = 7.6 Hz, 4H), 7.60−7.55 (m, 3H), 7.51 (d, J = 7.6 Hz, 1H), 7.42 (t, J = 8.0 Hz, 4H), 7.32 (d, J = 8.0 Hz, 1H), 7.24−7.22 (m, 1H), 6.01 (s, 1H), 4.15−4.07 (m, 1H), 3.88−3.80 (m, 1H), 0.95 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.6, 139.7, 134.9, 134.0, 133.8, 131.2, 129.4, 129.2, 128.8, 128.63, 128.58, 63.5, 62.2, 13.6; IR (KBr) 3064, 2981, 1738, 1583, 1491, 1356, 1217, 1060, 683, 541 cm^{-1}; HRMS-(DART) (m/z) (M + H)$^+$ calcd for $C_{22}H_{21}ClNO_6S_2$, 494.0499, found 494.0493.

*Ethyl 2-(3,4-dichlorophenyl)-2-(N-(phenylsulfonyl)phenylsulfon-amido)acetate (**3i**).* Compound **3i** was obtained as a white solid in 56% yield, 88 mg, R_f = 0.32 (petroleum ether:ethyl acetate = 5:1); mp 102−103 °C; ^{1}H NMR (400 MHz, $CDCl_3$, 7.26) δ 7.76 (d, J = 7.6 Hz, 4H), 7.72 (d, J = 1.6 Hz, 1H), 7.61 (t, J = 7.6 Hz, 2H), 7.50 (d, J = 1.6 Hz, 1H), 7.45 (t, J = 8.0 Hz, 4H), 7.38 (d, J = 8.4 Hz, 1H), 6.00 (s, 1H), 4.17−4.09 (m, 1H), 3.91−3.83 (m, 1H), 0.97 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.4, 139.5, 133.9, 133.1, 132.99, 132.97, 132.2, 130.3, 130.0, 128.7, 128.5, 62.8, 62.3, 13.5. IR (KBr) 3101, 3063, 2981, 1583, 1464, 1381, 1214, 1167, 681, 576, 549 cm^{-1}; HRMS-(DART) (m/z) (M + NH_4)$^+$ calcd for $C_{22}H_{23}Cl_2N_2O_6S_2$, 545.0375, found 545.0369.

*Ethyl 2-(N-(phenylsulfonyl)phenylsulfonamido)-2-(4-(tosyloxy)-phenyl)acetate (**3j**).* Compound **3j** was obtained as a white solid in 64% yield, 121 mg, R_f = 0.15 (petroleum ether:ethyl acetate = 5:1); mp 99−100 °C; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.78 (d, J = 8.0 Hz, 2H), 7.68−7.58 (m, 8H), 7.46 (t, J = 7.6 Hz, 4H), 7.34 (d, J = 8.0 Hz, 2H), 6.99 (d, J = 8.8 Hz, 2H), 6.02 (s, 1H), 4.15−4.07 (m, 1H), 3.86−3.78 (m, 1H), 2.46 (s, 3H), 0.95 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.8, 149.6, 145.6, 139.6, 133.8, 132.7, 132.2, 129.8, 128.7, 128.5, 128.4, 122.1, 63.3, 62.1, 21.7, 13.5; IR (KBr) 3071, 2986, 1728, 1498, 1376, 1239, 1172, 1092, 1015, 661, 584, 556 cm^{-1}; HRMS-(DART) (m/z) (M + NH_4)$^+$ calcd for $C_{29}H_{31}N_2O_9S_3$, 647.1192, found 647.1186.

*Ethyl 2-(4-(benzyloxy)phenyl)-2-(N-(phenylsulfonyl)phenylsulfon-amido)acetate (**3k**).* Compound **3k** was obtained as a white solid in 83% yield, 141 mg, R_f = 0.26 (petroleum ether:ethyl acetate = 5:1); mp 103−104 °C; ^{1}H NMR (400 MHz, $CDCl_3$, 7.26) δ 7.71 (d, J = 7.2 Hz, 4H), 7.60−7.54 (m, 4H), 7.48 (d, J = 7.2 Hz, 2H), 7.45−7.37 (m, 7H), 6.96 (d, J = 8.4 Hz, 2H), 6.09 (s, 1H), 5.13 (s, 2H), 4.18−4.10 (m, 1H), 3.91−3.83 (m, 1H), 0.98 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.2, 158.8, 139.9, 136.7, 133.5, 132.5, 128.6, 128.5, 128.4, 128.0, 127.3, 125.3, 114.4, 69.9, 63.9, 61.9, 13.5; IR (KBr) 3066, 2925, 2876, 1734, 1069, 1380, 1355, 1220, 1170, 754, 682, 582, 552 cm^{-1}; HRMS-(DART) (m/z) (M + NH_4)$^+$ calcd for $C_{29}H_{31}N_2O_7S_2$, 583.1573, found 583.1567.

*Ethyl 2-(4-methoxyphenyl)-2-(N-(phenylsulfonyl)phenylsulfon-amido)acetate (**3l**).* Compound **3l** was obtained as a white solid in 64% yield, 94 mg, R_f = 0.25 (petroleum ether:ethyl acetate = 5:1); mp 105−106 °C; ^{1}H NMR (400 MHz, $CDCl_3$, 7.26) δ 7.71 (d, J = 7.6 Hz, 4H), 7.58−7.56 (m, 4H), 7.42 (t, J = 7.6 Hz, 4H), 6.87 (d, J = 8.8 Hz,

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2H), 6.07 (s, 1H), 4.17−4.09 (m, 1H), 3.90−3.82 (m, 1H), 3.84 (s, 3H), 0.97 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.3, 159.8, 140.0, 133.5, 132.6, 128.5, 125.1, 113.5, 64.0, 61.9, 55.4, 13.6; IR (KBr) 3064, 2989, 2847, 1730, 1611, 1578, 1376, 1171, 1082, 616, 539 cm^{-1}; HRMS-(DART) (m/z) (M + H)$^+$ calcd for $C_{23}H_{24}NO_7S_2$, 490.0994, found 490.0989.

*Ethyl 2-(4-(methylthio)phenyl)-2-(N-(phenylsulfonyl)phenylsulfonamido)acetate (**3m**).* Compound **3m** was obtained as a white solid in 83% yield, 126 mg, R_f = 0.25 (petroleum ether:ethyl acetate = 5:1); mp 125−126 °C; ^{1}H NMR (400 MHz, $CDCl_3$, 7.26) δ 7.71 (d, J = 7.6 Hz, 4H), 7.59−7.54 (m, 4H), 7.42 (t, J = 8.0 Hz, 4H), 7.20 (d, J = 8.4 Hz, 2H), 6.06 (s, 1H), 4.17−4.09 (m, 1H), 3.91−3.83 (m, 1H), 2.51 (s, 3H), 0.97 (t, J = 7.2 Hz, 3H); ^{13}C NMR(100 MHz, $CDCl_3$) δ 167.0, 139.8, 139.7, 133.6, 131.5, 129.5, 128.53, 128.51, 125.6, 63.9, 62.0, 15.5, 13.6; IR (KBr) 3064, 2991, 2852, 1733, 1583, 1376, 1302, 1167, 1025, 681, 584, 549 cm^{-1}; HRMS-(DART) (m/z) (M + NH_4)$^+$ calcd for $C_{23}H_{27}N_2O_6S_3$, 523.1031, found 523.1026.

*Ethyl 2-(N-(phenylsulfonyl)phenylsulfonamido)-2-(p-tolyl)-acetate (**3n**).* Compound **3n** was obtained as a white solid in 70% yield, 99 mg, R_f = 0.32 (petroleum ether:ethyl acetate = 5:1); mp 120−121 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.69 (d, J = 8.0 Hz, 4H), 7.56 (t, J = 7.6 Hz, 2H), 7.51 (d, J = 8.0 Hz, 2H), 7.41 (t, J = 7.6 Hz, 4H), 7.15 (d, J = 8.0 Hz, 2H), 6.09 (s, 1H), 4.17−4.09 (m, 1H), 3.91−3.83 (m, 1H), 2.39 (s, 3H), 0.99 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.2, 140.0, 138.6, 133.5, 131.1, 130.0, 128.8, 128.54, 128.48, 64.2, 61.9, 21.1, 13.6; IR (KBr) 3074, 2989, 1733, 1513, 1379, 1302, 1169, 1061, 616, 586, 551 cm^{-1}; HRMS-(DART) (m/z) (M + NH_4)$^+$ calcd for $C_{23}H_{27}N_2O_6S_2$, 491.1311, found 491.1305.

*Ethyl 2-(N-(phenylsulfonyl)phenylsulfonamido)-2-(o-tolyl)-acetate (**3o**).* Compound **3o** was obtained as a white solid in 82% yield, 92 mg, R_f = 0.40 (petroleum ether:ethyl acetate = 5:1); mp 131−132 °C; 1H NMR (400 MHz, $CDCl_3$, TMS) δ 7.71 (d, J = 8.0 Hz, 4H), 7.54 (t, J = 7.6 Hz, 2H), 7.38 (t, J = 7.6 Hz, 4H), 7.34−7.32 (m, 1H), 7.22−7.19 (m, 2H), 6.85−6.83 (m, 1H), 6.46 (s, 1H), 4.30−4.22 (m, 1H), 4.09−4.01 (m, 1H), 2.05 (s, 3H), 1.16 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.5, 140.0, 139.3, 133.4, 132.7, 130.3, 129.4, 129.1, 128.5, 128.3, 125.6, 63.4, 62.1, 19.5, 13.9; IR (KBr) 3076, 2989, 1730, 1581, 1496, 1384, 1169, 1082, 1020, 606, 544 cm^{-1}; HRMS-(DART) (m/z) (M + NH_4)$^+$ calcd for $C_{23}H_{27}N_2O_6S_2$, 491.1311, found 491.1305.

*Ethyl 2-(3,4-dimethoxyphenyl)-2-(N-(phenylsulfonyl)phenylsulfonamido)acetate (**3p**).* Compound **3p**was obtained as a white solid in 37% yield, 58 mg, R_f = 0.14 (petroleum ether:ethyl acetate = 5:1); mp 153−154 °C ; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.73 (d, J = 7.6 Hz, 4H), 7.57 (t, J = 7.6 Hz, 2H), 7.43 (t, J = 7.6 Hz, 4H), 7.23 (dd, J_1 = 8.4 Hz, J_2 = 1.6 Hz, 1H), 7.14 (d, J = 1.6 Hz, 1H), 6.84 (d, J = 8.4 Hz, 1H), 6.06 (s, 1H), 4.17−4.09 (m, 1H), 3.92−3.84 (m, 1H), 3.92 (s, 3H), 3.76 (s, 1H), 0.98 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.2, 149.3, 148.4, 140.0, 133.6, 128.5, 125.2, 124.0, 114.2, 110.4, 64.2, 61.9, 56.0, 55.9, 13.6; IR (KBr) 3061, 2959, 2842, 1739, 1445, 1380, 1173, 1143, 683, 599, 552 cm^{-1}; HRMS-(DART) (m/z) (M + NH_4)$^+$ calcd for $C_{24}H_{29}N_2O_8S_2$, 537.1365, found 537.1369.

*Ethyl 2-(naphthalen-2-yl)-2-(N-(phenylsulfonyl)phenylsulfonamido)acetate (**3q**).* Compound **3q** was obtained as a white solid in 90% yield, 137 mg, R_f = 0.18 (petroleum ether:ethyl acetate = 10:1); mp 143−144 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.17 (s, 1H), 7.88−7.79 (m, 3H), 7.74−7.69 (m, 5H), 7.59−7.48 (m, 4H), 7.30 (t, J = 7.6 Hz, 4H), 6.35 (s, 1H), 4.26−4.18 (m, 1H), 4.00−3.92 (m, 1H), 1.04 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.3, 158.9, 140.0, 136.8, 133.5, 132.6, 128.6, 128.5, 128.0, 127.4, 125.3, 114.4, 69.9, 64.0, 61.9, 13.6; IR (KBr) 3061, 2954, 1743, 1381, 1354, 1272, 1125, 1082, 616, 549 cm^{-1}; HRMS-(DART) (m/z) (M + NH_4)$^+$ calcd for $C_{26}H_{27}N_2O_6S_2$, 527.1311, found 527.1305.

*N-(2-Oxo-1-phenylhex-5-en-1-yl)-N-(phenylsulfonyl)benzenesulfonamide (**3r**).* Compound **3r** was obtained as a white solid in 69% yield, 97 mg, R_f = 0.13 (petroleum ether:ethyl acetate = 10:1); mp 122−123 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.67 (d, J = 7.6 Hz, 4H), 7.62 (d, J = 6.8 Hz, 2H), 7.56 (t, J = 7.2 Hz, 2H), 7.42−7.33 (m, 7H), 6.15 (s, 1H), 5.67−5.58 (m, 1H), 5.20−5.13 (m, 2H), 4.60−4.55 (m, 1H), 4.36−4.31 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.9, 139.8, 133.6, 132.9, 131.2, 131.0, 128.7, 128.6, 128.2, 119.1, 66.7, 64.3; IR (KBr) 3064, 2924, 1735, 1496, 1446, 1217, 1167, 1080, 683, 599, 541 cm^{-1}; HRMS-(DART) (m/z) (M + NH_4)$^+$ calcd for $C_{23}H_{25}N_2O_6S_2$, 489.1154, found 489.1149.

*Ethyl 2-(4-(phenylethynyl)phenyl)-2-(N-(phenylsulfonyl)phenylsulfonamido)aceate (**3s**).* Compound **3s** was obtained as a white solid in 62% yield, 104 mg, R_f = 0.29 (petroleum ether:ethyl acetate = 10:1); mp 168−169 °C; ^{1}H NMR (400 MHz, $CDCl_3$, 7.26) δ 7.72 (d, J = 7.6 Hz, 4H), 7.64 (d, J = 8.4 Hz, 2H), 7.59 (t, J = 7.2 Hz, 4H), 7.51 (d, J = 8.4 Hz, 2H), 7.45 (t, J = 8.0 Hz, 4H), 7.38 (d, J = 3.2 Hz, 3H), 6.10 (s, 1H), 4.19−4.11 (m, 1H), 3.91−3.83 (m, 1H), 0.99 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.8, 139.7, 133.7, 133.0, 131.7, 131.2, 131.1, 128.6, 128.56, 128.49, 128.4, 123.8, 123.0, 90.4, 88.8, 63.8, 62.1, 13.6; IR (KBr) 3066, 2924, 1738, 1513, 1446, 1381, 1167, 1027, 683, 616, 549 cm^{-1}; HRMS-(DART) (m/z) (M + NH_4)$^+$ calcd for $C_{30}H_{29}N_2O_6S_2$, 577.1467, found 577.1462.

*Ethyl 2-(N-(phenylsulfonyl)phenylsulfonamido)-2-(4-(((2,5,7,8-tetramethyl-2-(4,8,12trimethyltridecyl)chroman-6-yl)oxy)methyl)-phenyl)acetate (**3t**).* Compound **3t** was obtained as a colorless oil in 76% yield, 205 mg, R_f = 0.31 (petroleum ether:ethyl acetate = 10:1); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.72−7.69 (m, 6H), 7.57 (t, J = 7.6 Hz, 2H), 7.51 (d, J = 8.4 Hz, 2H) 7.43 (t, J = 7.6 Hz, 4H), 6.18 (s, 1H), 4.74 (s, 2H), 4.21−4.13 (m, 1H), 3.95−3.87 (m, 1H), 2.64 (t, J = 6.4 Hz, 2H), 2.28 (s, 3H), 2.24 (s, 3H), 2.15 (s, 3H), 1.90−1.77 (m, 2H), 1.62−1.51 (m, 3H), 1.48−1.42 (m, 3H), 1.35−1.23 (m, 11H), 1.19−1.10 (m, 6H), 1.01 (t, J = 7.2 Hz, 3H), 0.90−0.86 (m, 13H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.1, 148.1, 148.0, 139.9, 138.8, 133.6, 132.4, 131.3, 128.6, 128.6, 127.8, 127.4, 125.8, 123.0, 117.7, 74.8, 74.1, 64.1, 62.0, 40.0, 39.3, 37.6−37.3(m), 37.3, 32.8, 32.7, 31.3, 31.2, 27.9, 24.8, 24.4, 23.9, 22.7, 22.6, 21.0, 20.7, 19.7, 19.7−19.6(m), 13.6, 12.9, 12.0, 11.8; IR (KBr) 2951, 2852, 2363, 1750, 1653, 1538, 1459, 1381, 1274, 1169, 1087, 763, 751, 686, 544, cm^{-1}; HRMS-(DART) (m/z) (M + H)$^+$ calcd for $C_{52}H_{72}NO_8S_2$, 902.4699, found 902.4694.

*Ethyl 2-(4-methyl-N-((4-nitrophenyl)sulfonyl)phenylsulfonamido)-2-phenylacetate (**3ab**).* Compound **3ab** was obtained as a white solid in 81% yield, 126 mg, R_f = 0.26 (petroleum ether:ethyl acetate = 5:1); mp 178−179 °C; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 8.15 (d, J = 8.8 Hz, 2H), 7.71 (d, J = 8.0 Hz, 2H), 7.65−7.61 (m, 4H), 7.44−7.36 (m, 3H), 7.28 (d, J = 8.0 Hz, 2H), 6.15 (s, 1H), 4.20−4.12 (m, 1H), 4.00−3.92 (m, 1H), 2.44 (s, 3H), 1.03 (t, J = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.8, 150.2, 145.6, 145.4, 136.0, 132.8, 131.2, 129.8, 129.4, 129.0, 128.8, 128.3, 123.5, 64.5, 62.2, 21.6, 13.6; IR (KBr) 3101, 3071, 2986, 1743, 1596, 1376, 1222, 1167, 1045, 943, 815, 776, 663, 546 cm^{-1}; HRMS-(DART) (m/z) (M + NH_4)$^+$ calcd for $C_{23}H_{26}N_3O_8S_2$, 536.1161, found 536.1156.

*Ethyl 2-(4-methylphenylsulfonamido)-2-phenylacetate (**4a**).*[17] Compound **4a** was obtained as a white solid in 81% yield, 81 mg, R_f = 0.10 (petroleum ether:ethyl acetate = 5:1); mp 74−75 °C; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.63 (d, J = 8.0 Hz, 2H), 7.25−7.19 (m, 7H), 5.76 (d, J = 8.0 Hz, 1H), 5.04 (d, J = 8.0 Hz, 1H), 4.08−3.93 (m, 2H), 2.38 (s, 3H), 1.09 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.0, 143.5, 136.9, 135.4, 129.4, 128.7, 128.4, 127.2, 127.0, 62.2, 59.3, 21.4, 13.8; IR (KBr) 3263, 3243, 2924, 2849, 1725, 1596, 1339, 1162, 1012, 920, 818, 534, 417 cm^{-1}.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge on the ACS Publications website at DOI: 10.1021/acs.joc.6b00233.

Mechanistic experiments, ^{1}H and ^{13}C NMR spectra for all described compounds. (PDF)

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Notes

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