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Synthesis of Sulfonamide-Based Ynamides and Ynamines in Water

Lei Zhao, Hongyi Yang, Ruikun Li, Ye Tao, Xiao-Feng Guo, Edward A. Anderson, Andrew Whiting, and Na Wu*

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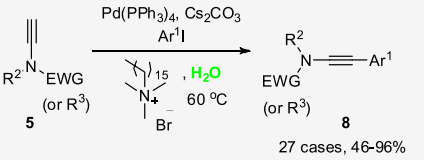
ABSTRACT: Ynamides, though relatively more stable than ynamines, are still moisture-sensitive and prone to hydration especially under acidic and heating conditions. Here we report an environmentally benign, robust protocol to synthesize sulfonamide-based ynamides and arylynamines via Sonogashira coupling reactions in water, using a readily available quaternary ammonium salt as the surfactant.



The "greening" of global chemical processes has become a major concern in the chemical industry.[1] As a nontoxic, inexpensive, benign, and renewable solvent for organic synthesis, water has been of widespread interest in recent years.[2] Ynamides, an attractive class of alkynes activated by the electron-donating ability of an amide nitrogen atom adjacent to an alkyne, are versatile functional groups that find use as fascinating building blocks for the synthesis of nitrogen-containing compounds.[3] However, the preparation of ynamides typically involves dry organic solvents.[4] This is because of ynamides' moisture-sensitivity, which can lead to decomposition and hydration of ynamides upon heating/acid-catalyzed/transition-metal-catalyzed conditions (Figure 1),[5,6]

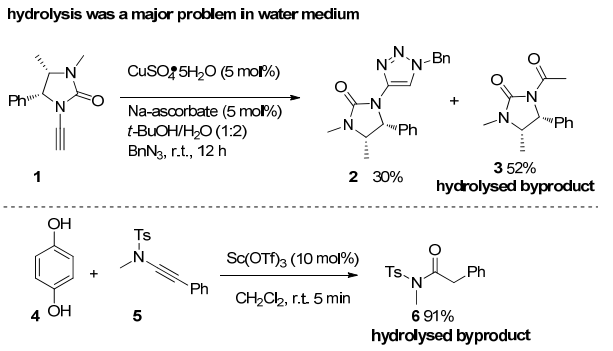


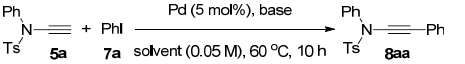
Figure 1. Hydrolysis of ynamides.[5]

as well as because of ynamides' insolubility in water, and as a result, water does not function as an efficient reaction medium. Recently, the development of micellar catalysis and the surfactants is revolutionizing chemical synthesis and catalysis in aqueous media, leading to an important benchtop alternative to the employment of organic solvents.[7a−c] Consequently, the investigation of ynamides' reactions conducted in aqueous media has attracted attention.[7d−f] Herein, with implicit challenge on possible hydration of the starting materials (terminal ynamides) and products (internal ynamides), we report the synthesis of ynamides, and less stable aryl ynamines,[8] which exempts from employing halo-alkynes,[9] via copper-free Sonogashira coupling reactions in water.

To explore the balance of reactivity and stability of ynamides in water, we chose the most stable class of ynamides—sulfonamide-based ynamide **5a**—as a model substrate. To avoid the homocoupling side reaction of terminal ynamides to 1,3-diynediamides instead of cross coupling,[10] we studied copper-free variations of the Sonogashira coupling reaction,[11] using different bases and palladium sources under the standard conditions (Table 1).

Gratifyingly, no diyne was observed under these conditions, although the desired coupling was accompanied by decomposition and/or hydrolysis of **5a**. An initial screen of bases

Table 1. Copper-Free Sonogashira Coupling Conditions[a]



entry	Pd	base (equiv)	solvent	yield[b] (%)
1	$PdCl_2$	Et_3N (2)	THF	12
2	$PdCl_2$	Et_3N (2) Cs_2CO_3 (1)	THF	18
3	$PdCl_2$	Et_3N (2)	H_2O	N.R.[c]
4	$Pd(PPh_3)_4$	Et_3N (2)	THF	30
5	$Pd(PPh_3)_4$	Cs_2CO_3 (2)	THF	93
6	$Pd(PPh_3)_4$	Cs_2CO_3 (2)	H_2O	11
7	$Pd(PPh_3)_4$	Cs_2CO_3 (2)	THF/H_2O (v/v = 1/3)	70

[a]**5a** (0.2 mmol), **7a** (0.2 mmol), Et_3N (0.056 mL) or Cs_2CO_3 (0.13 g), solvent (4 mL), 60 °C, 10 h, N_2. [b]Isolated yield. [c]N.R. = no reaction.

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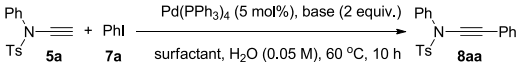
showed that Cs_2CO_3 (as opposed to an organic base) is crucial to achieve high yields in THF (Table 1, entry 5). In entry 6, **5a**'s hydrolyzed byproduct *N*-phenyl-*N*-tosylacetamide was isolated in 43% yield. We hypothesized that the main drawback in the use of water (low solubility, hydrolysis/decomposition of ynamides) could be overcome by using a surfactant, which might solubilize the ynamide or form emulsions.[12] In micellar solution, ynamides could be protected from hydrolysis by location at the hydrophobic core of micelle droplets, thus retarding decomposition in water. With the optimized base in hand (Cs_2CO_3), we therefore investigated ionic liquids and the effects of surfactants/phase transfer agents on Sonogashira coupling reactions to access ynamides **8aa** in water (Table 2).[13]

Table 2. Optimization of Additives for Ynamide Synthesis in Water[a]



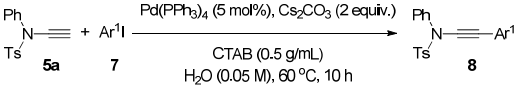
entry	ionic liquid (mL)	base (equiv)	yield[b] (%)
1	[BMIm][BF_4] (0.6)	Cs_2CO_3	14
2	[BMIm][BF_4] (2)	Cs_2CO_3	41
3	[BMIm][BF_4] (neat)[c]	Cs_2CO_3	N.R.[d]
4	[BMIm][PF_6] (0.6)	Cs_2CO_3	38
5	[BMIm][PF_6] (2)	Cs_2CO_3	41
6	[BMIm][PF_6] (neat)[c]	Cs_2CO_3	43
entry	surfactant (g)	base (equiv)	yield[b] (%)
7	SDS (0.02)	Cs_2CO_3	10
8	SDS (1)	Cs_2CO_3	39
9	CTAB (0.02)	Cs_2CO_3	14
10	CTAB (1)	Cs_2CO_3	64
11	CTAB (2)	Cs_2CO_3	84
12	CTAB (4)	Cs_2CO_3	63
13[e]	CTAB (2)	Cs_2CO_3	36
14[f]	CTAB (2)	Cs_2CO_3	49
15[g]	CTAB (2)	Cs_2CO_3	32
16	CTAB (2)	*t*-BuOK	50
17	CTAB (2)	KOH	25
18	CTAB (2)	TBAF·$3H_2O$	31
19	CTAB (2)	CsF	27
20	CTAB (2)	NH_4OAc	22
21	CTAB (2)	$NH_3·H_2O$	16

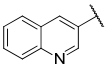
[a]**5a** (0.2 mmol), **7a** (0.2 mmol), Cs_2CO_3 (0.13 g), water (4 mL), 60 °C, 10 h, N_2. [b]Isolated yield. [c]No water was employed. [d]N.R. = no reaction. [e]The reaction was conducted at 40 °C. [f]The reaction was conducted at 80 °C. [g]The reaction was conducted at 100 °C. [BMIm][BF_4] = 1-Butyl-3-methylimidazolium tetrafluoroborate. [BMIm][PF_6] = 1-Butyl-3-methylimidazolium hexafluorophosphate. SDS = Sodium dodecyl sulfate. CTAB = Cetrimonium bromide.

Investigations into the effect of ionic liquids or surfactants revealed that, compared to the previous optimum conditions (Table 1, entry 6), the coupling yield was improved to 84% (Table 2, entry 11). No hydrolysis of either the terminal ynamide or product internal ynamide was observed, with the highest yield obtained using 0.5 g/mL of readily available, cheap cetrimonium bromide (CTAB) in water at 60 °C. Lower temperatures led to reduced yields, and competing hydrolysis of **5a** was observed (e.g., 26% of *N*-phenyl-*N*-tosylacetamide in entry 13), while higher temperatures induced rapid decomposition of **5a** (Table 2, entries 14 and 15). Other inorganic bases were investigated and proved less effective in CTAB-based micellar solution (Table 2, entries 16−21). They were again accompanied by hydrolysis of **5a**.

With optimized conditions in hand, we next investigated the scope of the aryl iodide coupling partner (Table 3). We were

Table 3. Substrate Scope with Respect to Aryl Iodide[a]



entry	Ar^1	**8**	yield(%)[b]
1	*p*-tol	**8ab**	65
2	*p*-OMe-C_6H_4	**8ac**	96
3	*o*-OMe-C_6H_4	**8ad**	82
4	*p*-AcNH-C_6H_4	**8ae**	92
5		**8af**	69
6		**8ag**	69
7		**8ah**	86
8	*p*-F-C_6H_4	**8ai**	72
9	*p*-CF_3-C_6H_4	**8aj**	80
10[c]	*p*-NO_2-C_6H_4	**8ak**	46
11	*m*-NO_2-C_6H_4	**8al**	71
12	1-Np	**8am**	76

[a]**5a** (0.24 mmol), **7** (0.2 mmol). [b]Isolated yield. [c]48 h.

delighted to find that aryl iodides featuring both electron-donating groups (EDG) and electron-withdrawing groups (EWG) were all well accommodated, affording internal ynamides **8aa**−**8al** in good to excellent yields (Table 3, entries 1−11). Noticeably, aryl iodides bearing strong EDGs such as methoxy and acetamide proved to be outstanding substrates, affording electron-rich ynamides which are relatively prone to hydrolysis[5c,14] yet are compatible with the reaction conditions (Table 3, entries 2−4).

Similarly, heterocyclic aryl iodides proved to be highly suitable substrates (Table 3, entries 5−7). The Sonogashira coupling of bicyclic aryl iodides was also successful, with quinolinyl **8ah** (entry 7) and naphthyl **8am** (entry 12) obtained in good yields. The configuration of **8aj** was confirmed by X-ray crystallographic analysis.[15]

Encouraged by these results, we next evaluated the scope of the ynamide substituent (Table 4). Compared with aryl ynamides, alkyl ynamides are more nucleophilic and thus could be more reactive toward hydrolysis in H_2O.[16] To our delight, both acyclic and cyclic alkyl ynamides were compatible with the standard reaction conditions, affording Sonogashira product **8** in good to excellent yields (Table 4, entries 1−9). A range of acyclic ynamides proved effective in the coupling reactions, including those bearing primary and secondary alkyl substituents (Table 4, entries 2−4), whereas tertiary alkyl (*t*-Bu) ynamides gave a complex mixture of products. Interestingly, the high ring strain of cyclic counterparts enabled productive formation of **8fa** and **8ga** in excellent yields as well. We presume that the increased nucleophilicity of the alkyl-substituted ynamide would be beneficial on the coupling and therefore enable effective conversion of starting materials to internal ynamides, as we were gratified to find out that hydrolyzed byproducts have been diminished with few

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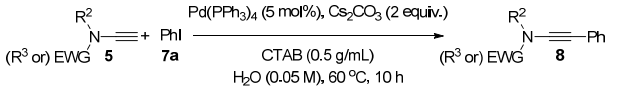
Table 4. Substrate Scope with Respect to Terminal Ynamide[a]



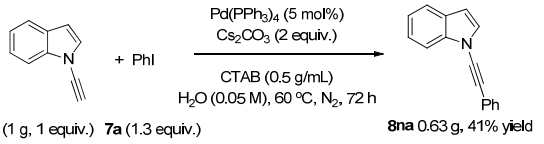
entry	R^2	R^3	product **8**	yield(%)[b]
1[c]	Bn	Ts	**8ba**	56
2[c]	*n*-Bu	Ts	**8ca**	52
3	*i*-Pr	Ts	**8da**	96
4		Ts	**8ea**	89
5		Ts	**8fa**	98
6		Ts	**8ga**	74
7[c]		Ts	**8ha**	56
8[c]		Ts	**8ia**	64
9		Ts	**8ja**	86
10		Ts	**8ka**	93
11	Ph	Ms	**8la**	84
12	Ph	Ns	**8ma**	68
13[c]	**5n**		**8na**	65
14[c]	**5o**		**8oa**	50
	5p[d]		**5q**[e]	**5r**[e]	**5s**[e]	

[a]**5** (0.24 mmol), **7a** (0.2 mmol). [b]Isolated yield. [c]48 h. [d]Hydrolysis. [e]Decomposition. For **5q**, DABCO, Et_3N, and Cs_2CO_3 have all been tested, respectively.

decompositions observed in entries 5, 6, and 9. Even more complex natural product (rosin)-based ynamides could be prepared in outstanding yield (entry 10). Exploration of the ynamide electron-withdrawing group led to further interesting results: Coupling of Ms- and Ns-ynamides was accomplished in good yields (entries 11 and 12), while aryl ynamines, which display higher reactivity and less stability toward hydrolysis,[8,17] accessed internal aryl ynamines in moderate yields (entries 13 and 14). Some limitations were observed when using ester-substituted ynamides (Boc-, oxazolidone-) and other electron-rich aryl ynamines (**5r**, **5s**), none of which provided the desired coupling products.

Ynamine **5n** was applied on a gram scale to test the reproducibility of the reaction (Scheme 1). It resulted in a

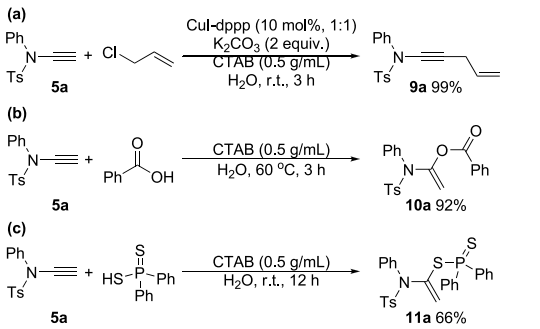
Scheme 1



drop in reaction yield to some extent, by a factor of the viscosity of surfactant which prevents the stirring bar from spinning rapidly and consequently reduces biphase particle collision. Scalability is challenging associated with the scaling-up of the developed protocol.

In order to explore the further development of their application, transformations of ynamide **5a** in H_2O were studied to explore the generality of aqueous synthetic procedures. Copper-catalyzed coupling of **5a** with allyl chloride under mild, aqueous conditions afforded allylic ynamide **9a** in quantitative yield (Scheme 2a). Interestingly, our currently

Scheme 2. Versatile Functionalizations of Ynamide



developed robust, affordable, and procedurally simple aqueous procedure allows for convenient hydroacyloxylation of the ynamide in excellent yield with trace amount of hydration sideproduct *N*-phenyl-*N*-tosylacetamide observed (Scheme 2b), as well as hydro-diithiophosphonylation of ynamide **5a** in moderate yield (Scheme 2c).[18]

An inexpensive, green, and convenient method to access internal ynamides has been developed that overcomes problematic hydrolysis encountered with other ynamide-forming procedures and provides a reliable means to prepare a diverse range of internal ynamides with extensive substituent variation. The strategy can access sulfonamide-based ynamides and aryl ynamines without requiring anhydrous conditions. The mild yet robust reaction conditions and the simple and cheap procedure may allow this synthesis to be extended to chemistry and materials science applications in both academic and industrial research settings.

EXPERIMENTAL SECTION

General Information. Reactions were performed in the presence of nitrogen applying the Schlenk line technique unless otherwise stated. Commercially available reagents were used throughout without further purification other than those detailed below. THF (AR) was distilled over sodium benzophenone ketyl under nitrogen, and H_2O was deionized water purified by a combination of the two methods reverse osmosis and ion-exchange resin. ^1H NMR and ^{13}C NMR spectra were recorded using a Bruker Advance 400 spectrometer operating at 400 MHz for ^1H NMR and at 100 MHz for ^{13}C NMR, using a Bruker Advance 500 spectrometer at 500 MHz for ^1H NMR and at 125 MHz for ^{13}C NMR, or using a Bruker Advance 600 spectrometer at 600 MHz for ^1H NMR and at 150 MHz for ^{13}C

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NMR. $CDCl_3$ and $(CD_3)_2CO$ were used as the solvents for all samples. ^1H NMR chemical shifts are reported using residual proton on non-deuterated solvent ($CDCl_3$: 7.26 ppm), whereas ^{13}C NMR spectra are reported using the carbon signals of the deuterated solvent ($CDCl_3$: 77.16 ppm). Product spots were visualized by UV light at 254 nm and subsequently developed using potassium permanganate solution as appropriate. All chromatography was carried out using silica gel (300−400 mesh) obtained from Qingdao Puke company. The removal of solvent was performed on a rotary evaporator in a vacuum. IR spectra were recorded in the range 4000−400 cm^{-1} on a PerkinElmer Spectrum FT/IR spectrometer using a KBr pellet. Melting points were determined using an electrothermal melting point apparatus, INESA SGWX-4B. High resolution mass spectrometry was carried out on a new ultraflextreme equipped with a TOF/TOF/Ultimate 3000 Nano HPLC. Room temperature range is around 25−34 °C.

Experimental Procedures of Synthesizing Terminal Ynamides. Ynamides **5a**,[19] **5b**,[19] **5c**,[20] **5d**,[21] **5e**,[22] **5j**,[23] and **5n**[24] were prepared as described previously, using procedures based upon the methodology originally described by Anderson and co-workers.[4e]

*Cycloheptyl-N-ethynyl-4-methylbenzenesulfonamide (**5j**).* (Table 4, entry 9) Prepared from (*E*)-*N*-cycloheptyl-*N*-(1,2-dichlorovinyl)-4-methylbenzenesulfonamide (1.11 g, 3.1 mmol); silica gel purification (3.5 cm × 14 cm, ethyl acetate/petroleum ether = 1:50, R_f = 0.51 (EtOAc/PE = 1:5)); yield: 64% (0.578 g, colorless oil); ^1H NMR (500 MHz, $CDCl_3$) δ 7.79 (d, 2H, J = 8.3 Hz), 7.32 (d, 2H, J = 8.0 Hz), 3.88−3.84 (m, 1H), 2.76 (s, 1H), 2.43 (s, 3H), 1.71−1.67 (m, 4H), 1.65−1.59 (m, 2H), 1.56−1.49 (m, 2H), 1.47−1.42 (m, 2H), 1.39−1.33 (m, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ 144.5, 136.0, 129.8, 127.4, 74.3, 61.4, 60.6, 33.3, 27.8, 24.2, 21.7; FT-IR (KBr) $\bar{\nu}$ 2930, 2860, 2131, 1597, 1364, 1168, 971, 814, 662, 592 cm^{-1}; HRMS (ESI$^+$) m/z calcd for $C_{16}H_{21}NNaO_2S^+$ $[M + Na]^+$314.1191 found 314.1188. Its spectroscopic data is consistent with a literature report.[23]

*Ethynyl-N-dehydroabietyl-4-methylbenzenesulfonamide (**5k**).* (Table 4, entry 10) Prepared from (*E*)-*N*-dehydroabietyl-*N*-(1,2-dichlorovinyl)-4-methylbenzenesulfonamide (2.56 g, 4.79 mmol); silica gel purification (3.5 cm × 14 cm, ethyl acetate/petroleum ether = 1:50, R_f = 0.54 (EtOAc/PE = 1:5)); yield: 44% (0.982 g, beige solid); mp 116.2−117.3 °C; ^1H NMR (500 MHz, $CDCl_3$) δ 7.82 (d, 2H, J = 8.3 Hz), 7.36 (d, 2H, J = 8.0 Hz), 7.19 (d, 1H, J = 8.2 Hz), 7.01 (dd, 1H, J_1 = 8.2 Hz, J_2 = 1.7 Hz), 6.89 (s, 1H), 3.22 (d, 2H, J = 2.8 Hz), 2.98−2.93 (m, 1H), 2.89 (d, 1H, J = 5.9 Hz), 2.84 (dt, 1H, J_1 = 13.8 Hz, J_2 = 6.8 Hz), 2.66 (s, 1H), 2.47 (s, 3H), 1.86−1.82 (m, 1H), 1.80−1.66 (m, 6H), 1.60−1.57 (m, 1H), 1.45 (dt, 1H, J_1 = 12.1 Hz, J_2 = 4.5 Hz), 1.26−1.23 (m, 9H), 1.03 (s, 3H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ 147.2, 145.7, 144.8, 134.7, 134.4, 129.8, 128.1, 126.9, 124.1, 123.9, 79.4, 62.6, 58.3, 44.6, 39.0, 38.2, 37.7, 36.5, 33.6, 29.7, 25.8, 24.1, 21.8, 19.2, 18.8, 18.6; FT-IR (KBr) $\bar{\nu}$ 3314, 2956, 2869, 2132, 1368, 1170, 815, 731, 657, 588, 546 cm^{-1}; HRMS (ESI$^+$) m/z calcd for $C_{29}H_{37}NNaO_2S^+$ $[M + Na]^+$ 486.2443 found 486.2447.

Experimental Procedures of Copper-Catalyzed C−N Coupling to Synthesize Terminal Ynamides. Ynamides **5f**,[23] **5i**,[24] **5o**,[23] **5p**,[25] and **5q**[21] were prepared as described previously, using procedures based upon the methodology originally described by Hsung and co-workers.[26]

*N-Cyclopropyl-N-ethynyl-4-methylbenzenesulfonamide (**5f**).* (Table 4, entry 5) Prepared from *N*-cyclopropyl-4-methylbenzenesulfonamide (1.1 g, 5 mmol); silica gel purification (3.5 cm × 14 cm, ethyl acetate/petroleum ether = 1:70, R_f = 0.67 (EtOAc/PE = 1:5)); yield: 64% (0.752 g, orange oil); ^1H NMR (400 MHz, $CDCl_3$) δ 7.73 (d, 2H, J = 8.4 Hz), 7.27 (d, 2H, J = 8.0 Hz), 2.65 (s, 1H), 2.64−2.60 (m, 1H), 2.35 (s, 3H), 0.76−0.70 (m, 2H), 0.69−0.63 (m, 2H); $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$) δ 145.0, 133.7, 129.7, 127.9, 75.5, 58.9, 32.4, 21.6, 6.4; FT-IR (KBr) $\bar{\nu}$ 3319, 2944, 2867, 1464, 1370, 1173, 883, 813, 678, 576 cm^{-1}; HRMS (ESI$^+$) m/z calcd for $C_{12}H_{14}NO_2S^+$ $[M + H]^+$ 236.0745 found 236.0747. Its spectroscopic data is consistent with a literature report.[23]

*N-Cyclobutyl-N-ethynyl-4-methylbenzenesulfonamide (**5g**).* (Table 4, entry 6) Prepared from *N*-cyclobutyl-4-methylbenzenesulfonamide (1.13 g, 5 mmol); silica gel purification (3.5 cm × 14 cm, ethyl acetate/petroleum ether = 1:80, R_f = 0.70 (EtOAc/PE = 1:5)); yield: 69% (0.859 g, yellowish oil); ^1H NMR (600 MHz, $CDCl_3$) δ 7.69 (d, 2H, J = 8.3 Hz), 7.24 (d, 2H, J = 8.0 Hz), 4.26 (quintd, 1H, J_1 = 8.4 Hz, J_2 = 0.6 Hz), 2.80 (s, 1H), 2.34 (s, 3H), 2.11−2.04 (m, 2H), 1.93−1.88 (m, 2H), 1.56−1.46 (m, 2H); $^{13}C\{^1H\}$ NMR (150 MHz, $CDCl_3$) δ 144.7, 134.9, 129.7, 127.4, 73.5, 61.5, 53.0, 28.0, 21.5, 14.3; FT-IR (KBr) $\bar{\nu}$ 3283, 2945, 2865, 2060, 1598, 1361, 1168, 1086, 814, 667, 547 cm^{-1}; HRMS (ESI$^+$) m/z calcd for $C_{13}H_{16}NO_2S^+$ $[M + H]^+$ 250.0902 found 250.0903.

*N-Cyclopentyl-N-ethynyl-4-methylbenzenesulfonamide (**5h**).* (Table 4, entry 7) Prepared from *N*-cyclopentyl-4-methylbenzenesulfonamide (1.19 g, 5 mmol); silica gel purification (3.5 cm × 14 cm, ethyl acetate/petroleum ether = 1:80, R_f = 0.70 (EtOAc/PE = 1:5)); yield: 56% (0.737 g, yellowish oil); ^1H NMR (600 MHz, $CDCl_3$) δ 7.79 (d, 2H, J = 8.2 Hz), 7.33 (d, 2H, J = 8.2 Hz), 4.21 (quint, 1H, J = 7.8 Hz), 2.78 (s, 1H), 2.43 (s, 3H), 1.75−1.70 (m, 2H), 1.66−1.60 (m, 2H), 1.59−1.54 (m, 2H), 1.48−1.43 (m, 2H); $^{13}C\{^1H\}$ NMR (150 MHz, $CDCl_3$) δ 144.7, 135.4, 129.8, 127.6, 73.9, 61.2, 60.6, 29.9, 24.0, 21.7; FT-IR (KBr) $\bar{\nu}$ 3292, 2961, 2871, 2129, 1598, 1362, 1168, 1091, 814, 663, 591, 547 cm^{-1}; HRMS (ESI$^+$) m/z calcd for $C_{14}H_{17}NNaO_2S^+$ $[M + Na]^+$ 286.0878 found 286.0879.

*N-Cyclohexyl-N-ethynyl-4-methylbenzenesulfonamide (**5i**).* (Table 4, entry 8) Prepared from *N*-cyclohexyl-4-methylbenzenesulfonamide (1.27 g, 5 mmol); silica gel purification (3.5 cm × 14 cm, ethyl acetate/petroleum ether = 1:50, R_f = 0.52 (EtOAc/PE = 1:5)); yield: 43% (0.637 g, yellowish oil); ^1H NMR (400 MHz, $CDCl_3$) δ 7.78 (d, 2H, J = 8.2 Hz), 7.29 (d, 2H, J = 8.1 Hz), 3.71−3.65 (m, 1H), 2.76 (s, 1H), 2.40 (s, 3H), 1.78−1.68 (m, 3H), 1.61−1.53 (m, 3H), 1.49−1.43 (m, 2H), 1.28−1.19 (m, 2H); $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$) δ 144.5, 136.2, 129.8, 127.4, 73.8, 60.8, 59.0, 30.8, 25.4, 24.8, 21.6; FT-IR (KBr) $\bar{\nu}$ 3318, 2940, 2865, 2128, 1454, 1363, 1165, 883, 813, 664, 593 cm^{-1}; HRMS (ESI$^+$) m/z calcd for $C_{15}H_{19}NNaO_2S^+$ $[M + Na]^+$ 300.1034 found 300.1037. Its spectroscopic data is consistent with a literature report.[24]

*9-Ethynyl-9H-carbazole (**5o**).* (Table 4, entry 14) Prepared from 9*H*-carbazole (0.334 g, 2 mmol); silica gel purification (2 cm × 14 cm, petroleum ether, R_f = 0.6 (PE)); yield: 49% (0.186 g, colorless oil); ^1H NMR (400 MHz, $CDCl_3$) δ 8.05 (d, 2H, J = 7.8 Hz), 7.71 (d, 2H, J = 8.1 Hz), 7.56 (m, 2H, J_1 = 7.2 Hz, J_2 = 1 Hz), 7.38 (td, 2H, J_1 = 7.3 Hz, J_2 = 0.8 Hz), 3.48 (s, 1H); $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$) δ 140.5, 126.9, 123.6, 122.3, 120.5, 111.4, 72.9, 62.8; FT-IR (KBr) $\bar{\nu}$ 3304, 2924, 2149, 1480, 1450, 1345, 1225, 747, 573 cm^{-1}; HRMS (ESI$^+$) m/z calcd for $C_{14}H_{10}N^+$ $[M + H]^+$ 192.0813 found 192.0799. Its spectroscopic data is consistent with a literature report.[23]

General Procedure of Witulski Rearragement Using Iodoalkynyl Salt to Synthesize Terminal Ynamides. Ynamides **5l**,[21] **5m**,[27] **5r**,[28] and **5s**[29] were prepared as described previously, using procedures based upon the methodology originally described by Witulski and co-workers.[30]

*N-Ethynyl-N-phenylmethanesulfonamide (**5l**).* (Table 4, entry 11) Prepared from *N*-phenylmethanesulfonamide (1.1 g, 4 mmol); silica gel purification (3.5 cm × 14 cm, ethyl acetate/petroleum ether = 1:50, R_f = 0.5 (EtOAc/PE = 1:5)); yield: 30% (0.234 g, yellowish prisms); mp 78.5−79.3 °C; ^1H NMR (500 MHz, $CDCl_3$) δ 7.53−7.51 (m, 2H), 7.44 (tt, 2H, J_1 = 7.4 Hz, J_2 = 1.6 Hz), 7.37 (tt, 1H, J_1 = 7.3 Hz, J_2 = 1.2 Hz), 3.12 (s, 3H), 2.97 (s, 1H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ 138.1, 129.6, 128.7, 125.7, 75.9, 59.8, 36.8; FT-IR (KBr) $\bar{\nu}$ 2922, 2150, 1490, 1360, 1166, 963, 767, 695, 515; HRMS (ESI$^+$) m/z calcd for $C_9H_{10}NO_2S^+$ $[M + H]^+$ 196.0432 found 196.0433. Its spectroscopic data is consistent with a literature report.[21]

*N-Ethynyl-para-nitro-N-phenylbenzenesulfonamide (**5m**).* (Table 4, entry 12) Prepared from 4-nitro-*N*-phenylbenzenesulfonamide (1.0 g, 3.6 mmol); silica gel purification (3.5 cm × 14 cm, ethyl acetate/petroleum ether = 1:50, R_f = 0.5 (EtOAc/PE = 1:5)); yield: 21% (0.285 g, yellowish solid); mp 139.8−140.8 °C; ^1H NMR (500 MHz, $CDCl_3$) δ 8.35 (dt, 2H, J_1 = 9.0 Hz, J_2 = 2.4 Hz), 7.89 (dt, 2H, J_1 = 9.0 Hz, J_2 = 2.4 Hz), 7.38−7.35 (m, 3H), 7.25−7.23 (m, 2H),

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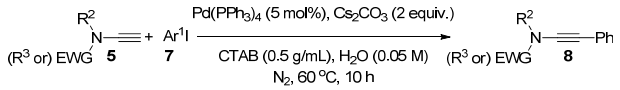
2.90 (s, 1H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ 151.0, 141.1, 137.6, 129.6, 129.2, 126.2, 124.3, 75.6, 59.9 (one carbon signal is missing due to the overlapping); FT-IR (KBr) $\bar{\nu}$ 2927, 2856, 2242, 1698, 1534, 1349, 1182, 1088, 803, 692, 607, 577 cm^{-1}; HRMS (ESI^+) m/z calcd for $C_{14}H_{11}N_2O_4S^+$ $[M + H]^+$ 303.0434 found 303.0428. Its spectroscopic data is consistent with a literature report.[27]

*1-Ethynyl-1H-benzoimidazole (**5r**).* Prepared from benzimidazole (1.07 g, 9.1 mmol); silica gel purification (3.5 cm × 14 cm, ethyl acetate/petroleum ether = 1:20, R_f = 0.4 (EtOAc/PE = 1:5)); yield: 11% (0.142 g, white crystalline solid); ^1H NMR (400 MHz, $CDCl_3$) δ 8.08 (s, 1H), 7.81 (d, 1H, J = 7.4 Hz), 7.58 (dd, 1H, J_1 = 7.8 Hz, J_2 = 0.6 Hz), 7.40 (td, 1H, J_1 = 7.4 Hz, J_2 = 1.0 Hz), 7.35 (td, 1H, J_1 = 7.4 Hz, J_2 = 1.1 Hz), 3.30 (s, 1H); $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$) δ 143.7, 141.9, 134.4, 125.0, 124.2, 120.9, 111.0, 70.3, 62.2. Its spectroscopic data is consistent with a literature report.[28]

*1-Ethynyl-1H-benzotriazole (**5s**).* Prepared from benzotriazole (0.74 g, 6.25 mmol); silica gel purification (3.5 cm × 14 cm, ethyl acetate/petroleum ether = 1:20, R_f = 0.4 (EtOAc/PE = 1:5)); yield: 16% (0.143 g, yellow prisms); mp 71.0–72.0 °C; ^1H NMR (500 MHz, $CDCl_3$) δ 8.11 (d, 1H, J = 8.4 Hz), 7.67 (d, 1H, J = 8.3 Hz), 7.63 (td, 1H, J_1 = 6.9 Hz, J_2 = 0.6 Hz), 7.46 (td, 1H, J_1 = 7.1 Hz, J_2 = 0.9 Hz), 3.84 (s, 1H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ 143.8, 134.4, 129.7, 125.5, 120.7, 110.0, 69.6, 68.7. Its spectroscopic data is consistent with a literature report.[29]

General Procedure of Sonogashira Coupling to Access Internal Ynamides/Ynamines in Water.



To a solution of ynamide/ynamine **5** (0.24 mmol) and aryl iodide **7** (0.2 mmol) in water (4 mL) in a 10 mL Schlenk tube was charged $Pd(PPh_3)_4$ (12 mg), Cs_2CO_3 (0.13 g), and cetrimonium bromide (2 g). After being stirred at 60 °C under nitrogen protection overnight using a heating mantle, the reaction mixture was extracted with EtOAc (3 × 20 mL). The combined organic layer was washed with brine, dried over $MgSO_4$, and concentrated in *vacuo*. The residue was purified by column chromatography on silica gel to afford internal ynamide/ynamine **8**.

Note: Some ynamides/ynamines are relatively less stable and hydrolyze in both $CDCl_3$ and d_6-acetone. The effective component of ynamide/ynamine **5** is 1 equiv, as they hydrolyzed partially (~10%) before the reaction was set up.

*Methyl-N-phenyl-N-(phenylethynyl)benzenesulfonamide (**8aa**).* Prepared from ynamide **5a** (65.1 mg, 0.24 mmol) and **7a** (22 μL, 0.2 mmol); silica gel purification (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:50, R_f = 0.54 (EtOAc/PE = 1:5)); yield: 84% (0.0583 g, white solid); mp 130.1–131.1 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 7.53 (d, 2H, J = 8.3 Hz), 7.30–7.26 (m, 2H), 7.25–7.20 (m, 5H), 7.20–7.16 (m, 5H), 2.32 (s, 3H); $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$) δ 145.1, 139.0, 133.0, 131.5, 129.6, 129.2, 128.38, 128.36, 128.1, 126.3, 122.7, 83.1, 70.6, 21.8 (one carbon signal is missing due to the overlapping); FT-IR (KBr) $\bar{\nu}$ 3298, 2961, 2240, 2130, 2926, 1595, 1490, 1374, 1176, 1090, 813, 691, 583, 549 cm^{-1}; HRMS (ESI^+) m/z calcd for $C_{21}H_{17}NNaO_2S^+$ $[M + Na]^+$ 370.0878 found 370.0876.

*Methyl-N-phenyl-N-(p-tolylethynyl)benzenesulfonamide (**8ab**).* (Table 3, entry 1) Prepared from ynamide **5a** (65.1 mg, 0.24 mmol) and **7b** (0.0436 g, 0.2 mmol); silica gel purification (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:50, R_f = 0.60 (EtOAc/PE = 1:5)); yield: 65% (0.0473 g, yellowish acicular solid); mp 105.1–106.2 °C; ^1H NMR (500 MHz, $CDCl_3$) δ 7.63 (d, 2H, J = 8.2 Hz), 7.35–7.32 (m, 5H), 7.31–7.29 (m, 4H), 7.12 (d, 2H, J = 7.9 Hz), 2.45 (s, 3H), 2.35 (s, 3H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ 145.0, 139.2, 138.3, 133.1, 131.6, 129.6, 129.17, 129.16, 128.4, 128.3, 126.4, 119.6, 82.4, 70.7, 21.8, 21.6; FT-IR (KBr) $\bar{\nu}$ 2926, 2856, 2239, 1595, 1489, 1454, 1374, 1174, 1089, 814, 692, 665, 580 cm^{-1}; HRMS (ESI^+) m/z calcd for $C_{22}H_{19}NNaO_2S^+$ $[M + Na]^+$ 384.1034 found 384.1039.

*N-((4-Methoxyphenyl)ethynyl)-4-methyl-N-phenylbenzenesulfonamide (**8ac**).* (Table 3, entry 2) Prepared from ynamide **5a** (65.1 mg, 0.24 mmol) and **7c** (0.0468 g, 0.2 mmol); silica gel purification (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:50, then 1:30, R_f = 0.4 (EtOAc/PE = 1:5)); yield: 96% (0.0725 g, yellowish acicular solid); mp 106.9–107.9 °C; ^1H NMR (500 MHz, d_6-acetone) δ 7.64 (d, 2H, J = 8.3 Hz), 7.46 (d, 2H, J = 8 Hz), 7.44–7.40 (m, 2H), 7.40–7.36 (m, 3H), 7.34–7.33 (m, 2H), 6.93 (dt, 2H, J_1= 8.9 Hz, J_2 = 2.1 Hz), 3.81 (s, 3H), 2.45 (s, 3H); $^{13}C\{^1H\}$ NMR (125 MHz, d_6-acetone) δ 160.9, 146.3, 140.1, 134.1, 134.0, 130.6, 130.1, 129.1, 129.0, 126.8, 115.05, 115.03, 82.4, 71.0, 55.7, 21.5; FT-IR (KBr) $\bar{\nu}$ 2926, 2855, 2237, 1708, 1596, 1488, 1370, 1172, 1088, 814, 694, 565 cm^{-1}; HRMS (ESI^+) m/z calcd for $C_{22}H_{20}NO_3S^+$ $[M + H]^+$ 378.1164 found 378.1167.

*N-((2-Methoxyphenyl)ethynyl)-4-methyl-N-phenylbenzenesulfonamide (**8ad**).* (Table 3, entry 3) Prepared from ynamide **5a** (65.1 mg, 0.24 mmol) and **7d** (26 μL, 0.2 mmol); silica gel purification (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:50, then 1:30, R_f = 0.4 (EtOAc/PE = 1:5)); yield: 82% (0.0617 g, yellowish oil); ^1H NMR (500 MHz, d_6-acetone) δ 7.71 (dt, 2H, J_1= 10.5 Hz, J_2 = 2.2 Hz), 7.46 (d, 2H, J = 10.2 Hz), 7.44–7.40 (m, 2H), 7.39–7.34 (m, 4H), 7.34–7.31 (m, 1H), 7.03 (d, 1H, J = 8.2 Hz), 6.93 (td, 1H, J_1= 9.5 Hz, J_2 = 1.2 Hz), 3.89 (s, 3H), 2.45 (s, 3H); $^{13}C\{^1H\}$ NMR (125 MHz, d_6-acetone) δ 161.2, 146.3, 134.0, 133.8, 133.7, 130.6, 130.5, 130.0, 129.13, 129.06, 126.7, 121.2, 112.5, 111.9, 87.4, 67.8, 56.1, 21.5; FT-IR (KBr) $\bar{\nu}$ 2925, 2854, 2239, 1713, 1596, 1492, 1463, 1371, 1248, 1173, 1089, 1025, 813, 753, 693, 577, 546 cm^{-1}; HRMS (ESI^+) m/z calcd for $C_{22}H_{20}NO_3S^+$ $[M + H]^+$ 378.1164 found 378.1165.

*N-(4-((4-Methyl-N-phenylphenylsulfonamido)ethynyl)phenyl)-acetamide (**8ae**).* (Table 3, entry 4) Prepared from ynamide **5a** (65.1 mg, 0.24 mmol) and **7e** (0.0522 g, 0.2 mmol); silica gel purification (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:2, R_f = 0.5 (EtOAc/PE = 1:1)); yield: 92% (0.0748 g, orange acicular solid); mp 136.2–137.5 °C; ^1H NMR (500 MHz, $CDCl_3$) δ 7.68 (brs, 1H), 7.61 (d, 2H, J = 8.3 Hz), 7.49 (d, 2H, J = 8.5 Hz), 7.36–7.33 (m, 3H), 7.32–7.27 (m, 6H), 2.45 (s, 3H), 2.16 (s, 3H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ 168.7, 145.2, 139.0, 138.1, 133.0, 132.6, 129.7, 129.2, 128.40, 128.38, 126.4, 119.6, 118.0, 82.5, 70.4, 24.7, 21.8; FT-IR (KBr) $\bar{\nu}$ 2926, 2855, 2222, 1673, 1596, 1524, 1490, 1369, 1316, 1165, 1090, 814, 695, 666, 579 cm^{-1}; HRMS (ESI^+) m/z calcd for $C_{23}H_{20}N_2NaO_3S^+$ $[M + Na]^+$427.1092 found 427.1090.

*4-Methyl-N-phenyl-N-(pyridin-3-ylethynyl)benzenesulfonamide (**8af**).* (Table 3, entry 5) Prepared from ynamide **5a** (65.1 mg, 0.24 mmol) and **7f** (26 μL, 0.2 mmol); silica gel purification (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:30, then 1:10, R_f = 0.3 (EtOAc/PE = 1:5)); yield: 69% (0.0484 g, orange solid); mp 116.5–117.7 °C; ^1H NMR (500 MHz, $CDCl_3$) δ 8.60 (d, 1H, J = 1.4 Hz), 8.50 (dd, 1H, J_1 = 4.7 Hz, J_2 = 1.1 Hz), 7.67 (dt, 1H, J_1 = 7.9 Hz, J_2 = 1.6 Hz), 7.62 (d, 2H, J = 8.2 Hz), 7.38–7.34 (m, 3H), 7.31–7.30 (m, 4H), 7.23 (dd, 1H, J_1 = 7.8 Hz, J_2 = 5.0 Hz), 2.45 (s, 3H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ 152.1, 148.4, 145.4, 138.6, 138.4, 133.0, 129.7, 129.3, 128.6, 128.3, 126.5, 123.1, 120.1, 86.2, 67.5, 21.8; FT-IR (KBr) $\bar{\nu}$ 2959, 2926, 2854, 2238, 1594, 1491, 1456, 1376, 1261, 1169, 1086, 1022, 801, 686, 654, 583, 562, 544 cm^{-1}; HRMS (ESI^+) m/z calcd for $C_{20}H_{16}N_2NaO_2S^+$ $[M + Na]^+$ 371.0830 found 371.0835.

*4-Methyl-N-phenyl-N-(thiophen-3-ylethynyl)-benzenesulfonamide (**8ag**).* (Table 3, entry 6) Prepared from ynamide **5a** (65.1 mg, 0.24 mmol) and **7g** (20 μL, 0.2 mmol); silica gel purification (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:50, R_f = 0.5 (EtOAc/PE = 1:5)); yield: 69% (0.0491 g, yellowish acicular solid); mp 132.6–133.8 °C; ^1H NMR (500 MHz, $CDCl_3$) δ 7.63 (d, 2H, J = 8.2 Hz), 7.40 (d, 1H, J = 2.8 Hz), 7.33–7.30 (m, 6H), 7.29–7.25 (m, 2H), 7.08 (d, 1H, J = 4.9 Hz), 2.46 (s, 3 H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ 145.1, 139.1, 133.3, 130.3, 129.6, 129.2, 129.0, 128.45, 128.37, 126.4, 125.4, 121.5, 82.5, 65.8, 21.9; FT-IR (KBr) $\bar{\nu}$ 2924, 2857, 2237, 1595, 1491, 1370, 1294, 1167, 1088, 866, 782, 690,

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657, 584, 565, 542 cm^{-1}; HRMS (ESI^+) m/z calcd for $C_{19}H_{15}NNaO_2S_2^+$ $[M + Na]^+$ 376.0442 found 376.0439.

*4-Methyl-N-phenyl-N-(quinolin-3-ylethynyl)benzenesulfonamide (**8ah**).* (Table 3, entry 7) Prepared from ynamide **5a** (65.1 mg, 0.24 mmol) and **7h** (0.052 g, 0.2 mmol); silica gel purification (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:15, R_f = 0.3 (EtOAc/PE = 1:5)); yield: 86% (0.0683 g, yellowish oil); ^1H NMR (500 MHz, $CDCl_3$) δ 8.84 (d, 1H, J = 2.1 Hz), 8.16 (d, 1H, J = 1.8 Hz), 8.07 (d, 1H, J = 8.4 Hz), 7.74 (d, 1H, J = 8.2 Hz), 7.69 (td, 1H, J_1 = 6.9 Hz, J_2 = 1.4 Hz), 7.66 (d, 2H, J = 8.4 Hz), 7.54 (td, 1H, J_1 = 7.0 Hz, J_2 = 1.0 Hz), 7.40−7.34 (m, 5H), 7.31 (d, 2H, J = 8.1 Hz), 2.44 (s, 3H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ 152.0, 146.7, 145.4, 138.7, 138.0, 133.0, 130.0, 129.7, 129.4, 129.3, 128.6, 128.4, 127.6, 127.4, 127.3, 126.4, 117.0, 86.1, 68.2, 21.8; FT-IR (KBr) $\bar{\nu}$ 3065, 2929, 2856, 2235, 1596, 1490, 1376, 1305, 1175, 1163, 1091, 917, 813, 754, 692, 666, 580, 546 cm^{-1}; HRMS (ESI^+) m/z calcd for $C_{24}H_{18}N_2NaO_2S^+$ $[M + Na]^+$ 421.0987 found 421.0989.

*N-((4-Fluorophenyl)ethynyl)-4-methyl-N-phenylbenzenesulfonamide (**8ai**).* (Table 3, entry 8) Prepared from ynamide **5a** (65.1 mg, 0.24 mmol) and **7i** (23 μL, 0.2 mmol); silica gel purification (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:50, R_f = 0.61 (EtOAc/PE = 1:5)); yield: 72% (0.0526 g, yellowish acicular solid); mp 82.1−83.0 °C; ^1H NMR (500 MHz, d_6-acetone) δ 7.66 (dt, 2H, J_1 = 8.4 Hz, J_2 = 1.8 Hz), 7.50−7.45 (m, 4H), 7.45−7.40 (m, 3H), 7.35−7.33 (m, 2H), 7.15 (tt, 2H, J_1 = 8.9 Hz, J_2 = 2.2 Hz), 2.45 (s, 3H); $^{13}C\{^1H\}$ NMR (125 MHz, d_6-acetone) δ 163.3 (d, $^1J_{C-F}$ = 246.2 Hz), 146.5, 139.8, 134.5 (d, $^3J_{C-F}$ = 8.4 Hz), 133.9, 130.7, 130.2, 129.3, 129.1, 126.9, 119.6 (d, $^4J_{C-F}$ = 3.4 Hz), 116.5 (d, $^2J_{C-F}$ = 22 Hz), 83.6, 70.1, 21.5; FT-IR (KBr) $\bar{\nu}$ 2926, 2855, 2242, 1598, 1508, 1374, 1175, 836, 691, 580 cm^{-1}; HRMS (ESI^+) m/z calcd for $C_{21}H_{16}FNNaO_2S^+$ $[M + Na]^+$ 388.0783 found 388.0782.

*4-Methyl-N-phenyl-N-((4-(trifluoromethyl)phenyl)ethynyl)-benzenesulfonamide (**8aj**).* (Table 3, entry 9) Prepared from ynamide **5a** (65.1 mg, 0.24 mmol) and **7j** (29 μL, 0.2 mmol); silica gel purification (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:50, R_f = 0.61 (EtOAc/PE = 1:5)); yield: 80% (0.0654 g, white prisms); mp 151.8−152.6 °C; ^1H NMR (500 MHz, $CDCl_3$) δ 7.63 (d, 2H, J = 8.2 Hz), 7.56 (d, 2H, J = 8.3 Hz), 7.48 (d, 2H, J = 8.2 Hz), 7.38−7.36 (m, 3H), 7.33−7.30 (m, 4H), 2.45 (s, 3H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ 145.4, 138.7, 133.1, 131.3, 129.8, 129.4, 128.8 (q, J = 97 Hz), 128.7, 128.4, 126.8, 126.5, 125.3 (q, J = 3.8 Hz), 124.2 (q, J = 270.4 Hz), 85.7, 69.8, 21.8; FT-IR (KBr) $\bar{\nu}$ 2925, 2854, 2237, 1594, 1490, 1376, 1323, 1174, 841, 656, 574 cm^{-1}; HRMS (ESI^+) m/z calcd for $C_{22}H_{16}F_3NNaO_2S^+$ $[M + Na]^+$ 438.0752 found 438.0756.

*4-Methyl-N-((4-nitrophenyl)ethynyl)-N-phenylbenzenesulfonamide (**8ak**).* (Table 3, entry 10) Prepared from ynamide **5a** (65.1 mg, 0.24 mmol) and **7k** (0.0498 g, 0.2 mmol); silica gel purification (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:50, R_f = 0.61 (EtOAc/PE = 1:5)); yield: 46% (0.0361 g, yellowish powder); mp 118.9−120.1 °C; ^1H NMR (500 MHz, d_6-acetone) δ 8.23 (dt, 2H, J_1 = 9.0 Hz, J_2 = 2.4 Hz), 7.70 (dt, 2H, J_1 = 8.4 Hz, J_2 = 1.8 Hz), 7.66 (dt, 2H, J_1 = 9.0 Hz, J_2 = 2.3 Hz), 7.49−7.46 (m, 2H), 7.47−7.44 (m, 3H), 7.37−7.35 (m, 2H), 2.45 (s, 3H); $^{13}C\{^1H\}$ NMR (125 MHz, d_6-acetone) δ 147.6, 146.9, 139.2, 133.8, 132.2, 130.8, 130.6, 130.4, 129.7, 129.1, 127.0, 124.6, 89.3, 70.7, 21.6; FT-IR (KBr) $\bar{\nu}$ 2925, 2854, 1598, 1522, 1488, 1346, 1168, 1087, 854, 694, 562 cm^{-1}; HRMS (ESI^+) m/z calcd for $C_{21}H_{16}N_2NaO_4S^+$ $[M + Na]^+$ 415.0728 found 415.0732.

*4-Methyl-N-((3-nitrophenyl)ethynyl)-N-phenylbenzenesulfonamide (**8al**).* (Table 3, entry 11) Prepared from ynamide **5a** (65.1 mg, 0.24 mmol) and **7l** (0.0498 g, 0.2 mmol); silica gel purification (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:50, then 1:30, R_f = 0.4 (EtOAc/PE = 1:5)); yield: 71% (0.056 g, yellowish oil); ^1H NMR (500 MHz, $CDCl_3$) δ 8.18 (s, 1H), 8.13−8.11 (m, 1H), 7.69 (d, 1H, J = 7.7 Hz), 7.63 (d, 2H, J = 8.3 Hz), 7.49 (t, 1H, J = 8 Hz), 7.39−7.37 (m, 3H), 7.34−7.30 (m, 4H), 2.46 (s, 3H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ 148.2, 145.6, 138.5, 136.9, 133.0, 129.8, 129.46, 129.43, 128.8, 128.3, 126.5, 125.9, 124.8, 122.6, 85.7, 68.8, 21.8; FT-IR (KBr) $\bar{\nu}$ 2925, 2854, 2239, 1530, 1351, 1170, 794, 691, 584 cm^{-1}; HRMS (ESI^+) m/z calcd for $C_{21}H_{16}N_2NaO_4S^+$ $[M + Na]^+$ 415.0728 found 415.0733.

*4-Methyl-N-(naphthalen-1-ylethynyl)-N-phenylbenzenesulfonamide (**8am**).* (Table 3, entry 12) Prepared from ynamide **5a** (65.1 mg, 0.24 mmol) and **7m** (29 μL, 0.2 mmol); silica gel purification (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:50, R_f = 0.5 (EtOAc/PE = 1:5)); yield: 76% (0.061 g, yellowish oil); ^1H NMR (500 MHz, d_6-acetone) δ 8.25 (d, 1H, J = 8.1 Hz), 7.96 (d, 1H, J = 8.0 Hz), 7.92 (d, 1H, J = 8.3 Hz), 7.71 (d, 2H, J = 8.2 Hz), 7.65 (d, 1H, J = 7.1 Hz), 7.62 (td, 1H, J_1 = 7.0 Hz, J_2 = 1.3 Hz), 7.58 (td, 1H, J_1 = 6.8 Hz, J_2 = 1.2 Hz), 7.50−7.41 (m, 8H), 2.45 (s, 3H); $^{13}C\{^1H\}$ NMR (125 MHz, d_6-acetone) δ 146.6, 139.9, 134.3, 134.02, 134.00, 133.96, 130.8, 130.6, 130.3, 129.41, 129.37, 129.3, 129.1, 127.8, 127.5, 126.9, 126.6, 126.3, 120.9, 88.6, 69.5, 21.6; FT-IR (KBr) $\bar{\nu}$ 3060, 2926, 2852, 2232, 1594, 1489, 1373, 1174, 1122, 1090, 800, 773, 691, 586, 571, 548 cm^{-1}; HRMS (ESI^+) m/z calcd for $C_{25}H_{20}NO_2S^+$ $[M + H]^+$ 398.1209 found 398.1200.

*N-Benzyl-4-methyl-N-(phenylethynyl)benzenesulfonamide (**8ba**).* (Table 4, entry 1) Prepared from ynamide **5b** (0.0684 g, 0.24 mmol) and PhI (22 μL, 0.2 mmol); silica gel purification (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:50, R_f = 0.6 (EtOAc/PE = 1:5)); yield: 56% (0.040 g, yellowish acicular crystal); mp 122.8−124.0 °C; ^1H NMR (400 MHz, d_6-acetone) δ 7.91 (d, 2H, J = 8.3 Hz), 7.48 (d, 2H, J = 7.9 Hz), 7.42−7.38 (m, 2H), 7.38−7.34 (m, 2H), 7.34−7.24 (m, 6H), 4.64 (s, 2H), 2.45 (s, 3H); $^{13}C\{^1H\}$ NMR (100 MHz, d_6-acetone) δ 145.9, 135.8, 135.6, 131.6, 130.8, 129.7, 129.3, 129.2, 129.1, 128.5, 123.6, 83.8, 71.8, 56.3, 21.5 (one carbon signal is missing due to the overlapping); FT-IR (KBr) $\bar{\nu}$ 2930, 2856, 1699, 1597, 1496, 1455, 1357, 1166, 974, 814, 699, 578, 547 cm^{-1}; HRMS (ESI^+) m/z calcd for $C_{22}H_{20}NO_2S^+$ $[M + H]^+$ 362.1209 found 362.1179.

*N-Butyl-4-methyl-N-(phenylethynyl)benzenesulfonamide (**8ca**).* (Table 4, entry 2) Prepared from ynamide **5c** (0.0603 g, 0.24 mmol) and PhI (22 μL, 0.2 mmol); silica gel purification (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:50, R_f = 0.54 (EtOAc/PE = 1:5)); yield: 52% (0.034 g, orange oil); ^1H NMR (500 MHz, $CDCl_3$) δ 7.85 (d, 2H, J = 8.3 Hz), 7.38−7.35 (m, 4H), 7.32−7.27 (m, 3H), 3.41 (t, 2H, J = 7.2 Hz), 2.46 (s, 3H), 1.73−1.67 (m, 2H), 1.43−1.34 (m, 2H), 0.94 (t, 3H, J = 7.4 Hz); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ 144.7, 134.7, 131.4, 129.9, 128.4, 127.83, 127.80, 123.1, 82.6, 70.7, 51.5, 30.1, 21.8, 19.6, 13.7; FT-IR (KBr) $\bar{\nu}$ 2960, 2927, 2234, 1598, 1366, 1171, 1091, 756, 691, 676, 583, 547 cm^{-1}; HRMS (ESI^+) m/z calcd for $C_{19}H_{21}NNaO_2S^+$ $[M + Na]^+$ 350.1191 found 350.1192.

*N-Isopropyl-4-methyl-N-(phenylethynyl)benzenesulfonamide (**8da**).* (Table 4, entry 3) Prepared from ynamide **5d** (0.0569 g, 0.24 mmol) and PhI (22 μL, 0.2 mmol); silica gel purification (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:50, R_f = 0.51 (EtOAc/PE = 1:5)); yield: 96% (0.0601 g, yellowish oil); this ynamide hydrolyzes quickly in $CDCl_3$ and d_6-acetone to afford *N*-isopropyl-2-phenyl-*N*-tosylacetamide; however, it is intact for HRMS; ^1H NMR (500 MHz, $CDCl_3$) δ 7.70 (d, 2H, J = 8.3 Hz), 7.34−7.32 (m, 3H), 7.31−7.27 (m, 2H), 7.16−7.15 (m, 2H), 4.43 (hept, 1H, J = 6.8 Hz), 4.08 (s, 2H), 2.47 (s, 3H), 1.41 (d, 6H, J = 6.9 Hz); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ 171.6, 144.8, 137.2, 134.2, 130.0, 129.5, 128.6, 127.5, 127.1, 53.6, 44.7, 21.7, 20.6; FT-IR (KBr) $\bar{\nu}$ 2973, 2929, 1691, 1598, 1496, 1455, 1353, 1164, 1085, 988, 725, 669, 588, 554 cm^{-1}; HRMS (ESI^+) m/z calcd for $C_{18}H_{20}NO_2S^+$ $[M + H]^+$ 314.1215 found 314.1235.

*(S)-4-Methyl-N-(1-phenylethyl)-N-(phenylethynyl)-benzenesulfonamide (**8ea**).* (Table 4, entry 4) Prepared from ynamide **5e** (0.0719 g, 0.24 mmol) and PhI (22 μL, 0.2 mmol); silica gel purification (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:50, R_f = 0.5 (EtOAc/PE = 1:5)); yield: 89% (0.0667 g, yellowish oil); ^1H NMR (500 MHz, $CDCl_3$) δ 7.58 (d, 2H, J = 8.3 Hz), 7.25−7.19 (m, 7 H), 7.18−7.15 (m, 3H), 7.12 (d, 2H, J = 8.1 Hz), 5.16 (q, 1H, J = 7.1 Hz), 2.31 (s, 3H), 1.51 (d, 3H, J = 7 Hz); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ 144.4, 139.9, 135.5, 131.2, 129.9, 129.6, 128.5, 128.4, 128.1, 127.7, 127.0, 123.3, 80.5, 73.4, 59.1, 21.7, 19.8; FT-IR (KBr) $\bar{\nu}$ 3063, 3032, 2978, 2929, 1699, 1597, 1496, 1453, 1356, 1169, 1084, 975, 696, 668, 581, 548 cm^{-1}; HRMS (ESI^+) m/z calcd for $C_{23}H_{21}NNaO_2S^+$ $[M + Na]^+$ 398.1191 found 398.1189.

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*N-Cyclopropyl-4-methyl-N-(phenylethynyl)benzenesulfonamide (**8fa**).* (Table 4, entry 5) Prepared from ynamide **5f** (0.056 g, 0.24 mmol) and PhI (22 μL, 0.2 mmol); silica gel purification (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:100, R_f = 0.66 (EtOAc/PE = 1:5)); yield: 98% (0.061 g, yellowish oil); ^{1}H NMR (400 MHz, d_6-acetone) δ 7.92 (d, 2H, *J* = 8.2 Hz), 7.52 (d, 2H, *J* = 8.1 Hz), 7.39−7.33 (m, 5H), 2.90 (quint, 1H, *J* = 5.1 Hz), 2.47 (s, 3H), 0.83 (d, 4H, *J* = 5.3 Hz); ^{13}C{^{1}H} NMR (100 MHz, d_6-acetone) δ 146.1, 134.7, 131.9, 130.8, 129.3, 128.9, 128.7, 123.7, 82.9, 71.1, 33.6, 21.6, 6.6; FT-IR (KBr) $\bar{\nu}$ 2923, 2851, 2234, 1370, 1174, 1091, 862, 814, 755, 672, 573, 548 cm^{-1}; HRMS (ESI$^+$) *m*/*z* calcd for $C_{18}H_{17}NNaO_2S^+$ [M + Na]$^+$ 334.0878 found 334.0872.

*N-Cyclobutyl-4-methyl-N-(phenylethynyl)benzenesulfonamide (**8ga**).* (Table 4, entry 6) Prepared from ynamide **5g** (0.0598 g, 0.24 mmol) and PhI (22 μL, 0.2 mmol); silica gel purification (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:40, R_f = 0.46 (EtOAc/PE = 1:5)); yield: 74% (0.0507 g, orange oil); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.83 (d, 2H, *J* = 8.3 Hz), 7.43−7.42 (m, 2H), 7.35−7.30 (m, 5H), 4.48 (quint, 1H, *J* = 7.9 Hz), 2.45 (s, 3H), 2.30−2.21 (m, 2H), 2.11−2.05 (m, 2H), 1.72−1.60 (m, 2H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 144.7, 135.3, 131.5, 129.8, 128.4, 127.9, 127.7, 123.1, 80.1, 73.3, 53.8, 28.5, 21.8, 14.6; FT-IR (KBr) $\bar{\nu}$ 2926, 2854, 1703, 1495, 1455, 1356, 1168, 1092, 974, 813, 725, 700, 665, 588, 550 cm^{-1}; HRMS (ESI$^+$) *m*/*z* calcd for $C_{19}H_{19}NNaO_2S^+$ [M + Na]$^+$ 348.1034 found 348.1035.

*N-Cyclopentyl-4-methyl-N-(phenylethynyl)benzenesulfonamide (**8ha**).* (Table 4, entry 7) Prepared from ynamide **5h** (0.0631 g, 0.24 mmol) and PhI (22 μL, 0.2 mmol); silica gel purification (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:60, R_f = 0.58 (EtOAc/PE = 1:5)); yield: 56% (0.0379 g, orange oil); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.86 (d, 2H, *J* = 8.3 Hz), 7.39−7.37 (m, 2H), 7.35 (d, 2H, *J* = 8.0 Hz), 7.32−7.27 (m, 3H), 4.38 (quint, 1H, *J* = 8.0 Hz), 2.46 (s, 3H), 1.84−1.79 (m, 2H), 1.72−1.63 (m, 4H), 1.53−1.50 (m, 2H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 144.6, 135.6, 131.3, 129.8, 128.4, 127.8, 127.7, 123.2, 80.4, 72.8, 61.2, 30.4, 24.4, 21.8; FT-IR (KBr) $\bar{\nu}$ 2925, 2855, 2130, 1596, 1489, 1374, 1174, 1091, 813, 761, 691, 657, 584, 548 cm^{-1}; HRMS (ESI$^+$) *m*/*z* calcd for $C_{20}H_{21}NNaO_2S^+$ [M + Na]$^+$ 362.1191 found 362.1193.

*N-Cyclohexyl-4-methyl-N-(phenylethynyl)benzenesulfonamide (**8ia**).* (Table 4, entry 8) Prepared from ynamide **5i** (0.067 g, 0.24 mmol) and PhI (22 μL, 0.2 mmol); silica gel purification (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:100, R_f = 0.71 (EtOAc/PE = 1:5)); yield: 64% (0.045 g, orange oil); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.86 (d, 2H, *J* = 8.4 Hz), 7.39 (dd, 2H, J_1 = 8.1 Hz, J_2 = 1.8 Hz), 7.35−7.30 (m, 4H), 7.29−7.27 (m, 1H), 3.86 (tt, 1H, J_1 = 11.8 Hz, J_2 = 4.1 Hz), 2.45 (s, 3H), 1.79−1.76 (m, 2H), 1.73−1.71 (m, 2H), 1.63−1.59 (m, 1H), 1.53 (td, 2H, J_1 = 12.3 Hz, J_2 = 3.6 Hz), 1.37−1.30 (m, 2H), 1.20−1.08 (m, 1H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 144.5, 136.4, 131.4, 129.8, 128.4, 127.7, 127.5, 123.4, 80.4, 72.5, 59.7, 31.3, 25.5, 25.0, 21.8; FT-IR (KBr) $\bar{\nu}$ 2932, 2854, 1590, 1454, 1359, 1169, 1090, 996, 813, 667, 591, 550 cm^{-1}; HRMS (ESI$^+$) *m*/*z* calcd for $C_{21}H_{24}NO_2S^+$ [M + H]$^+$ 354.1528 found 354.1537.

*N-Cycloheptyl-4-methyl-N-(phenylethynyl)benzenesulfonamide (**8ja**).* (Table 4, entry 9) Prepared from ynamide **5j** (0.0696 g, 0.24 mmol) and PhI (22 μL, 0.2 mmol); silica gel purification (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:50, R_f = 0.54 (EtOAc/PE = 1:5)); yield: 86% (0.063 g, orange oil); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.87 (d, 2H, *J* = 8.3 Hz), 7.40 (dd, 2H, J_1 = 8.0 Hz, J_2 = 1.6 Hz), 7.36 (d, 2H, *J* = 8.1 Hz), 7.34−7.29 (m, 3H), 4.06 (hept, 1H, *J* = 4.9 Hz), 2.47 (s, 3H), 1.86−1.75 (m, 4H), 1.73−1.67 (m, 2H), 1.62−1.56 (m, 2H), 1.47−1.41 (m, 2H), 1.54−1.49 (m, 2H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 144.4, 136.1, 131.3, 129.8, 128.3, 127.62, 127.56, 123.4, 80.8, 72.3, 61.9, 33.7, 28.1, 24.4, 21.8; FT-IR (KBr) $\bar{\nu}$ 2926, 2856, 2234, 1693, 1598, 1495, 1455, 1362, 1167, 1090, 971, 813, 705, 666, 591, 550 cm^{-1}; HRMS (ESI$^+$) *m*/*z* calcd for $C_{22}H_{25}NNaO_2S^+$ [M + Na]$^+$ 390.1504 found 390.1501.

*N-Phenylacetylenyl-N-dehydroabietyl-4-methylbenzenesulfonamide (**8ka**).* (Table 4, entry 10) Prepared from ynamide **5k** (0.111 g, 0.24 mmol) and PhI (22 μL, 0.2 mmol); silica gel purification (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:70, R_f = 0.63 (EtOAc/PE = 1:5)); yield: 93% (0.100 g, white powder); mp 157.4−158.4 °C; ^{1}H NMR (500 MHz, d_6-acetone) δ 7.90 (d, 2H, *J* = 8.3 Hz), 7.50 (d, 2H, *J* = 8.0 Hz), 7.33−7.31 (m, 3H), 7.28−7.26 (m, 2H), 7.18 (d, 1H, *J* = 8.2 Hz), 6.97 (dd, 1H, J_1 = 8.1 Hz, J_2 = 1.5 Hz), 6.81 (s, 1H), 3.42 (d, 1H, *J* = 13.9 Hz), 3.35 (d, 1H, *J* = 13.9 Hz), 2.97−2.90 (m, 1H), 2.81−2.76 (m, 2H), 2.45 (s, 3H), 2.35 (d, 1H, *J* = 11.7 Hz), 1.99 (d, 1H, *J* = 11.8 Hz), 1.84−1.79 (m, 2H), 1.78−1.75 (m, 2H), 1.73−1.70 (m, 1H), 1.60−1.59 (m, 1H), 1.42−1.33 (m, 1H), 1.22 (s, 3H), 1.18 (dd, J_1 = 6.9 Hz, J_2 = 0.9 Hz, 6H), 1.06 (s, 3H); ^{13}C{^{1}H} NMR (125 MHz, d_6-acetone) δ 148.1, 146.3, 145.9, 135.4, 135.3, 131.8, 130.7, 129.3, 128.8, 128.7, 127.5, 124.8, 124.5, 123.8, 86.8, 70.1, 63.2, 45.2, 39.4, 39.1, 38.2, 37.2, 34.3, 25.8, 24.42, 24.36, 21.5, 19.8, 19.24, 19.21; FT-IR (KBr) $\bar{\nu}$ 2929, 2869, 2235, 1598, 1495, 1367, 1170, 1002, 813, 754, 692, 655, 589, 547; HRMS (ESI$^+$) *m*/*z* calcd for $C_{35}H_{41}NNaO_2S^+$ [M + Na]$^+$ 562.2756 found 562.2752.

*N-Phenyl-N-(phenylethynyl)methanesulfonamide (**8la**).* (Table 4, entry 11) Prepared from ynamide **5l** (0.047 g, 0.24 mmol) and PhI (22 μL, 0.2 mmol); silica gel purification (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:50, R_f = 0.61 (EtOAc/PE = 1:5)); yield: 84% (0.046 g, orange powder); mp 118.6−119.4 °C; ^{1}H NMR (400 MHz, d_6-acetone) δ 7.66 (d, 2H, *J* = 7.8 Hz), 7.53−7.48 (m, 4H), 7.44−7.40 (m, 1H), 7.38−7.36 (m, 3H), 3.32 (s, 3H); ^{13}C{^{1}H} NMR (100 MHz, d_6-acetone) δ 139.9, 132.2, 130.3, 129.3, 129.1, 129.0, 126.6, 123.3, 83.5, 71.0, 37.4; FT-IR (KBr) $\bar{\nu}$ 2925, 2851, 2240, 1593, 1490, 1366, 1167, 959, 756, 691, 545; HRMS (ESI$^+$) *m*/*z* calcd for $C_{15}H_{14}NO_2S^+$ [M + H]$^+$ 272.0745 found 272.0740.

*p-Nitro-N-phenyl-N-(phenylethynyl)benzenesulfonamide (**8ma**).* (Table 4, entry 12) Prepared from ynamide **5m** (0.0725 g, 0.24 mmol) and PhI (22 μL, 0.2 mmol); silica gel purification (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:50, R_f = 0.58 (EtOAc/PE = 1:5)); yield: 68% (0.051 g, yellowish prisms); mp 102.9−104.1 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.36 (dt, 2H, J_1 = 9.0 Hz, J_2 = 2.0 Hz), 7.93 (dt, 2H, J_1 = 9.0 Hz, J_2 = 2.3 Hz), 7.41−7.38 (m, 5H), 7.34−7.31 (m, 5H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 151.0, 141.3, 138.4, 131.8, 129.62, 129.61, 129.0, 128.69, 128.58, 126.3, 124.3, 122.0, 81.8, 71.3; FT-IR (KBr) $\bar{\nu}$ 3104, 2924, 2852, 2241, 1592, 1533, 1490, 1382, 1348, 1181, 1088, 925, 855, 784, 738, 691, 607, 576, 558 cm^{-1}; HRMS (ESI$^+$) *m*/*z* calcd for $C_{20}H_{14}N_2NaO_4S^+$ [M + Na]$^+$ 401.0572 found 401.0578.

*1-(Phenylethynyl)-1H-indole (**8na**).* (Table 4, entry 13) Prepared from ynamide **5n** (0.0339 g, 0.24 mmol) and PhI (22 μL, 0.2 mmol); silica gel purification (2 cm × 14 cm, petroleum ether, R_f = 0.80 (PE)); yield: 65% (0.0282 g, yellowish powder); mp 56.8−58.1 °C; prepared from ynamide **5n** (1 g, 7.08 mmol) and PhI (1 mL, 9.2 mmol), yield: 41% (0.63 g); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.70 (d, 1H, *J* = 8.2 Hz), 7.67 (d, 1H, *J* = 8.0 Hz), 7.61 (d, 2H, *J* = 7.4 Hz), 7.44−7.38 (m, 4H), 7.32 (d, 1H, *J* = 3.3 Hz), 7.28 (t, 1H, *J* = 7.6 Hz), 6.65 (d, 1H, *J* = 3.3 Hz); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 138.2, 131.5, 128.9, 128.6, 128.1, 128.0, 123.7, 122.7, 122.1, 121.3, 111.4, 105.7, 80.9, 70.7; FT-IR (KBr) $\bar{\nu}$ 2924, 2241, 1522, 1459, 1348, 1204, 1164, 742, 690 cm^{-1}; HRMS (ESI$^+$) *m*/*z* calcd for $C_{16}H_{12}N^+$ [M + H]$^+$ 218.0970 found 218.0968.

*9-(Phenylethynyl)-9H-carbazole (**8oa**).* (Table 4, entry 14) Prepared from ynamide **5o** (0.0459 g, 0.24 mmol) and PhI (22 μL, 0.2 mmol); silica gel purification (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:80, R_f = 0.53 (EtOAc/PE = 1:10)); yield: 50% (0.0267 g, white powder); mp 108.7−110.0 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.07 (d, 2H, *J* = 7.7 Hz), 7.77 (d, 2H, *J* = 8.1 Hz), 7.67 (d, 2H, *J* = 6.7 Hz), 7.57 (t, 2H, *J* = 8 Hz), 7.46−7.37 (m, 5H); ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 140.6, 131.5, 128.6, 128.1, 126.9, 123.7, 123.1, 122.2, 120.5, 111.4, 79.0, 74.7; FT-IR (KBr) $\bar{\nu}$ 3052, 2922, 2247, 1480, 1452, 1224, 747, 720, 689, 563 cm^{-1}; HRMS (ESI$^+$) *m*/*z* calcd for $C_{20}H_{14}N^+$ [M + H]$^+$ 268.1126 found 268.1134.

*Procedure to Synthesize 4-Methyl-N-(pent-4-en-1-yn-1-yl)-N-phenylbenzenesulfonamide (**9a**).* To a solution of ynamide **5a** (0.135 mg, 0.5 mmol), allyl chloride (0.163 mL, 2 mmol), and cetrimonium bromide (2 g) in water (4 mL) was charged CuI (9.5 mg), dppp (20.6 mg), and K_2CO_3 (0.138 g) under nitrogen protection. After being stirred at room temperature under nitrogen protection for 3 h, the reaction mixture was extracted with EtOAc (3

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× 20 mL). The combined organic layer was washed with brine, dried over $MgSO_4$, and concentrated *in vacuo*. The residue was purified by column chromatography on silica gel (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:40, R_f = 0.58 (EtOAc/PE = 1:5)) to afford **9a** as colorless oil; yield: 99% (0.154 g); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48 (d, 2H, J_1 = 8.4 Hz, J_2 = 1.7 Hz), 7.24−7.20 (m, 2H), 7.19−7.17 (m, 5H), 5.73 (dquint, 1H, J_1 = 17.0 Hz, J_2 = 5.1 Hz), 5.21 (dq, 1H, J_1 = 17.0 Hz, J_2 = 1.8 Hz), 5.02 (dq, 1H, J_1 = 10.0 Hz, J_2 = 1.7 Hz), 3.01 (dt, 2H, J_1 = 5.1 Hz, J_2 = 1.8 Hz), 2.35 (s, 3H); ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 144.9, 139.3, 133.1, 132.6, 129.5, 129.1, 128.4, 128.1, 126.3, 116.2, 76.3, 66.9, 22.9, 21.8; FT-IR (KBr) $\bar{\nu}$ 2925, 2854, 1708, 1596, 1490, 1361, 1165, 1088, 922, 813, 756, 696, 569; HRMS (ESI$^+$) m/z calcd for $C_{18}H_{18}NO_2S^+$ $[M + H]^+$ 312.1058 found 312.1060.

*Hydroacyloxylation of Ynamide in Water to Synthesize 1-(4-Methyl-N-phenylphenylsulfonamido)vinyl Benzoate (**10a**).* To a 10 mL round-bottom flask was charged ynamide **5a** (0.054 g, 0.2 mmol), benzoic acid (0.0268 g, 0.22 mmol), and cetrimonium bromide (2 g) in water (4 mL). The reaction was stirred at 60 °C using a heating mantle for 3 h. Then, the reaction mixture was extracted with EtOAc (3 × 20 mL). The combined organic layer was washed with brine, dried over $MgSO_4$, and concentrated *in vacuo*. The residue was purified by column chromatography on silica gel (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:40, R_f = 0.38 (EtOAc/PE = 1:5)) to afford **10a** as yellowish oil; yield: 92% (0.072 g); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.76 (d, 2H, J = 8.4 Hz), 7.56 (d, 2H, J = 8.3 Hz), 7.49 (tt, 1H, J_1 = 7.4 Hz, J_2 = 1.2 Hz), 7.31 (t, 2H, J = 8 Hz), 7.25−7.23 (m, 5H), 7.09 (d, 2H, J = 8.1 Hz), 5.02 (dt, 2H, J_1 = 2.7 Hz, J_2 = 1.8 Hz), 2.28 (s, 3H); ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 163.4, 145.7, 144.1, 138.7, 136.7, 133.8, 130.1, 129.5, 129.4, 129.0, 128.7, 128.5, 128.1, 101.9, 21.6 (one carbon signal is missing due to the overlapping); FT-IR (KBr) $\bar{\nu}$ 2929, 1709, 1596, 1491, 1363, 1164, 812, 654, 693, 564 cm^{-1}; HRMS (ESI$^-$) m/z calcd for $C_{22}H_{18}NO_4S^-$ $[M - H]^-$ 392.0957 found 392.0956.

*Hydrodithiophosphonylation of Ynamide in Water to Synthesize 1-(4-Methyl-N-phenylphenylsulfonamido)vinyl Diphenylphosphinodithioate (**11a**).* To a 10 mL round-bottom flask was charged ynamide **5a** (0.054 g, 0.2 mmol), diphenylphosphinodithioic acid (0.0601 g, 0.24 mmol), and cetrimonium bromide (2 g) in water (4 mL). The reaction was stirred at room temperature for 12 h. Then, the reaction mixture was extracted with EtOAc (3 × 20 mL). The combined organic layer was washed with brine, dried over $MgSO_4$, and concentrated *in vacuo*. The residue was purified by column chromatography on silica gel (2 cm × 14 cm, ethyl acetate/petroleum ether = 1:40, R_f = 0.49 (EtOAc/PE = 1:5)) to afford **11a** as white powder; mp 116.1−117.2 °C; yield: 66% (0.069 g); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.69 (dd, 2H, J_1 = 7.1 Hz, J_2 = 1.4 Hz), 7.65 (dd, 2H, J_1 = 7.1 Hz, J_2 = 1.4 Hz), 7.48 (d, 2H, J = 8.3 Hz), 7.40−7.36 (m, 2H), 7.30−7.26 (m, 4H), 7.18−7.09 (m, 5H), 7.01−6.98 (m, 2H), 5.75 (t, 1H, J = 1.7 Hz), 5.58 (t, 1H, J = 1.7 Hz), 2.33 (s, 3H); ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 144.1, 137.3 (J = 93.6 Hz), 135.7 (J = 6.3 Hz), 133.3 (J = 84.6 Hz), 132.0 (J = 3.2 Hz), 131.8 (J = 11.1 Hz), 129.7, 129.2, 129.0, 128.7, 128.6, 128.4, 128.2, 125.4 (J = 5.6 Hz), 21.7; FT-IR (KBr) $\bar{\nu}$ 2926, 1709, 1438, 1366, 1165, 812, 694, 655, 563 cm^{-1}; HRMS (ESI$^+$) m/z calcd for $C_{27}H_{25}NO_2PS_3^+$ $[M + H]^+$ 522.0785 found 522.0740.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge at https://pubs.acs.org/doi/10.1021/acs.joc.0c02326.

^{1}H and ^{13}C NMR spectra for compounds **5**, **8**, **9a**, **10a**, and **11a** (PDF)

Accession Codes

CCDC 1890688 contains the supplementary crystallographic data for this paper. These data can be obtained free of charge via www.ccdc.cam.ac.uk/data_request/cif, or by emailing data_request@ccdc.cam.ac.uk, or by contacting The Cambridge Crystallographic Data Centre, 12 Union Road, Cambridge CB2 1EZ, UK; fax: +44 1223 336033.

■ AUTHOR INFORMATION

Corresponding Author

Na Wu − *School of Chemistry and Bioscience, University of Bradford, Bradford, West Yorkshire BD7 1DP, U.K.;* orcid.org/0000-0003-1668-6652; Email: n.wu1@bradford.ac.uk

Authors

Lei Zhao − *State Key Laboratory for the Chemistry and Molecular Engineering of Medicinal Resources, School of Chemistry and Pharmaceutical Science, Guangxi Normal University, Guilin, Guangxi 541004, China*

Hongyi Yang − *State Key Laboratory for the Chemistry and Molecular Engineering of Medicinal Resources, School of Chemistry and Pharmaceutical Science, Guangxi Normal University, Guilin, Guangxi 541004, China*

Ruikun Li − *State Key Laboratory for the Chemistry and Molecular Engineering of Medicinal Resources, School of Chemistry and Pharmaceutical Science, Guangxi Normal University, Guilin, Guangxi 541004, China*

Ye Tao − *State Key Laboratory for the Chemistry and Molecular Engineering of Medicinal Resources, School of Chemistry and Pharmaceutical Science, Guangxi Normal University, Guilin, Guangxi 541004, China*

Xiao-Feng Guo − *College of Biomedical Engineering, Taiyuan University of Technology, Taiyuan, Shanxi 030024, China*

Edward A. Anderson − *Chemistry Research Laboratory, University of Oxford, Oxford OX1 3TA, U.K.;* orcid.org/0000-0002-4149-0494

Andrew Whiting − *Department of Chemistry, Durham University, Durham DH1 3LE, U.K.;* orcid.org/0000-0001-8937-8445

Complete contact information is available at: https://pubs.acs.org/10.1021/acs.joc.0c02326

Notes

The authors declare no competing financial interest.

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