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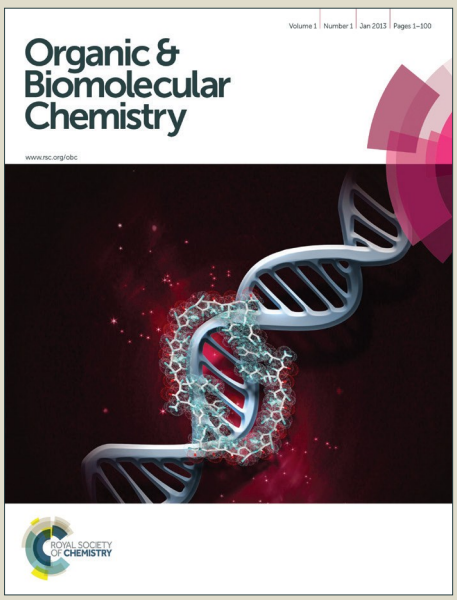

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Selective synthesis of functionalized pyrroles from 3-aza-1,5-enynes†

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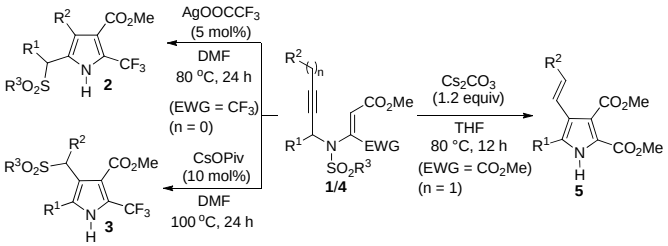
2-Trifluoromethyl-5-(arylsulfonyl)methyl pyrroles and 2-trifluoromethyl-4-(arylsulfonyl)methyl pyrroles were selectively synthesized from trifluoromethyl-substituted 3-aza-1,5-enynes via cyclization/sulfonyl group migration cascade catalyzed by $AgOOCCF_3$ and CsOPiv, respectively. Alkyvinyl-substituted pyrroles were generated from seven-atoms skeleton 3-aza-1,5-enynes via aryl sulfinic acid elimination in the presence of Cs_2CO_3. Two ion-pair intermediates were proposed and a key intermediate, aza-diene-yne, was successfully isolated in the mechanistic studies.

Introduction

Pyrroles are one of the most important heterocycles, are widely found as key constituents in numerous natural products, biologically active compounds, commercial and potent pharmaceutical drugs, and functional materials.[1] Although there have been numerous methods for their synthesis,[2] developing new synthetic methods and obtaining structural novel products with new substitution patterns remain attract the interest of chemists. As a continuation of our effort on 3-aza-1,5-enyne cycloisomerization reactions[3] and pyrrole ring constructions[3a,3e,4], we report herein the synthesis of three kinds of functionalized pyrroles from 3-aza-1,5-enynes (Scheme 1).



Scheme 1 Synthesis of functionalized pyrroles from 3-aza-1,5-enynes.

It is well known that incorporation of trifluoromethyl group into organic molecules can significantly change their physical, chemical, and biological properties.[5] Among these useful trifluoromethyl-substituted compounds, trifluoromethyl pyrroles such as the insecticide chlorfenapyr[6], antitumor compound[7], and general anesthesia inducer[8], have been shown to exhibit significant biological activities. Meanwhile, sulfones have been extensively used as key synthons in organic synthesis,[9] and compounds containing sulfone moiety also have evident bioactivity.[10] In addition, alkene is one of the most fundamental functional group in organic chemistry. Therefore, the pyrroles bearing the above mentioned functional groups reported in this article are highly functionalized and may have potential applications.

Results and discussion

Synthesis of 2-trifluoromethyl-5-(arylsulfonyl)methyl pyrroles 2.

3-Aza-1,5-enyne **1a** was chosen as the model substrate to screen the reaction conditions (Table 1). When **1a** was heated in DMF at 100 °C, the desired pyrrole **2a** was generated in 35% HPLC yield (entry 1). We reasoned that coin metals, gold, copper, or silver, may catalyze this reaction because these metals are efficient catalysts in transforming of polyunsaturated substrates.[1b,11] When 10 mol% Au(I) or Au(III) was added, however, no improved efficiency was observed (entries 2–5). To our delight, higher yields were presented when copper salts were used as catalyst (54–73%, entries 6–9). Twenty kinds of silver salts [both (Ag(I) and Ag(II)] were also screened (entries 10–29), and among these silver salts, $AgOOCCF_3$ exhibited the highest activity (86% HPLC yield, entry 27). When 10 mol% $AgOOCCF_3$ was used as catalyst, changing the solvent afforded inferior results (entries 30–37). Decreasing the amount of $AgOOCCF_3$ from 10 mol% to 5 mol% did not decrease the yield (entry 38 versus entry 27). Using of 5 mol% $AgOOCCF_3$ as catalyst, neither lowering the reaction temperature to 80 °C (entry 39) nor elevating the temperature to 120 °C (entry 40) affect the yield obviously. Therefore, the following conditions were eventually chosen for subsequent studies: $AgOOCCF_3$ (5 mol%) in DMF at 80 °C under argon atmosphere for 24 hours (entry 39).

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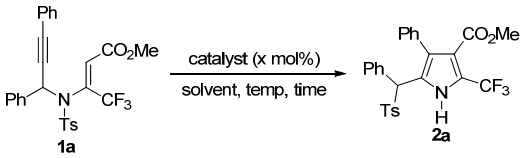
† Electronic Supplementary Information (ESI) available: NMR spectra of all compounds, and crystallographic information files (CIF) for compounds **3a** and **5m**. See DOI: 10.1039/x0xx00000x

Table 1 Screening of the reaction conditions for the synthesis of pyrroles **2a**

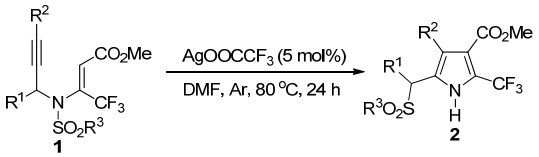


Entry	catalyst (x mol%)	Solvent	Temp (°C)	Time (h)	Yield (%)[b]
1	-	DMF	100	24	35
2	AuCl (10)	DMF	100	24	14
3	Ph_3PAuCl (10)	DMF	100	24	33
4	IPrAuCl (10)	DMF	100	24	29
5	$AuCl_3$ (10)	DMF	100	24	10
6	CuOAc (10)	DMF	100	24	73
7	$[(CH_3CN)_4Cu]PF_6$ (10)	DMF	100	24	61
8	$CuBr_2$ (10)	DMF	100	24	73
9	$Cu(OTf)_2$ (10)	DMF	100	24	54
10	AgI (10)	DMF	100	24	42
11	AgBr (10)	DMF	100	24	46
12	$AgVO_3$ (10)	DMF	100	24	56
13	Ag_3PO_4 (10)	DMF	100	24	64
14	$AgAsF_6$ (10)	DMF	100	24	68
15	$AgNO_3$ (10)	DMF	100	24	69
16	AgF (10)	DMF	100	24	78
17	$AgPF_6$ (10)	DMF	100	24	79
18	AgOTf (10)	DMF	100	24	77
19	Ag_2O (10)	DMF	100	24	79
20	Ag_2WO_4 (10)	DMF	100	24	73
21	Ag_2CO_3 (10)	DMF	100	24	74
22	Ag_2SO_4 (10)	DMF	100	24	72
23	AgOAc (10)	DMF	100	24	78
24	$AgBF_4$ (10)	DMF	100	24	82
25	$AgNTf_2$ (10)	DMF	100	24	82
26	$AgSbF_6$ (10)	DMF	100	24	84
27	$AgOOCCF_3$ (10)	DMF	100	24	86
28	AgF_2 (10)	DMF	100	24	78
29	AgO (10)	DMF	100	24	70
30	$AgOOCCF_3$ (10)	CH_2Cl_2	100	24	15
31	$AgOOCCF_3$ (10)	acetone	100	24	34
32	$AgOOCCF_3$ (10)	THF	100	24	40
33	$AgOOCCF_3$ (10)	1,4-dioxane	100	24	54
34	$AgOOCCF_3$ (10)	DMSO	100	24	56
35	$AgOOCCF_3$ (10)	toluene	100	24	56
36	$AgOOCCF_3$ (10)	NMP	100	24	68
37	$AgOOCCF_3$ (10)	MeCN	100	24	83
38	$AgOOCCF_3$ (5)	DMF	100	24	86
39	$AgOOCCF_3$ (5)	DMF	80	24	85
40	$AgOOCCF_3$ (5)	DMF	120	7	84

[a] In 0.1 mmol scale. [b] HPLC yields using naphthalene as an internal standard.

We next explored the scope and generality of this reaction, and the results were given in Table 2. Both electron-deficient and electron-rich on aromatic groups R^1 were all well tolerated, (entries 1–4 and 6–10). Fused ring was also suitable for this process (entry 11). However, 2-MeO-substituted subtract **1e** gave an inseparable mixture (entry 5), and alkyl group (R^1) was not tolerated (entry 12). Groups (R^2) directly connected to the alkyne moiety containing both aryl (entries 13–17) and alkyl (entries 18–20) substituents were also tolerated. The substitutes on R^3 had slight impact on product yields (entry 7 versus entry 21, entry 9 versus entry 22).

Table 2. Scope of the synthesis of pyrroles **2**[a]

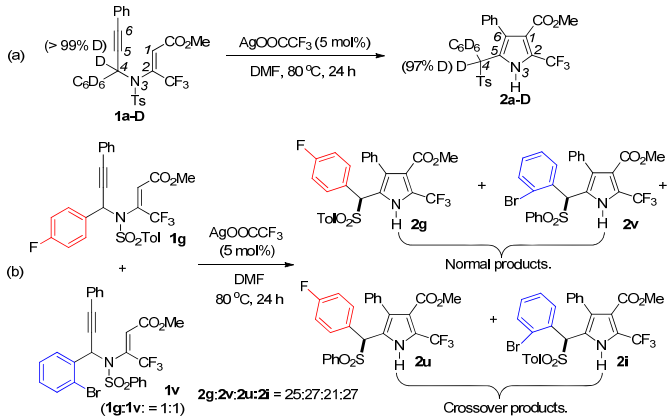


Entry	1	R^1	R^2	R^3	2	Yield (%)[b]
1	**1a**	Ph	Ph	4-MeC_6H_4	**2a**	84
2	**1b**	2-MeC_6H_4	Ph	4-MeC_6H_4	**2b**	80
3	**1c**	3-MeC_6H_4	Ph	4-MeC_6H_4	**2c**	67
4	**1d**	4-MeC_6H_4	Ph	4-MeC_6H_4	**2d**	73
5	**1e**	2-$MeOC_6H_4$	Ph	4-MeC_6H_4	**2e**	-[c]
6	**1f**	2-FC_6H_4	Ph	4-MeC_6H_4	**2f**	84
7	**1g**	4-FC_6H_4	Ph	4-MeC_6H_4	**2g**	77
8	**1h**	2-ClC_6H_4	Ph	4-MeC_6H_4	**2h**	92
9	**1i**	2-BrC_6H_4	Ph	4-MeC_6H_4	**2i**	83
10	**1j**	2-$CF_3C_6H_4$	Ph	4-MeC_6H_4	**2j**	69
11	**1k**	1-naphthyl	Ph	4-MeC_6H_4	**2k**	70
12	**1l**	^{i}Pr	Ph	4-MeC_6H_4	**2l**	N.R.[d]
13	**1m**	Ph	2-MeC_6H_4	4-MeC_6H_4	**2m**	78
14	**1n**	Ph	3-MeC_6H_4	4-MeC_6H_4	**2n**	84
15	**1o**	Ph	4-MeC_6H_4	4-MeC_6H_4	**2o**	86
16	**1p**	Ph	4-FC_6H_4	4-MeC_6H_4	**2p**	73
17	**1q**	Ph	4-ClC_6H_4	4-MeC_6H_4	**2q**	83
18	**1r**	Ph	^{n}Pr	4-MeC_6H_4	**2r**	71
19	**1s**	Ph	^{n}Bu	4-MeC_6H_4	**2s**	75
20	**1t**	Ph	Cy	4-MeC_6H_4	**2t**	47
21	**1u**	4-FC_6H_4	Ph	Ph	**2u**	71
22	**1v**	2-BrC_6H_4	Ph	Ph	**2v**	79

[a] Reaction conditions: **1** (0.2 mmol), $AgOOCCF_3$ (5 mol%), DMF (1 mL), 80 °C, 24 h, under argon atmosphere. [b] Isolated yields. [c] Inseparable mixture. [d]140 °C; N.R. = no reaction.

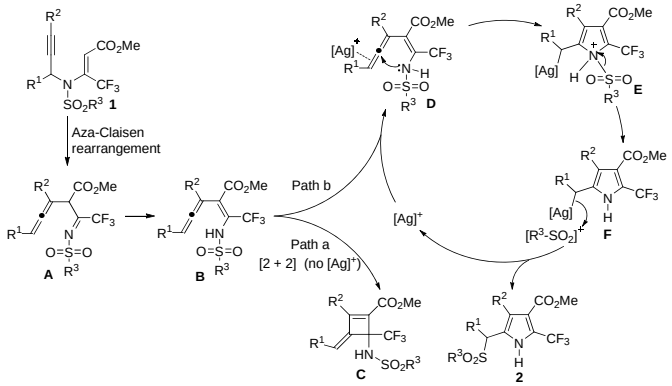
A deuterium-labeling experiment was performed to explore the reaction mechanism. Substrate deuterated at the C4-position (**1a-D**) was subjected to the standard reaction conditions (Scheme 2a), the deuterium atom was incorporated into the Ts-connecting carbon of the product (**2a-D**). This indicated that C–H bond at the C4-position did not cleavage during the reaction. A crossover experiment was also carried

out (Scheme 2b). 3-Aza-1,5-enynes **1g** and **1v** which bearing different substituents were subjected to react in the same reaction tube, and both normal products (**2g** and **2v**) and crossover products (**2u** and **2i**) were detected, suggesting that the sulfonyl group migration was in an intermolecular manner.



Scheme 2 Mechanistic studies.

A plausible mechanism is proposed as shown in Scheme 3. 3-Aza-1,5-enyne **1** is transformed into intermediate **A** via an aza-Claisen rearrangement.[3] Followed by an imine-enamine isomerization generates intermediate **B**.[13] The intermediate **B** can go through different pathways under different conditions. In the absence of Ag(I) or other transition-metals, [2 + 2] cycloaddition gives the cyclobutenes **C** (Path a, Scheme 3).[3c] In contrast, in the presence of Ag(I) (Path b, Scheme 3), Ag(I) activates one of the double bonds of the allene moiety to give intermediate **D**. Cyclization of **D** provides intermediate **E**. N–S bond cleavage generates intermediate **F** which is a combination of metallorganic compound and an organic cation. In the last step, the organic cation displaces the Ag(I) cation to form the desired pyrroles **2** and releases the Ag(I) catalyst.

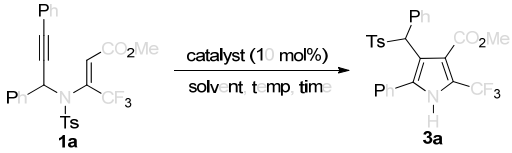


Scheme 3 Proposed mechanism for the formation of pyrroles **2**.

Synthesis of 2-trifluoromethyl-4-(arylsulfonyl)methyl pyrroles 3.

After successfully obtain pyrroles **2**, we turned our attentions to synthesize another kind of functionalized pyrroles, 4-(arylsulfonyl)-methyl-2-(trifluoromethyl)-pyrroles **3**. Similar to our previous work,[3a] base is needed in this reaction (Table 3). In the absence of a base, the desired pyrrole **3a** was not detedcted (entry 1). When 10 mol% Cs_2CO_3 was used as catalyst, the product **3a** was generated in 48% HPLC yield (entry 2). The structure of **3a** was unambiguously confirmed by X-ray crystal diffraction analysis.[12] NaOMe and NaO^{t}Bu afforded inferior yields (entries 3 and 4). The use of LiHMDS and KOAc increased the yield of **3a** to 64% and 70%, respectively (entries 5 and 6). Organic base, DBU and DABCO, afforded moderate yields (entries 7 and 8). To our delight, CsOPiv exhibited higher performance, and **3a** was generated in 80% yield (entry 9). Lowering or elevating the reaction temperature did not increase the yield (entries 10 and 11). The reactions carried out in solvents such as CH_2Cl_2, toluene, 1,4-dioxane, and 1,2-dichlororehane (DCE) were very sluggish (entries 12–15). Further screening the solvents (MeCN, THF, acetone, and DMSO) demonstrated that DMSO afforded a very slight high yield (81%, entry 19) than DMF (80%, entry 9). Considering that DMF was easily handled than DMSO, we still use DMF as solvent. The optimized reaction conditions were as following: 10 mol% of CsOPiv as catalyst, DMF as solvent, at 100 °C for 24 hours.

Table 3 Screening of the reaction conditionsfor the synthesis of pyrroles **3**[a]



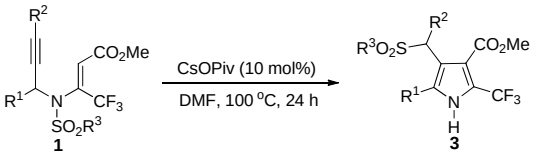
Entry	Catalyst	Solvent	Temp (°C)	Time (h)	Yield (%)[b]
1	-	DMF	100	24	N.D.[c]
2	Cs_2CO_3	DMF	100	24	48
3	NaOMe	DMF	100	24	36
4	NaO^{t}Bu	DMF	100	24	46
5	LiHMDS	DMF	100	24	64
6	KOAc	DMF	100	24	70
7	DBU	DMF	100	24	50
8	DABCO	DMF	100	24	61
9	CsOPiv	DMF	100	24	80
10	CsOPiv	DMF	80	48	77
11	CsOPiv	DMF	120	6	73
12	CsOPiv	CH_2Cl_2	100	24	7
13	CsOPiv	toluene	100	24	N.D.[c]
14	CsOPiv	1,4-dioxane	100	24	7
15	CsOPiv	DCE	100	24	4
16	CsOPiv	MeCN	100	24	66
17	CsOPiv	THF	100	24	37
18	CsOPiv	acetone	100	24	65
19	CsOPiv	DMSO	100	24	81

[a] In 0.1 mmol scale. [b] HPLC yields using naphthalene as an internal standard. [c] N.D. = not detected by HPLC.

Following the optimized conditions, we next explored the scope and limitation of this reaction (Table 4). Both electron-deficient and electron-rich groups on aromatic groups (R^1 and R^2) were tolerated, gave moderate to good yields (entries 1–12). However, 2-Me-C_6H_4, 2-MeO-C_6H_4, and 1-naphthyl-substituted 3-aza-1,5-enynes (**1b**, **1e**, and **1k**, respectively) generated crude products which were very hard to be purified (entries 2, 5 and 11). Alkyl group (R^1) was not tolerated in this

reaction (entry 12). When R^2 was alkyl, a very complicated mixture was obtained and no major product was isolated (entries 18–20). The substitutes on R^3 had no significant impact on product yields (entry 7 versus entry 21, entry 9 versus entry 22).

Table 4 Scope of the Synthesis of Pyrroles **3**[a]

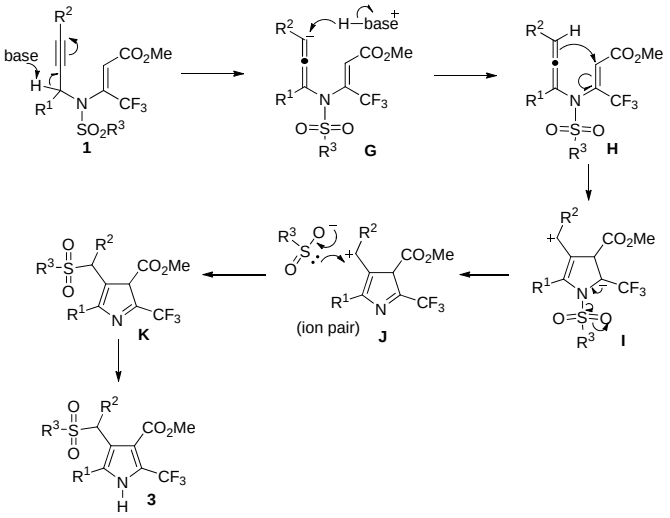


1 **3**

Entry	1	R^1	R^2	R^3	3	Yield (%)[b]
1	**1a**	Ph	Ph	4-MeC_6H_4	**3a**	77
2	**1b**	2-MeC_6H_4	Ph	4-MeC_6H_4	**3b**	-[c]
3	**1c**	3-MeC_6H_4	Ph	4-MeC_6H_4	**3c**	73
4	**1d**	4-MeC_6H_4	Ph	4-MeC_6H_4	**3d**	58
5	**1e**	2-$MeOC_6H_4$	Ph	4-MeC_6H_4	**3e**	-[c]
6	**1f**	2-FC_6H_4	Ph	4-MeC_6H_4	**3f**	53
7	**1g**	4-FC_6H_4	Ph	4-MeC_6H_4	**3g**	60
8	**1h**	2-ClC_6H_4	Ph	4-MeC_6H_4	**3h**	62
9	**1i**	2-BrC_6H_4	Ph	4-MeC_6H_4	**3i**	57
10	**1j**	2-$CF_3C_6H_4$	Ph	4-MeC_6H_4	**3j**	78
11	**1k**	1-naphthyl	Ph	4-MeC_6H_4	**3k**	-[c]
12	**1l**	^{i}Pr	Ph	4-MeC_6H_4	**3l**	N.R.[d]
13	**1m**	Ph	2-MeC_6H_4	4-MeC_6H_4	**3m**	81
14	**1n**	Ph	3-MeC_6H_4	4-MeC_6H_4	**3n**	82
15	**1o**	Ph	4-MeC_6H_4	4-MeC_6H_4	**3o**	69
16	**1p**	Ph	4-FC_6H_4	4-MeC_6H_4	**3p**	73
17	**1q**	Ph	4-ClC_6H_4	4-MeC_6H_4	**3q**	75
18	**1r**	Ph	^{n}Pr	4-MeC_6H_4	**3r**	-[e]
19	**1s**	Ph	^{n}Bu	4-MeC_6H_4	**3s**	-[e]
20	**1t**	Ph	Cy	4-MeC_6H_4	**3t**	-[e]
21	**1u**	4-FC_6H_4	Ph	Ph	**3u**	67
22	**1v**	2-BrC_6H_4	Ph	Ph	**3v**	57[f]

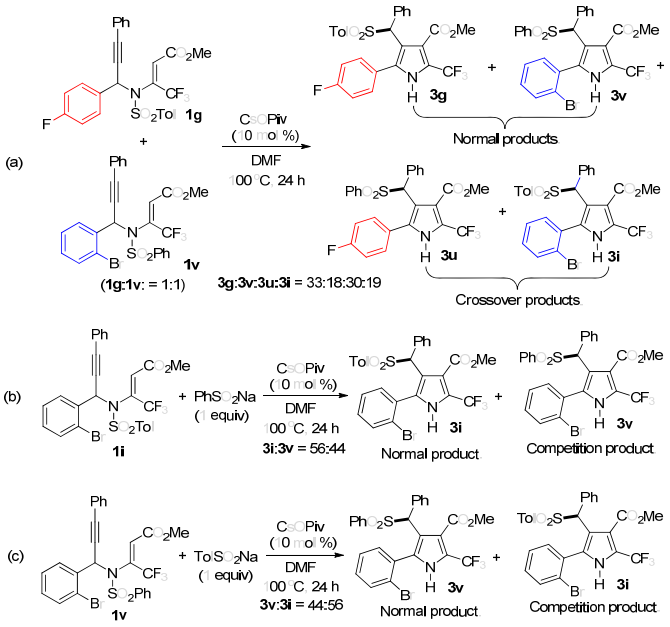
[a] Reaction conditions: **1** (0.2 mmol), CsOPiv (10 mol%), DMF (1 mL), 100 °C, 24 h, under argon atmosphere. [b] Isolated yields. [c] Inseparable mixture. [d] N.R. = no reaction. [e] Very complicated mixtures. [f] In 0.4 mmol scale.

The proposed mechanism of this reaction (Scheme 4) was similar to our previous study.[3a] The propargyl moiety of **1** is transformed into allene **H** firstly. One of the double bonds of the allene moiety of **H** attacks the carbon atom of olefin moiety affords intermediate **I**. An ion pair **J** is formed through N–S bond cleavege. The recombination of the cation and the anion of **J** results in the formation of the C–S bond of **K**, and then **K** aromatized to pyrroles **3**.



Scheme 4 Proposed mechanism for the formation of pyrroles **3**.

To verify the ion pair intermediate **J**, a crossover experiment (Scheme 5a) and two competetion experiments (Scheme 5b and 5c) were carried out.[3a] Equimolecular of starting materials **1g** and **1v** was allowed to react in the same reaction tube under the standard conditions, not only the normal products (**3g** and **3v**) but also the crossover products (**3u** and **3i**) were observed (Scheme 5a). One equivalent of sodium phenyl sulfinate was added to reactant with **1i**, which has a *p*-tolyl group, besides the normal product **3i**, competition product **3v** was also observed (Scheme 5b). Meanwhile, the combination of one equivalent of sodium *p*-tolyl sulfinate and **1v**, which has a phenyl group, exhibited the same competitive reaction phenomenon (Scheme 5c). These results strongly support the prensence of the ion pair **J**.

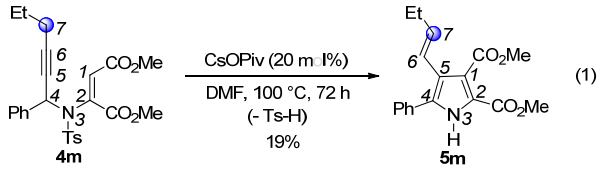


Scheme 5 Crossover and competetion experiments.

Synthesis of alkylvinyl pyrroles 5.

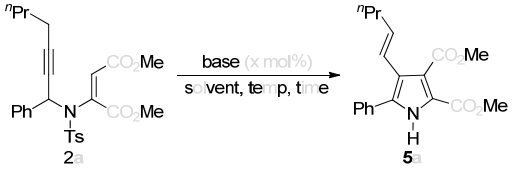
Along with the research continuation, we found that the propyl-/diester-substituted 3-aza-1,5-enyne **4m** can generated

a new kind of pyrrole product, 4-(but-1-en-1-yl)-pyrrole **5m**, in the presence of 20 mol% CsOPiv (eq. 1). The structure of **5m** was also unambiguously confirmed by X-ray crystal diffraction analysis.[12]



One carbon (C7 in **4m**) of the propyl group was incorporated into the double bond of the product (eq. 1). Ts-H (*p*-toluenesulfinic acid) elimination occurred in this transformation, and the isolated yield of the product, 19%, was not more than the base amount, 20% (eq. 1). We reasoned that the eliminated *p*-toluenesulfinic acid may neutralize the base, CsOPiv, thus the product yield was not higher than the base amount. Therefore, stoichiometric base may be needed to neutralize the in situ generated acid. With this hypothesis in mind, we further screened the reaction conditions using butyl-substituted 3-aza-1,5-enyne **4a** as model substrate in DMF (Table 5). In addition to 20 mol% Cs_2CO_3, one equivalent of a second base, such as NEt_3, Na_2CO_3, NaOAc, NaOH, and DBU, were tested (entries 1–5), and the desired product was obtained in 31–69% yield (entries 1–5). When 1.2 equivalents of Cs_2CO_3 was used without a second base, **5a** could be generated in 70% yield (entry 6). Shortening reaction time from 12 hours to 4 hours obviously decrease the efficiency (entry 6 versus entry 7). If 1.2 equivalents of CsOPiv were employed instead of Cs_2CO_3, no higher yield was obtained (entry 8 versus entry 6). We next screened the solvent effect using 1.2 equivalent of Cs_2CO_3. Among the tested solvents (CH_3OH, toluene, DCE, DMSO, 1,4-dioxane, CH_3CN, and THF) (entries 9–15), THF was the best choice (80% yield, entry 15). Reducing the amount of Cs_2CO_3 to 1.0 equivalent or increasing the amount to 1.5 equivalents slightly decreased the yield (entries 16 and 17 versus entry 15). Both elevating the temperature to 120 °C (entry 18) and lowering the reaction temperature to 60 °C (entry 20) slightly decreased the yield. Further lowering the reaction temperature to 25 °C, the yield was very low (5%, entry 21). When the reaction was carried out at 80 °C, the yield was highest among the tested conditions (81%, entry 19). Thus the following conditions were eventually chosen as the optimal reaction conditions: 1.2 equivalents of Cs_2CO_3, in THF at 80 °C for 12 hours under argon atmosphere (entry 19).

Table 5 Screening of the reaction conditionsfor the synthesis of pyrroles **5**[a]

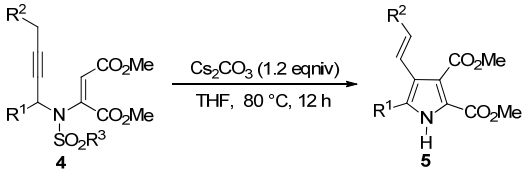


Entry	Base (x mol%)	Solvent	Temp (°C)	Time (h)	Yield (%)[b]
1	Cs_2CO_3 (20) + NEt_3 (100)	DMF	100	12	31
2	Cs_2CO_3 (20) + Na_2CO_3 (100)	DMF	100	12	39
3	Cs_2CO_3 (20) + NaOAc (100)	DMF	100	12	68
4	Cs_2CO_3 (20) + NaOH (100)	DMF	100	12	68
5	Cs_2CO_3 (20) + DBU (100)	DMF	100	12	69
6	Cs_2CO_3 (120)	DMF	100	12	70
7	Cs_2CO_3 (120)	DMF	100	4	60
8	CsOPiv (120)	DMF	100	12	60
9	Cs_2CO_3 (120)	CH_3OH	100	12	N.D.[c]
10	Cs_2CO_3 (120)	toluene	100	12	N.D.[c]
11	Cs_2CO_3 (120)	DCE	100	12	5
12	Cs_2CO_3 (120)	DMSO	100	12	16
13	Cs_2CO_3 (120)	1,4-dioxane	100	12	38
14	Cs_2CO_3 (120)	CH_3CN	100	12	65
15	Cs_2CO_3 (120)	THF	100	12	80
16	Cs_2CO_3 (100)	THF	100	12	77
17	Cs_2CO_3 (150)	THF	100	12	76
18	Cs_2CO_3 (120)	THF	120	12	65
19	Cs_2CO_3 (120)	THF	80	12	81
20	Cs_2CO_3 (120)	THF	60	12	68
21	Cs_2CO_3 (120)	THF	25	12	5

[a] Reaction conditions: **4a** (0.1 mmol), solvent (1 mL), under argon atmosphere. [b] HPLC yields using naphthalene as an internal standard. [c] N.D. = not detected by HPLC.

With the optimized conditions in hand, we next explored the scope and limitations of this reaction (Table 6). Electron-neutral group (entry 1), -donating groups (entries 2–4), -withdrawing groups (entries 6–11) in aryl R^1 were tolerated, and the desired products were isolated with low to high yields (10–90%). However, the substrate **4b** bearing 2-MeC_6H_4 exhibited very low efficiency (10% yield, entry 2), and the substrate **4e** bearing 2-$MeOC_6H_4$ gave a very compilcated mixture, the desired product **5e** was not successfully isolated (entry 5). This probably is attributed to the steric factor. A fused ring was also suitable for this process (entry 12). Changing ^{n}Pr (R^2) to Et had no significant effect on the yield (entry 13 versus entry 1). When R^2 was phenyl, a *Z*/*E* = 1:1.4 mixture **5n** was obtained in 20% yield (entry 14). The electronic properties of the sulfonyl group (R^3) had a very slightly impact on the yield (entries 8, 15, and 16; the substrates **4h**, **4o**, and **4p** generated the same product, labeled as **5h**).

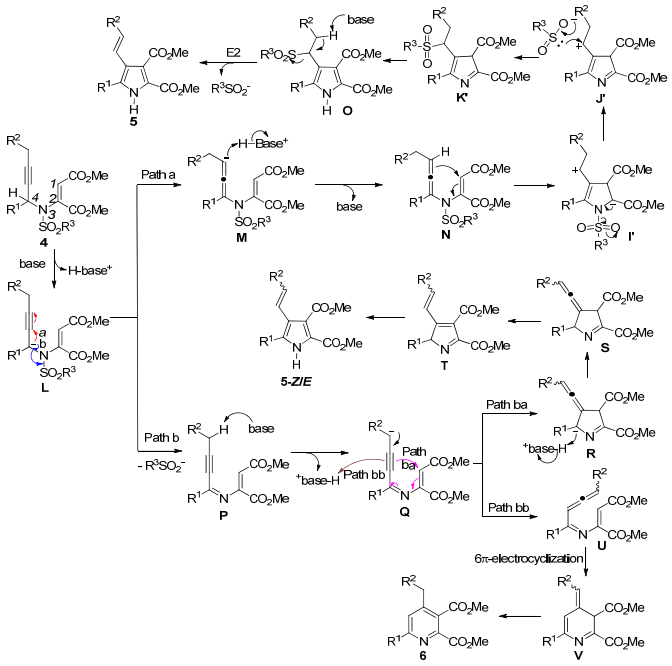
Table 6. Scope of the synthesis of pyrroles **5**[a]



Entry	**4**	R^1	R^2	R^3	**5**	Yield (%)[b]
1	**4a**	Ph	^{n}Pr	4-MeC_6H_4	**5a**	86
2	**4b**	2-MeC_6H_4	^{n}Pr	4-MeC_6H_4	**5b**	10
3	**4c**	3-MeC_6H_4	^{n}Pr	4-MeC_6H_4	**5c**	80
4	**4d**	4-MeC_6H_4	^{n}Pr	4-MeC_6H_4	**5d**	69
5	**4e**	2-$MeOC_6H_4$	^{n}Pr	4-MeC_6H_4	**5e**	-[c]

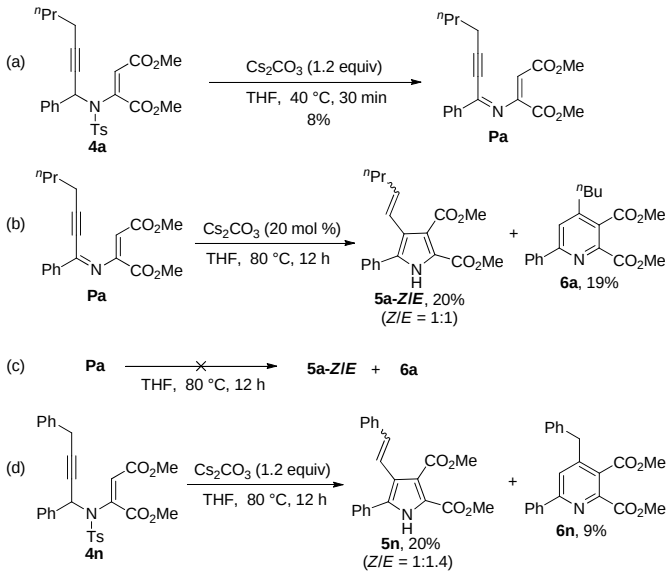
6	**4f**	3-MeOC$_6$H$_4$	^{n}Pr	4-MeC$_6$H$_4$	**5f**	90
7	**4g**	2-FC$_6$H$_4$	^{n}Pr	4-MeC$_6$H$_4$	**5g**	82
8	**4h**	4-FC$_6$H$_4$	^{n}Pr	4-MeC$_6$H$_4$	**5h**	82
9	**4i**	4-ClC$_6$H$_4$	^{n}Pr	4-MeC$_6$H$_4$	**5i**	87
10	**4j**	4-BrC$_6$H$_4$	^{n}Pr	4-MeC$_6$H$_4$	**5j**	74
11	**4k**	2-CF$_3$C$_6$H$_4$	^{n}Pr	4-MeC$_6$H$_4$	**5k**	70
12	**4l**	2-naphthyl	^{n}Pr	4-MeC$_6$H$_4$	**5l**	79
13	**4m**	Ph	Et	4-MeC$_6$H$_4$	**5m**	82
14	**4n**	Ph	Ph	4-MeC$_6$H$_4$	**5n**[d]	20
15	**4o**	4-FC$_6$H$_4$	^{n}Pr	Ph	**5h**	79
16	**4p**	4-FC$_6$H$_4$	^{n}Pr	4-ClC$_6$H$_4$	**5h**	78

[a] Reaction conditions: **4** (0.3 mmol), Cs_2CO_3 (0.36 mmol), THF (3 mL), 80 °C, 12 h, under argon atmosphere. [b] Isolated yields. [c] Very complicated mixtures, the desired products was not successfully obtained. [d] A *Z*/*E* = 1:1.4 mixture.



Scheme 6 Proposed mechanism for the formation of pyrrole **5**.

After exploring the substrate scope, we then turned our attention to the mechanism (Scheme 6). Initially, the base abstracts the proton bound to C4 of the starting material **4** to generate anion intermediate **L** and $^+$base-H species. There are two possible pathways (Path a and Path b) for the following reactions. In Path a, allene intermediate **N** is formed by giving back the proton of $^+$base-H. Then intermediate **N** passes through intermediates similar to that described in Scheme 4, that is **I'–K'**, to give pyrrole **O**.[3a] Followed by elimination of R^3SO_2H (the final byproducts are R^3SO_2Cs and $CsHCO_3$) to generate the pyrrole **5**. This elimiantion propbly is an E2 process for the (*Z*)-isomer is the sole product. Another possilble pathway (Path b) is that reactant **4** firstly eliminates R^3SO_2H (the final byproducts are R^3SO_2Cs and $CsHCO_3$) to form aza-dien-yne intermediate **P** (Path b). The base abatract a proton of **P** to give intermediate **Q**. There are also two pathways (Path ba and Path bb) for the following reactions of **Q**. In Path ba, directly cyclization to generate intermediate **R**, and returning the proton to give intermediate **S**. Then intermediate **S** passes through two isomeriazations to generate the ***Z*/*E*** mixture product **5-*Z*/*E***. In Path bb, another kind of allene **U** is formed, then a 6π-clectrocyclization occurs to give intermediate **V**. Intermediate **V** isomerized to pyridine **6**. Unfortunately, we are failed to obtain the intermediate **O**. However, to our delight, we successfully isolated the intermediate **Pa** albeit in very low yield (8%) at a lower temparature (40 °C) and for a shorter reaction time (30 min) (Scheme 7a). When the compound **Pa** was used as starting material in the presence of 20 mol% of Cs_2CO_3, a *Z*/*E* = 1 : 1 mixture pyrrole **5a-*Z*/*E*** was obtained in 20% yield, accompanied with pyridine **6a**[3d] in 19% yield (Scheme 7b). In contrast, in the absence of the base (Cs_2CO_3), no reaction took place, and recovering of the starting material **Pa** (Scheme 7c). The phenyl (R^2)-substituted **4n** aslo generate a *Z*/*E* mixture **5n** and pyrrole **6n** under the standard conditions in 20%, and 9% yield, respectively (Scheme 7d). These mechanistic studies suggest that both Path a and Path b are plausible. For the substrates where R^2 was alkyl, Path a was dominant. In contrast, when R^2 was aryl, the raction probably mainly passed through Path b.



Scheme 7 Mechanistic studies.

Conclusions

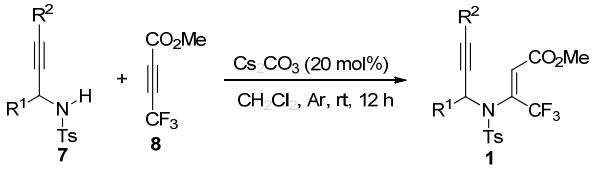
In summary, we have developed efficient cyclization strategies for the synthesis of functionalized 2-trifluoromethyl-5-(arylsulfonyl)methyl pyrroles, 2-trifluoromethyl-4-(arylsulfonyl)methyl pyrroles, and alkyvinyl pyrroles from the versatile 3-aza-1,5-enynes. The chemoselectivity of these reactions was controlled by the reaction conditions and substitution patterns of the starting materials. In these three transfer processes, the C–S bond of sulfamide in the starting materials broke down via sulfonyl group migration or aryl sulfinic acid elimination. The reaction pathways of 3-aza-1,5-enynes such as aza-Claisen rearrangement/cyclization, propargyl-allene isomerization/cyclization, propargyl-allene isomerization/cyclization/sulfinic acid elimination, and sulfinic acid elimination/cyclization, were proposed in the plausible mechanisms. And an important

intermediate, aza-diene-yne, was successfully isolated in the course of mechanism studies. These results maybe will provide new insight into the chemistry of enyne cycloisomerization.

Experimental section

General Information. Solvents were treated to anhydrous prior to use according to the standard methods or purchased from commercial sources in anhydrous grade. All reactions were carried out under an atmosphere of argon using standard Schlenk techniques or in an argon filled glove-box. Column chromatography was carried out on silica gel (300–400 mesh) using a forced flow of eluent at 0.3–0.5 bar pressure. ^{1}H NMR, ^{13}C NMR and ^{19}F NMR were recorded at a 400 or 500 MHz spectrometers at room temperature. The chemical shifts for ^{1}H NMR were recorded in ppm downfield from tetramethylsilane (TMS) with TMS resonance (0.00 ppm) as the internal standard. The chemical shifts for ^{13}C NMR were recorded in ppm downfield using the central peak of $CDCl_3$ (77.16 ppm) or $(CD_3)_2CO$ (29.84 ppm) as the internal standard.[14] Coupling constants (*J*) are reported in Hz and refer to apparent peak multiplications. The abbreviations *s*, *d*, *t*, *q* and *m* stand for singlet, doublet, triplet, quartet and multiplet in that order. HRMS data were obtained with a HPLC–Q–TOF mass spectrometer (ESI).

General Procedure for Preparation the Starting Materials 3-Aza-1,5-enynes 1. 3-Aza-1,5-enynes **1** was prepared according literature[3c]: propargyl amine **7**[15] was placed in a dried flask, CH_2Cl_2 was added until the dissolution of the solid. Subsequenly, alkyne **8**[16] (1.2 equiv) and Cs_2CO_3 (20 mol%) was added. The resulting mixture was stirred at room temperature under argon atmosphere until the consummation of popargyl amines detected by TLC (usually 12 h). The solvent was evaporated under vacuum and the crude product was directly purified by silica gel flash column chromatography eluting with petroleum ether/ethyl acetate (20 : 1, v/v) to give the desired compounds **1**. Compounds **1a–1t** and **1a-D** are known.[3c] Compounds **1u** and **1v** are new.



(*E*)-methyl4,4,4-trifluoro-3-(*N*-(1-(4-fluorophenyl)-3-phenylprop-2-yn-1-yl)-phen-ylsulfonamido)but-2-enoate (1u): white solid; 548.8 mg (in 5.0 mmol scale); 21% yield; mp 87–88 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.03 – 7.92 (m, 2H), 7.62 (t, *J* = 7.4 Hz, 1H), 7.57 – 7.50 (m, 4H), 7.38 – 7.27 (m, 3H), 7.25 – 7.15 (m, 2H), 7.05 (t, *J* = 8.6 Hz, 2H), 6.42 (s, 1H), 6.33 (s, 1H), 3.75 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.3 (d, *J* = 249.0 Hz), 162.4, 138.1, 133.9, 133.8, 131.7, 131.1 (d, *J* = 8.5 Hz), 130.4 (d, *J* = 3.2 Hz), 129.4, 129.3, 128.8, 128.7, 128.6, 121.3, 119.5 (q, *J* = 277.9 Hz), 115.8 (d, *J* = 21.9 Hz), 90.0, 83.3, 56.3, 52.8; ^{19}F NMR (376 MHz, $CDCl_3$) δ -62.73 (s, 3F), -111.98 (s, 1F); HRMS (Q-TOF, m/z) calcd for $C_{26}H_{23}F_4N_2O_4S$ $[M + NH_4]^+$ 535.1309, found 535.1317.

(*E*)-methyl 3-(*N*-(1-(2-bromophenyl)-3-phenylprop-2-yn-1-yl)phenylsulfonamido)-4,4,4-trifl- uorobut-2-enoate (1v): white solid; 1.10 g (in 5.0 mmol scale); 38% yield; mp 112–113 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 (d, *J* = 7.6 Hz, 2H), 7.66 – 7.54 (m, 3H), 7.47 (t, *J* = 7.6 Hz, 2H), 7.39 – 7.28 (m, 4H), 7.28 – 7.17 (m, 3H), 6.84 (s, 1H), 6.55 (s, 1H), 3.75 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.4, 133.8, 133.6, 133.3, 132.1, 131.5, 131.2, 129.3, 129.2, 129.1, 128.9, 128.5, 127.6, 125.2, 121.2, 119.4 (q, *J* = 278.2 Hz), 89.7, 84.1, 56.7, 52.8; ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.47; HRMS (Q-TOF, m/z) calcd for $C_{26}H_{23}BrF_3N_2O_4S$ $[M + NH_4]^+$ 595.0509, found 595.0523.

General Procedure for Synthesis of Pyrroles 2. To a glass Schlenk tube (10 mL) equipped with a magnetic stirrer bar, starting material **1** (0.2 mmol), $AgOOCCF_3$ (2.2 mg, 5 mol%) and DMF (1 mL) were added. The resulting mixture was stirred at 80 °C under argon protection for 24 h. After cooling down to room temperature, the solvent was removed under vacuum. The residue was directly purified by silica gel flash column chromatography eluting with petroleum ether/ethyl acetate (20 : 1, v/v) to give the desired pyrroles **2**.

Methyl 4-phenyl-5-(phenyl(tosyl)methyl)-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (2a): white solid; 86.1 mg; 84% yield; mp 152–153 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.10 (s, 1H), 7.41 – 7.32 (m, 7H), 7.30 – 7.18 (m, 5H), 6.72 – 6.62 (m, 2H), 5.17 (s, 1H), 3.62 (s, 3H), 2.41 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.8, 145.6, 134.5, 132.0, 131.0, 129.91, 129.87, 129.7, 129.6, 129.4, 129.2, 128.4, 128.0, 127.9, 123.6 (q, *J* = 40.0 Hz), 122.7, 120.3 (q, *J* = 268.9 Hz), 114.9 (q, *J* = 1.9 Hz), 66.6, 51.6, 21.7; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.67; HRMS (Q-TOF, m/z) calcd for $C_{27}H_{23}F_3NO_4S^+$ $[M + H]^+$ 514.1294, found 514.1286.

Methyl 4-phenyl-5-(phenyl(tosyl)methyl)-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate-d_6 (2a-D): white solid; 87.1 mg; 84% yield; mp 151–152 °C;^{1}H NMR (400 MHz, $CDCl_3$) δ 10.08 (s, 1H), 7.38 (d, *J* = 8.3 Hz, 2H), 7.31 – 7.17 (m, 5H), 6.81 – 6.57 (m, 2H), 5.17 (s, 0.03H), 3.62 (s, 3H), 2.41 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.8, 145.6, 134.5, 132.0, 129.91, 129.88, 129.7, 128.4, 128.0, 127.9, 123.6 (q, *J* = 40.3 Hz), 122.7, 120.3 (q, *J* = 268.7 Hz), 114.9 (q, *J* = 2.4 Hz), 51.6, 21.7; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.12; HRMS (Q-TOF, m/z) calcd for $C_{27}H_{17}D_6F_3NO_4S^+$ $[M + H]^+$ 520.1671, found 520.1674.

Methyl 4-phenyl-5-(*o*-tolyl(tosyl)methyl)-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (2b): white solid; 84.2 mg; 80% yield; mp 150–151 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.27 (s, 1H), 7.64 (d, *J* = 7.6 Hz, 1H), 7.43 (d, *J* = 8.3 Hz, 2H), 7.30 – 7.20 (m, 7H), 7.05 (d, *J* = 7.2 Hz, 1H), 6.72 (d, *J* = 6.8 Hz, 2H), 5.53 (s, 1H), 3.62 (s, 3H), 2.41 (s, 3H), 1.69 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.8, 145.6, 137.8, 134.8, 132.4, 131.2, 130.0, 129.9, 129.49, 129.45, 129.4, 128.8, 128.4, 128.1, 127.9, 126.9, 123.41 (q, *J* = 39.4 Hz), 123.36, 120.3 (q, *J* = 268.7 Hz), 114.9, 62.2, 51.6, 21.8, 19.1; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.67; HRMS (Q-TOF, m/z) calcd for $C_{28}H_{25}F_3NO_4S^+$ $[M + H]^+$ 528.1451, found 528.1474.

Methyl 4-phenyl-5-(*m*-tolyl(tosyl)methyl)-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (2c): white solid; 70.2 mg; 67% yield; mp 119–120 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.05 (s, 1H), 7.38 (d, *J* = 8.3 Hz, 2H), 7.31 – 7.27 (m, 1H), 7.26 – 7.16 (m, 6H), 7.12 (d, *J* = 5.5 Hz, 2H), 6.71 – 6.61 (m, 2H),

5.13 (s, 1H), 3.62 (d, *J* = 2.8 Hz, 3H), 2.42 (s, 3H), 2.33 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.8, 145.5, 139.1, 134.7, 132.0, 130.9, 130.3, 130.2, 130.0, 129.9, 129.7, 129.2, 128.5, 128.0, 127.9, 126.7, 123.6 (q, *J* = 39.5 Hz), 122.8, 120.3 (q, *J* = 268.8 Hz), 114.9 (q, *J* = 1.9 Hz), 66.6, 51.6, 21.8, 21.6; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.13; HRMS (Q-TOF, m/z) calcd for $C_{28}H_{25}F_3NO_4S^+$ $[M + H]^+$ 528.1451, found 528.1468.

Methyl 4-phenyl-5-(*p*-tolyl(tosyl)methyl)-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (2d): white solid; 76.5 mg; 73% yield; mp 148–149 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.07 (s, 1H), 7.37 (t, *J* = 9.4 Hz, 3H), 7.24 – 7.15 (m, 8H), 6.76 – 6.59 (m, 2H), 5.14 (s, 1H), 3.61 (s, 3H), 2.41 (s, 3H), 2.34 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.8, 145.5, 139.5, 134.7, 132.0, 130.0, 129.92, 129.85, 129.5, 129.2, 128.7, 128.4, 127.9, 127.8, 123.5 (q, *J* = 39.5 Hz), 122.9, 120.3 (q, *J* = 268.7 Hz), 114.9 (q, *J* = 2.0 Hz), 66.4, 51.6, 21.7, 21.3; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.09; HRMS (Q-TOF, m/z) calcd for $C_{28}H_{25}F_3NO_4S$ $[M + H]^+$ 528.1451, found 528.1467.

Methyl 5-((2-fluorophenyl)(tosyl)methyl)-4-phenyl-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (2f): white solid; 89.8 mg; 84% yield; mp 157–158 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.15 (s, 1H), 7.61 (td, *J* = 7.6, 1.6 Hz, 1H), 7.40 (d, *J* = 8.3 Hz, 2H), 7.37 – 7.18 (m, 7H), 7.00 (ddd, *J* = 9.6, 8.3, 0.9 Hz, 1H), 6.76 – 6.66 (m, 2H), 5.61 (s, 1H), 3.63 (s, 3H), 2.42 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.8, 160.6 (d, *J* = 249.9 Hz), 145.7, 134.2, 131.8, 131.5 (d, *J* = 8.7 Hz), 130.4 (d, *J* = 1.9 Hz), 130.1, 129.9, 129.8, 128.5, 127.94, 127.87, 125.1 (d, *J* = 3.7 Hz), 123.8 (q, *J* = 39.5 Hz), 121.9, 120.2 (q, *J* = 268.6 Hz), 118.8, 116.2 (q, *J* = 22.6 Hz), 115.0 (q, *J* = 2.2 Hz), 59.5, 59.5, 51.6, 21.7; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.75 (s, 3F), -116.02 (s, 1F); HRMS (Q-TOF, m/z) calcd for $C_{27}H_{22}F_4NO_4S^+$ $[M + H]^+$ 532.1200, found 532.1225.

Methyl 5-((4-fluorophenyl)(tosyl)methyl)-4-phenyl-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (2g): white solid; 82.3 mg; 77% yield; mp 165–166 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.11 (s, 1H), 7.39 (d, *J* = 8.3 Hz, 2H), 7.33 – 7.27 (m, 3H), 7.26 – 7.20 (m, 4H), 7.11 – 7.00 (m, 2H), 6.65 (dt, *J* = 8.3, 1.9 Hz, 2H), 5.15 (s, 1H), 3.62 (s, 3H), 2.43 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.3 (d, *J* = 250.0 Hz), 162.7, 145.7, 134.4, 131.9, 131.5 (d, *J* = 8.5 Hz), 130.0, 129.83, 129.79, 128.4, 128.00, 127.95, 126.8 (d, *J* = 3.4 Hz), 123.7 (q, *J* = 39.5 Hz), 122.4, 120.2 (q, *J* = 268.8 Hz), 116.3 (d, *J* = 21.8 Hz), 115.1 (q, *J* = 2.1 Hz), 65.9, 51.6, 21.7; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.66 (s, 3F), -112.03 (s, 1F); HRMS (Q-TOF, m/z) calcd for $C_{27}H_{22}F_4NO_4S^+$ $[M + H]^+$ 532.1200, found 532.1202.

Methyl 5-((2-chlorophenyl)(tosyl)methyl)-4-phenyl-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (2h): white solid; 100.1 mg; 92% yield; mp 143–144°C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.29 (s, 1H), 7.77 (d, *J* = 7.6 Hz, 1H), 7.43 (d, *J* = 8.1 Hz, 2H), 7.36 – 7.31 (m, 1H), 7.28 – 7.16 (m, 7H), 6.75 (d, *J* = 7.4 Hz, 2H), 6.02 (s, 1H), 3.63 (s, 3H), 2.41 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.8, 145.8, 135.4, 134.3, 131.9, 130.6, 130.3, 130.2, 130.0, 129.9, 129.6, 129.2, 128.7, 128.0, 127.8, 127.7, 123.7 (q, *J* = 39.5 Hz), 122.4, 120.3 (q, *J* = 268.7 Hz), 115.2 (q, *J* = 2.2 Hz), 62.0, 51.6, 21.8; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.12; HRMS (Q-TOF, m/z) calcd for $C_{27}H_{22}ClF_3NO_4S^+$ $[M + H]^+$ 548.0905, found 548.0911.

Methyl 5-((2-bromophenyl)(tosyl)methyl)-4-phenyl-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (2i): white solid; 98.3 mg; 83% yield; mp 146–149 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.31 (s, 1H), 7.77 (dd, *J* = 7.9, 1.5 Hz, 1H), 7.49 – 7.42 (m, 3H), 7.36 (td, *J* = 7.7, 1.1 Hz, 1H), 7.29 – 7.14 (m, 6H), 6.80 – 6.71 (m, 2H), 6.06 (s, 1H), 3.62 (s, 3H), 2.41 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.8, 145.8, 134.3, 133.6, 131.9, 130.8, 130.7, 130.34, 130.28, 130.1, 129.9, 128.7, 128.2, 128.1, 127.8, 126.4, 123.6 (q, *J* = 39.5 Hz), 122.4, 120.3 (q, *J* = 268.9 Hz), 115.1 (q, *J* = 2.1 Hz), 64.8, 51.6, 21.8; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.64; HRMS (Q-TOF, m/z) calcd for $C_{27}H_{22}BrF_3NO_4S^+$ $[M + H]^+$ 592.0400, found 592.0403.

Methyl 4-phenyl-5-(tosyl(2-(trifluoromethyl)phenyl)-methyl)-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (2j): white solid; 80.0 mg; 69% yield; mp 149–150 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.26 (s, 1H), 8.03 (d, *J* = 7.9 Hz, 1H), 7.60 (dd, *J* = 17.9, 7.8 Hz, 2H), 7.50 (d, *J* = 8.3 Hz, 2H), 7.45 (t, *J* = 7.7 Hz, 1H), 7.32 – 7.24 (m, 3H), 7.19 (dd, *J* = 11.5, 4.4 Hz, 2H), 6.58 (d, *J* = 7.2 Hz, 2H), 5.86 (s, 1H), 3.61 (s, 3H), 2.44 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.8, 146.1, 134.5, 132.5, 131.6, 130.9, 130.6, 130.3, 130.1, 130.0, 129.8, 129.5, 129.1, 128.8, 127.9, 127.3 (q, *J* = 5.5 Hz), 123.9 (q, *J* = 39.5 Hz), 121.7, 120.6 (q, *J* = 275.0 Hz), 120.3 (q, *J* = 268.9 Hz), 115.4 (q, *J* = 2.0 Hz), 61.9, 51.6, 21.8; ^{19}F NMR (376 MHz, $CDCl_3$) δ -58.46 (s, 3F), -59.72 (s, 3F); HRMS (Q-TOF, m/z) calcd for $C_{28}H_{22}F_6NO_4S^+$ $[M + H]^+$ 582.1168, found 582.1166.

Methyl 5-(naphthalen-1-yl(tosyl)methyl)-4-phenyl-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (2k): white solid; 79.1 mg; 70% yield; mp 169–170 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.29 (s, 1H), 8.03 (d, *J* = 7.3 Hz, 1H), 7.84 (d, *J* = 8.2 Hz, 1H), 7.78 (d, *J* = 8.1 Hz, 1H), 7.52 (t, *J* = 7.8 Hz, 1H), 7.44 – 7.36 (m, 3H), 7.30 (t, *J* = 7.4 Hz, 1H), 7.22 – 7.15 (m, 3H), 7.14 – 7.08 (m, 3H), 6.66 (d, *J* = 7.8 Hz, 2H), 6.16 (s, 1H), 3.62 (s, 3H), 2.32 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.8, 145.6, 134.7, 134.0, 132.2, 131.3, 130.23, 130.17, 129.8, 129.6, 129.1, 128.5, 128.0, 127.9, 127.44, 127.42, 126.8, 126.0, 125.4, 123.7 (q, *J* = 39.5 Hz), 123.3, 122.1, 120.3 (q, *J* = 268.7 Hz), 114.9 (q, *J* = 2.1 Hz), 61.0, 51.6, 21.6; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.60; HRMS (Q-TOF, m/z) calcd for $C_{31}H_{25}F_3NO_4S^+$ $[M + H]^+$ 564.1451, found 564.1461.

Methyl 5-phenyl-4-(*o*-tolyl(tosyl)methyl)-2-(trifluoro-methyl)-1*H*-pyrrole-3-carboxylate (2m): white solid; 78% yield; 82.0 mg; mp 152–153 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.25 (s, 1H), 7.64 (d, *J* = 7.4 Hz, 1H), 7.43 (d, *J* = 8.2 Hz, 2H), 7.25 (dt, *J* = 21.7, 7.5 Hz, 7H), 7.05 (d, *J* = 7.3 Hz, 1H), 6.72 (d, *J* = 6.8 Hz, 2H), 5.53 (s, 1H), 3.62 (s, 3H), 2.41 (s, 3H), 1.69 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.8, 145.6, 137.8, 134.8, 132.4, 131.2, 130.0, 129.9, 129.49, 129.46, 129.4, 128.8, 128.4, 128.1, 127.9, 126.9, 123.41 (q, *J* = 39.5 Hz), 123.36, 120.3 (q, *J* = 268.7 Hz), 114.9 (d, *J* = 2.1 Hz), 62.1, 51.6, 21.8, 19.1; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.11; HRMS (Q-TOF, m/z) calcd for $C_{28}H_{25}F_3NO_4S^+$ $[M + H]^+$ 528.1451, found 528.1456.

Methyl 5-(phenyl(tosyl)methyl)-4-(*m*-tolyl)-2-(trifluoro-methyl)-1*H*-pyrrole-3-carboxylate (2n): white solid; 88.5 mg; 84% yield; mp 132–133 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.08 (s, 1H), 7.41 – 7.33 (m, 7H), 7.22 (d, *J* = 8.2 Hz, 2H), 7.11 (dd, *J* = 11.8, 7.4 Hz, 2H), 6.52 (d, *J* = 7.1 Hz, 1H), 6.33 (s, 1H), 5.16 (s,

1H), 3.63 (s, 3H), 2.43 (s, 3H), 2.23 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.8, 145.5, 137.4, 134.7, 131.9, 131.2, 130.5, 130.0, 129.9, 129.6, 129.4, 129.3, 128.7, 128.5, 127.9, 127.1, 123.5 (q, *J* = 39.5 Hz), 122.7, 120.3 (q, *J* = 268.9 Hz), 114.9 (q, *J* = 2.1 Hz), 66.7, 51.6, 21.8, 21.4; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.10; HRMS (Q-TOF, m/z) calcd for $C_{28}H_{28}F_3N_2O_4S$ $[M + NH_4]^+$ 545.1716, found 545.1728.

Methyl 5-(phenyl(tosyl)methyl)-4-(*p*-tolyl)-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (2o): white solid; 90.3 mg; 86% yield; mp 122–123 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.07 (s, 1H), 7.41 – 7.32 (m, 7H), 7.21 (d, *J* = 8.0 Hz, 2H), 7.04 (d, *J* = 7.8 Hz, 2H), 6.55 (d, *J* = 8.0 Hz, 2H), 5.19 (s, 1H), 3.63 (s, 3H), 2.42 (s, 3H), 2.34 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.9, 145.5, 137.6, 134.6, 131.1, 129.9, 129.8, 129.6, 129.5, 129.4, 129.2, 128.9, 128.7, 128.5, 123.5 (q, *J* = 39.5 Hz), 122.6, 120.3 (q, *J* = 268.8 Hz), 114.9 (q, *J* = 2.2 Hz), 66.6, 51.6, 21.7, 21.3; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.66; HRMS (Q-TOF, m/z) calcd for $C_{28}H_{25}F_3NO_4S^+$ $[M + H]^+$ 528.1451, found 528.1471.

Methyl 4-(4-fluorophenyl)-5-(phenyl(tosyl)methyl)-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (2p): white solid; 78.0 mg; 73% yield; mp 173–174 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.13 (s, 1H), 7.43 – 7.27 (m, 7H), 7.21 (d, *J* = 8.1 Hz, 2H), 6.94 (t, *J* = 8.6 Hz, 2H), 6.67 (dd, *J* = 8.4, 5.5 Hz, 2H), 5.11 (s, 1H), 3.64 (s, 3H), 2.42 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.7, 162.5 (d, *J* = 247.5 Hz), 145.7, 134.5, 131.7 (d, *J* = 8.1 Hz), 131.4, 131.0, 129.9, 129.53, 129.49, 129.3, 128.7, 128.5, 127.9 (d, *J* = 3.3 Hz), 123.8 (q, *J* = 39.6 Hz), 122.9, 120.2 (q, *J* = 268.9 Hz), 115.04 (d, *J* = 21.5 Hz), 66.7, 51.3, 21.8; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.19 (s, 3F), -113.92 (s, 1F); HRMS (Q-TOF, m/z) calcd for $C_{27}H_{22}F_4NO_4S^+$ $[M + H]^+$ 532.1200, found 532.1210.

Methyl 4-(4-chlorophenyl)-5-(phenyl(tosyl)methyl)-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (2q): white solid; 90.8 mg; 83% yield; mp 157–158 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.15 (s, 1H), 7.41 – 7.32 (m, 5H), 7.31 – 7.26 (m, 2H), 7.25 – 7.26 (m, 4H), 6.64 (d, *J* = 8.3 Hz, 2H), 5.10 (s, 1H), 3.64 (s, 3H), 2.42 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.6, 145.7, 134.4, 134.1, 131.4, 131.0, 130.5, 129.9, 129.5, 129.3, 128.5, 128.5, 128.33, 128.27, 123.9 (q, *J* = 39.5 Hz), 122.9, 120.2 (q, *J* = 269.0 Hz), 114.9 (q, *J* = 2.0 Hz), 66.7, 51.7, 21.8; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.20; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.12; HRMS (Q-TOF, m/z) calcd for $C_{27}H_{22}ClF_3NO_4S^+$ $[M + H]^+$ 548.0905, found 548.0908.

Methyl 5-(phenyl(tosyl)methyl)-4-propyl-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (2r): white solid; 95.9 mg; 71% yield; mp 143–144 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.02 (s, 1H), 7.50 (d, *J* = 8.2 Hz, 2H), 7.35 (s, 5H), 7.22 (d, *J* = 8.1 Hz, 2H), 5.37 (s, 1H), 3.80 (s, 3H), 2.46 – 2.29 (m, 5H) (3H + 2H), 1.09 (dd, *J* = 14.7, 7.3 Hz, 2H), 0.66 (t, *J* = 7.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.4, 145.7, 134.6, 131.2, 129.9, 129.7, 129.4, 129.2, 129.0, 128.6, 123.5 (q, *J* = 39.1 Hz), 121.5, 120.4 (q, *J* = 268.6 Hz), 114.6 (q, *J* = 1.9 Hz), 66.9, 51.5, 26.3, 23.9, 21.7, 13.9; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.23; HRMS (Q-TOF, m/z) calcd for $C_{24}H_{28}F_3N_2O_4S^+$ $[M + NH_4]^+$ 497.1722, found 497.1732.

Methyl 4-butyl-5-(phenyl(tosyl)methyl)-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (2s): white solid; 74.4 mg; 75% yield; mp 89–90 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.04 (s, 1H), 7.51 (d, *J* = 8.2 Hz, 2H), 7.36 (s, 5H), 7.23 (d, *J* = 8.1 Hz, 2H), 5.36 (s, 1H), 3.80 (s, 3H), 2.45 – 2.32 (m, 5H), 1.09 – 1.02 (m, 2H), 0.96 – 0.82 (m, 2H), 0.73 (t, *J* = 7.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.4, 145.7, 134.6, 131.1, 129.9, 129.7, 129.4, 129.3, 129.2, 128.6, 123.5 (q, *J* = 39.3 Hz), 121.4, 120.4 (q, *J* = 268.5 Hz), 114.5 (q, *J* = 1.9 Hz), 66.8, 51.5, 32.9, 24.1, 22.5, 21.7, 13.9; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.23; HRMS (Q-TOF, m/z) calcd for $C_{25}H_{30}F_3N_2O_4S^+$ $[M + NH_4]^+$ 511.1873, found 511.1922.

Methyl 4-cyclohexyl-5-(phenyl(tosyl)methyl)-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (2t): white solid; 48.8 mg; 47% yield; mp 151–152 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.04 (s, 1H), 7.51 (d, *J* = 8.3 Hz, 2H), 7.37 (s, 5H), 7.24 (d, *J* = 8.1 Hz, 2H), 5.60 (s, 1H), 3.81 (s, 3H), 2.79 – 2.67 (m, 1H), 2.39 (s, 3H), 1.62 (d, *J* = 6.3 Hz, 3H), 1.33 – 1.21 (m, 3H), 1.20 – 1.13 (m, *J* = 22.4, 5.9 Hz, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.1, 145.7, 134.8, 132.8, 131.1, 129.92, 129.89, 129.4, 129.2, 128.6, 122.9 (q, *J* = 39.0 Hz), 120.9, 120.5 (q, *J* = 268.2 Hz), 114.8 (q, *J* = 2.0 Hz), 67.4, 51.7, 36.0, 32.4, 32.2, 27.2, 27.1, 26.1, 21.7; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.04; HRMS (Q-TOF, m/z) calcd for $C_{27}H_{32}F_3N_2O_4S^+$ $[M + NH_4]^+$ 537.2029, found 537.2046.

Methyl 5-((4-fluorophenyl)(phenylsulfonyl)methyl)-4-phenyl-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (2u): white solid; 73.6 mg; 71% yield; mp 138–139 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.08 (s, 1H), 7.63 (t, *J* = 7.3 Hz, 1H), 7.52 (d, *J* = 7.3 Hz, 2H), 7.44 (t, *J* = 7.8 Hz, 2H), 7.31 (td, *J* = 8.9, 6.3 Hz, 3H), 7.23 (t, *J* = 7.4 Hz, 2H), 7.06 (t, *J* = 8.5 Hz, 2H), 6.63 (d, *J* = 7.0 Hz, 2H), 5.17 (s, 1H), 3.61 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.4 (d, *J* = 250.3 Hz), 162.7, 137.4, 134.5, 131.8, 131.6 (d, *J* = 8.5 Hz), 130.0, 129.9, 129.4, 128.4, 128.1, 128.0, 126.7 (d, *J* = 3.5 Hz), 123.9 (q, *J* = 39.6 Hz), 122.2, 120.2 (q, *J* = 268.9 Hz), 116.4 (d, *J* = 21.9 Hz), 115.1 (q, *J* = 2.2 Hz), 65.9, 51.7; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.17 (s, 3F), -111.24 (s, 1F); HRMS (Q-TOF, m/z) calcd for $C_{26}H_{20}F_4NO_4S^+$ $[M + H]^+$ 518.1044, found 518.1050.

Methyl 5-((2-bromophenyl)(phenylsulfonyl)methyl)-4-phenyl-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (2v): white solid; 91.1 mg; 79% yield; mp 146–147 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.26 (s, 1H), 7.77 (dd, *J* = 7.9, 1.5 Hz, 1H), 7.65 – 7.56 (m, 3H), 7.47 – 7.37 (m, 4H), 7.29 – 7.17 (m, 4H), 6.79 – 6.71 (m, 2H), 6.07 (s, 1H), 3.63 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.8, 137.3, 134.6, 133.7, 131.9, 130.9, 130.7, 130.5, 130.4, 130.1, 129.3, 128.7, 128.3, 128.2, 127.9, 126.4, 123.8 (q, *J* = 39.5 Hz), 122.2, 120.3 (q, *J* = 268.7 Hz), 115.3 (q, *J* = 2.1 Hz), 64.8, 51.7; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.17; HRMS (Q-TOF, m/z) calcd for $C_{26}H_{20}BrF_3NO_4S^+$ $[M + H]^+$ 578.0243, found 578.0246.

Procedure for the Crossover Experiment. To a glass Schlenk tube (10 mL) equipped with a magnetic stirrer bar, **1g** (53.2 mg, 0.1 mmol), **1v** (57.8 mg, 0.1 mmol), $AgOOCCF_3$ (2.2 mg, 5 mol%), and DMF (0.5 mL) were added. The resulting mixture was stirred at 80 °C under argon atmosphere for 24 h. After cooling down to room temperature, the mixture was diluted with acetonitrile (5 mL), and the products were determined by HPLC. **2g**:**2v**:**2u**:**2i** = 25:27:21:27 (the ratio of peak area in HPLC of the corresponding product).

General Procedure for Synthesis of Pyrroles 3. To a glass Schlenk tube (10 mL) equipped with a magnetic stirrer bar, starting material **1** (0.2 mmol), CsOPiv (4.7 mg, 10 mol%) and DMF (1 mL) were added. The resulting mixture was stirred at 100 °C under argon protection for 24 h. After cooling down to room temperature, the solvent was removed under vacuum. The residue was directly purified by silica gel flash column chromatography eluting with petroleum ether/ethyl acetate (20 : 1, v/v) to give the desired pyrroles **3**.

Methyl 5-phenyl-4-(phenyl(tosyl)methyl)-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (3a): white solid; 78.6 mg; 77% yield; mp 210–211 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.93 (s, 1H), 7.49 (d, *J* = 8.0 Hz, 2H), 7.32 (t, *J* = 7.4 Hz, 1H), 7.24 (d, *J* = 7.8 Hz, 2H), 7.19 (t, *J* = 7.6 Hz, 2H), 7.13 (d, *J* = 8.1 Hz, 2H), 7.08 (t, *J* = 7.3 Hz, 1H), 7.05 – 6.96 (m, 4H), 6.68 (s, 1H), 3.74 (s, 3H), 2.35 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.9, 144.3, 136.1, 135.3, 133.1, 130.7, 130.3, 129.8, 129.3, 129.2, 129.0, 127.93, 127.85, 127.6, 121.7 (q, *J* = 39.3 Hz), 120.3 (q, *J* = 268.7 Hz), 116.4 (q, *J* = 2.0 Hz), 115.3, 65.8, 51.7, 21.6; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.11; HRMS (Q-TOF, m/z) calcd for $C_{27}H_{26}F_3N_2O_4S^+$ $[M + NH_4]^+$ 531.1560, found 531.1588.

Methyl4-(phenyl(tosyl)methyl)-5-(*m*-tolyl)-2-(trifluoromethyl)-1*H*-pyrrole-3- carboxylate (3c): white solid; 77.3 mg; 73% yield; mp 214–215 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.89 (s, 1H), 7.48 (d, *J* = 8.2 Hz, 2H), 7.28 (d, *J* = 7.5 Hz, 2H), 7.12 (t, *J* = 9.3 Hz, 5H), 7.03 (t, *J* = 7.5 Hz, 2H), 6.95 – 6.85 (m, 1H), 6.62 (d, *J* = 8.5 Hz, 2H), 3.73 (s, 3H), 2.36 (s, 3H), 2.19 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.9, 144.2, 137.5, 136.1, 135.6, 133.2, 131.2, 130.1, 129.9, 129.8, 129.3, 129.0, 127.9, 127.8, 127.6, 121.54 (q, *J* = 39.3 Hz), 127.51, 120.3 (q, *J* = 268.5 Hz), 116.4 (q, *J* = 2.0 Hz), 115.1, 65.8, 51.7, 21.6, 21.3; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.08; HRMS (Q-TOF, m/z) calcd for $C_{28}H_{25}F_3NO_4S^+$ $[M + H]^+$ 528.1451, found 528.1453.

Methyl 4-(phenyl(tosyl)methyl)-5-(*p*-tolyl)-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (3d): white solid; 61.6 mg; 58% yield; mp 233–234 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.74 (s, 1H), 7.51 (d, *J* = 8.2 Hz, 2H), 7.27 (d, *J* = 7.5 Hz, 2H), 7.12 (dd, *J* = 14.8, 7.7 Hz, 3H), 7.03 (t, *J* = 6.9 Hz, 4H), 6.92 (d, *J* = 8.0 Hz, 2H), 6.67 (s, 1H), 3.76 (s, 3H), 2.36 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.9, 144.2, 139.3, 136.2, 135.4, 133.3, 130.6, 129.9, 129.3, 129.0, 128.7, 127.9, 127.6, 127.4, 121.6 (q, *J* = 39.4 Hz), 120.4 (q, *J* = 268.4 Hz), 116.4 (q, *J* = 2.3 Hz), 115.3, 65.9, 51.7, 21.7, 21.5; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.16; HRMS (Q-TOF, m/z) calcd for $C_{28}H_{25}F_3NO_4S^+$ $[M + H]^+$ 528.1451, found 528.1459.

Methyl 5-(2-fluorophenyl)-4-(phenyl(tosyl)methyl)-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (3f): white solid; 56.2 mg; 53% yield; mp 218–219 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.85 (s, 1H), 7.35 (d, *J* = 8.2 Hz, 2H), 7.17 – 7.11 (m, 1H), 7.07 – 7.03 (m, 2H), 6.99 – 6.89 (m, 4H), 6.98 – 6.90 (m, 3H), 6.67 (t, *J* = 9.0 Hz, 1H), 6.60 (s, 1H), 3.55 (s, 3H), 2.17 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.6, 161.0 (d, *J* = 249.1 Hz), 144.4, 135.9, 134.1, 132.9, 131.6 (d, *J* = 8.2 Hz), 129.6, 129.3, 129.1, 128.5, 127.9, 127.6, 123.6 (d, *J* = 3.6 Hz), 122.5 (q, *J* = 39.2 Hz), 120.2 (q, *J* = 268.6 Hz), 117.5, 116.2 (q, *J* = 2.1 Hz), 115.3, 115.1, 65.2, 51.6, 21.7; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.39 (s, 3F), -112.29 (s, 1F); HRMS (Q-TOF, m/z) calcd for $C_{27}H_{25}F_4N_2O_4S^+$ $[M + NH_4]^+$ 549.1466, found 549.1487.

Methyl 5-(4-fluorophenyl)-4-(phenyl(tosyl)methyl)-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (3g): white solid; 63.6 mg; 60% yield; mp 219–220 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.83 (s, 1H), 7.54 (d, *J* = 8.2 Hz, 2H), 7.18 (t, *J* = 8.2 Hz, 4H), 7.11 – 6.96 (m, 5H), 6.92 – 6.85 (m, 2H), 6.81 (s, 1H), 3.77 (s, 3H), 2.37 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.8, 163.4 (d, *J* = 249.4 Hz), 144.4, 136.0, 134.1, 133.1, 133.0, 129.7, 129.4, 129.1, 127.9, 127.6, 126.4 (d, *J* = 3.4 Hz), 121.8 (q, *J* = 39.4 Hz), 120.3 (q, *J* = 268.8 Hz), 116.24 (q, *J* = 2.3 Hz), 116.16, 114.9 (d, *J* = 21.7 Hz), 65.4, 51.7, 21.7; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.22 (s, 3F), -111.54 (s, 1F); HRMS (Q-TOF, m/z) calcd for $C_{27}H_{21}F_4NO_4SNa^+$ $[M + Na]^+$ 554.1020, found 554.1023.

Methyl 5-(2-chlorophenyl)-4-(phenyl(tosyl)methyl)-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (3h): white solid; 68.1 mg; 62% yield; mp 224–225 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.91 (s, 1H), 7.58 (d, *J* = 8.3 Hz, 2H), 7.48 (d, *J* = 7.0 Hz, 1H), 7.30 (td, *J* = 7.7, 1.8 Hz, 1H), 7.26 – 7.20 (m, 1H), 7.19 – 7.10 (m, 5H), 7.05 (t, *J* = 7.4 Hz, 1H), 6.92 (t, *J* = 7.7 Hz, 2H), 6.86 (s, 1H), 3.78 (s, 3H), 2.35 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.8, 144.3, 135.90, 135.86, 134.9, 132.1, 131.6, 131.0, 129.8, 129.4, 129.22, 129.20, 128.9, 127.8, 127.6, 126.2, 122.2 (q, *J* = 39.5 Hz), 120.3 (q, *J* = 268.4 Hz), 118.9, 115.9 (q, *J* = 2.2 Hz), 65.3, 51.7, 21.7; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.30; HRMS (Q-TOF, m/z) calcd for $C_{27}H_{25}ClF_3N_2O_4S^+$ $[M + NH_4]^+$ 565.1170, found 565.1181.

Methyl 5-(2-bromophenyl)-4-(phenyl(tosyl)methyl)-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (3i): white solid; 67.7 mg; 57% yield; mp 211–212 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.86 (s, 1H), 7.59 (d, *J* = 8.2 Hz, 3H), 7.31 (t, *J* = 6.7 Hz, 2H), 7.26 – 7.20 (m, 1H), 7.16 (d, *J* = 8.1 Hz, 2H), 7.13 – 6.99 (m, 3H), 6.90 (dd, *J* = 13.4, 5.6 Hz, 3H), 3.79 (s, 3H), 2.35 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.8, 144.3, 135.9, 135.0, 133.1, 132.0, 131.8, 131.3, 131.2, 130.0, 129.4, 129.2, 127.8, 127.6, 126.7, 126.1, 122.1 (q, *J* = 39.3 Hz), 120.3 (q, *J* = 268.9 Hz), 116.1, 115.8 (q, *J* = 2.3 Hz), 65.4, 51.7, 21.7; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.26; HRMS (Q-TOF, m/z) calcd for $C_{27}H_{25}BrF_3N_2O_4S^+$ $[M + NH_4]^+$ 609.0665, found 609.0678.

Methyl 4-(phenyl(tosyl)methyl)-2-(trifluoromethyl)-5-(2-(trifluoromethyl)phenyl)-1*H*-pyrrole-3-carboxylate (3j): white solid; 90.4 mg; 78% yield; mp 198–199 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.07 (s, 1H), 8.13 – 7.47 (m, 5H), 7.41 (d, *J* = 5.8 Hz, 1H), 7.15 (d, *J* = 8.1 Hz, 2H), 6.93 (d, *J* = 20.3 Hz, 4H), 6.81 (t, *J* = 7.2 Hz, 2H), 3.82 (s, 3H), 2.33 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.0, 144.3, 135.8, 131.1, 130.5, 130.3, 130.0, 129.93, 129.90, 129.4, 129.1, 128.0, 127.6, 127.5, 125.9, 125.8, 123.2 (q, *J* = 274.8 Hz), 122.1 (q, *J* = 39.4 Hz), 120.2 (q, *J* = 268.6 Hz), 116.3, 116.2 (q, *J* = 1.2 Hz), 65.5, 51.7, 21.6; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.37; HRMS (Q-TOF, m/z) calcd for $C_{28}H_{25}F_6N_2O_4S^+$ $[M + NH_4]^+$ 599.1434, found 599.1454.

Methyl 5-phenyl-4-(*o*-tolyl(tosyl)methyl)-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (3m): white solid; 85.3 mg; 81% yield; mp 212–213 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.91 (s, 1H), 7.58 (d, *J* = 8.2 Hz, 2H), 7.37 (d, *J* = 7.9 Hz, 1H), 7.26 (dd, *J* = 9.9, 5.1 Hz, 1H), 7.17 (d, *J* = 8.2 Hz, 2H), 7.10 (t, *J* = 7.7 Hz, 2H), 7.00 – 6.86 (m, 5H), 6.55 – 6.47 (m, 1H), 3.74 (s, 3H), 2.36 (s,

3H), 2.07 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.7, 144.2, 136.9, 136.1, 135.8, 131.1, 131.0, 130.4, 130.1, 129.5, 129.32, 129.28, 128.9, 127.6, 127.4, 124.8, 121.4 (q, *J* = 39.3 Hz), 120.4 (q, *J* = 268.5 Hz), 116.2 (q, *J* = 2.2 Hz), 114.4, 62.6, 51.5, 21.6, 19.9; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.10; HRMS (Q-TOF, m/z) calcd for $C_{28}H_{28}F_3N_2O_4S^+$ $[M + NH_4]^+$ 545.1716, found 545.1733.

Methyl 5-phenyl-4-(*m*-tolyl(tosyl)methyl)-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (3n): white solid; 86.3 mg; 82% yield; mp 185–186 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.83 (s, 1H), 7.52 (d, *J* = 8.2 Hz, 2H), 7.34 (t, *J* = 7.5 Hz, 1H), 7.23 (dd, *J* = 14.1, 6.2 Hz, 2H), 7.15 (d, *J* = 8.1 Hz, 2H), 7.05 (dd, *J* = 6.0, 4.6 Hz, 3H), 7.01 – 6.95 (m, 1H), 6.90 (t, *J* = 6.1 Hz, 2H), 6.71 (s, 1H), 3.76 (s, 3H), 2.36 (s, 3H), 2.07 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.9, 144.2, 137.4, 136.1, 135.2, 132.8, 131.0, 130.6, 130.5, 129.30, 129.27, 129.0, 128.4, 127.82, 127.76, 127.1, 121.6 (q, *J* = 39.3 Hz), 120.3 (q, *J* = 268.4 Hz), 116.3 (q, *J* = 4.1 Hz), 115.6, 65.6, 51.7, 21.7, 21.4; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.15; HRMS (Q-TOF, m/z) calcd for $C_{28}H_{28}F_3N_2O_4S^+$ $[M + NH_4]^+$ 545.1716, found 545.1735.

Methyl 5-phenyl-4-(*p*-tolyl(tosyl)methyl)-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (3o): white solid; 72.5 mg; 69% yield; mp 226–227 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.82 (s, 1H), 7.50 (d, *J* = 8.2 Hz, 2H), 7.34 (t, *J* = 7.5 Hz, 1H), 7.21 (t, *J* = 7.7 Hz, 2H), 7.17 – 7.08 (m, 4H), 7.08 – 7.00 (m, 2H), 6.81 (d, *J* = 8.0 Hz, 2H), 6.62 (s, 1H), 3.76 (s, 3H), 2.36 (s, 3H), 2.21 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.9, 144.2, 137.3, 136.2, 135.2, 130.8, 130.4, 129.9, 129.7, 129.3, 129.2, 129.0, 128.6, 127.9, 121.6 (q, *J* = 39.2 Hz), 120.4 (q, *J* = 268.6 Hz), 116.5 (q, *J* = 1.8 Hz), 115.5, 65.7, 51.7, 21.7, 21.1; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.11; HRMS (Q-TOF, m/z) calcd for $C_{28}H_{28}F_3N_2O_4S^+$ $[M + NH_4]^+$ 545.1716, found 545.1731.

Methyl 4-((4-fluorophenyl)(tosyl)methyl)-5-phenyl-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (3p): white solid; 77.9 mg; 73% yield; mp 221–222 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.76 (s, 1H), 7.53 (d, *J* = 8.2 Hz, 2H), 7.38 (t, *J* = 7.5 Hz, 1H), 7.28 – 7.14 (m, 6H), 7.08 (d, *J* = 7.3 Hz, 2H), 6.72 –6.65 (m, 3H), 3.78 (s, 3H), 2.37 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.9, 162.2 (d, *J* = 247.4 Hz), 144.5, 135.8, 135.2, 131.7 (d, *J* = 8.2 Hz), 130.9, 130.3, 129.5, 129.4, 129.0, 128.7 (d, *J* = 3.3 Hz), 128.1, 121.7 (d, *J* = 39.6 Hz), 120.3 (q, *J* = 268.5 Hz), 116.3, 115.3, 114.7 (d, *J* = 21.4 Hz), 65.0, 51.8, 21.7; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.20, -114.30; HRMS (Q-TOF, m/z) calcd for $C_{27}H_{25}F_4N_2O_4S^+$ $[M + NH_4]^+$ 549.1466, found 549.1478.

Methyl 4-((4-chlorophenyl)(tosyl)methyl)-5-phenyl-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (3q): white solid; 82.2 mg; 75% yield; mp 219–220 °C; ^{1}H NMR (400 MHz, acetone-d_6) δ 11.64 (s, 1H), 7.55 (d, *J* = 8.2 Hz, 2H), 7.38 (t, *J* = 7.4 Hz, 3H), 7.32 – 7.23 (m, 4H), 7.10 (d, *J* = 8.5 Hz, 2H), 7.04 (d, *J* = 7.5 Hz, 2H), 6.53 (s, 1H), 3.77 (s, 3H), 2.39 (s, 3H); ^{13}C NMR (100 MHz, acetone-d_6) δ 164.6, 145.5, 137.1, 137.0, 133.8, 133.2, 132.3, 131.5, 131.2, 130.3, 129.7, 129.6, 128.53, 128.45, 122.0 (q, *J* = 39.3 Hz), 121.6 (q, *J* = 267.8 Hz), 117.5 (q, *J* = 2.1 Hz), 114.9, 66.2, 52.0, 21.5; ^{19}F NMR (376 MHz, acetone-d_6) δ -58.96; HRMS (Q-TOF, m/z) calcd for $C_{27}H_{21}ClF_3NO_4SNa^+$ [M + Na]$^+$ 570.0724, found 570.0726.

Methyl 5-(4-fluorophenyl)-4-(phenyl(phenylsulfonyl)-methyl)-2-(trifluoromeths-yl)-1*H*-pyrrole-3-carboxylate (3u): white solid; 69.0 mg; 67% yield; mp 221–222 °C; ^{1}H NMR (400 MHz, acetone-d_6) δ 11.64 (s, 1H), 7.71 (d, *J* = 7.5 Hz, 2H), 7.64 (t, *J* = 7.4 Hz, 1H), 7.51 (t, *J* = 7.7 Hz, 2H), 7.34 (d, *J* = 7.4 Hz, 2H), 7.16 (t, *J* = 7.2 Hz, 1H), 7.12 – 7.04 (m, 4H), 6.99 (t, *J* = 8.8 Hz, 2H), 6.71 (s, 1H), 3.76 (s, 3H); ^{13}C NMR (100 MHz, acetone-d_6) δ 164.5, 164.0 (d, *J* = 246.7 Hz), 140.2, 135.8, 134.41, 134.35, 133.9 (d, *J* = 8.6 Hz), 130.5, 129.7, 129.6, 128.6, 128.4, 127.8 (d, *J* = 3.2 Hz), 122.1 (q, *J* = 39.2 Hz), 121.6 (q, *J* = 267.6 Hz), 117.3 (q, *J* = 2.0 Hz), 115.9, 115.2 (d, *J* = 21.8 Hz), 66.4, 52.0; ^{19}F NMR (376 MHz, acetone-d_6) δ -59.07 (s, 3F), -114.05 (s, 1F); HRMS (Q-TOF, m/z) calcd for $C_{26}H_{19}F_4NO_4SNa$ [M + Na]$^+$ 540.0863, found 540.0869.

Methyl 5-(2-bromophenyl)-4-(phenyl(phenylsulfonyl-methyl)-2-(trifluoromethyl)-1*H*-pyrrole-3-carboxylate (3v): white solid; 130.9 mg (in 0.4 mmol scale); 57% yield; mp 239–240 °C; ^{1}H NMR (400 MHz, acetone-d_6) δ 11.70 (s, 1H), 7.76 (d, *J* = 7.5 Hz, 2H), 7.64 (t, *J* = 7.4 Hz, 1H), 7.52 (t, *J* = 7.7 Hz, 2H), 7.35 (d, *J* = 4.5 Hz, 3H), 7.22 – 7.03 (m, 3H), 6.91 (d, *J* = 27.9 Hz, 3H), 3.80 (s, 3H); ^{13}C NMR (100 MHz, acetone-d_6) δ 164.5, 140.0, 135.7, 134.8, 134.6, 134.4, 132.7, 132.6, 131.9, 130.8, 129.8, 129.7, 128.4, 128.3, 127.4, 127.2, 122.3 (q, *J* = 39.0 Hz), 121.6 (q, *J* = 267.8 Hz), 116.7, 116.0, 66.3, 52.0; ^{19}F NMR (376 MHz, acetone-d_6) δ -59.14; HRMS (Q-TOF, m/z) calcd for $C_{26}H_{19}BrF_3NO_4SNa$ [M + Na]$^+$ 600.0062, found 600.0068.

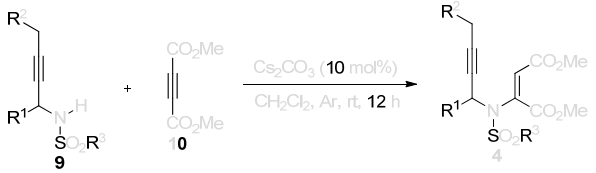
Procedure for the Crossover and Competition Experiments. To a glass Schlenk tube (10 mL) equipped with a magnetic stirrer bar, **1g** (53.2 mg, 0.1 mmol), **1v** (57.8 mg, 0.1 mmol), CsOPiv (4.7 mg, 10 mol%), and DMF (0.5 mL) were added. The resulting mixture was stirred at 100 °C under argon atmosphere for 24 h. After cooling down to room temperature, the mixture was diluted with acetonitrile (5 mL), and the products were determined by HPLC. **3g**:**3v**:**3u**:**3i** = 33:18:30:19 (the ratio of peak area in HPLC of the corresponding product).

To a glass Schlenk tube (10 mL) equipped with a magnetic stirrer bar, **1i** (59.2 mg, 0.1 mmol), $PhSO_2Na$ (16.4 mg, 0.1 mmol), CsOPiv (2.3 mg, 10 mol%), and DMF (0.5 mL) were added. The resulting mixture was stirred at 100 °C under argon atmosphere for 24 h. After cooling down to room temperature, the mixture was diluted with acetonitrile (5 mL), and the products were determined by HPLC. **3i**:**3v** = 56:44 (the ratio of peak area in HPLC of the corresponding product).

To a glass Schlenk tube (10 mL) equipped with a magnetic stirrer bar, **1v** (57.8 mg, 0.1 mmol), $TolSO_2Na$ (17.8 mg, 0.1 mmol), CsOPiv (2.3 mg, 10 mol%), and DMF (0.5 mL) were added. The resulting mixture was stirred at 100 °C under argon atmosphere for 24 h. After cooling down to room temperature, the mixture was diluted with acetonitrile (5 mL), and the products were determined by HPLC. **3v**:**3i** = 44:56 (the ratio of peak area in HPLC of the corresponding product).

General Procedure for Preparation the Starting Materials 3-Aza-1,5-enynes 4. Propargyl amines **9**[15] and dimethyl but-2-ynedioate **10** (1.2 equiv) were placed in a dried flask under argon atmosphere, CH_2Cl_2 was added until the dissolution of the solid. Subsequenly, Cs_2CO_3 (10 mol%) was added. The resulting mixture was stirred at room temperature until the

consummation of popargyl amines detected by TLC (usually 12 hours). The solvent was evaporated under vacuum and the crude product was directly purified by silica gel flash column chromatography eluting with petroleum ether/ethyl acetate (20 : 1, v/v)to give the desired compounds **4**. **4a**[3a] and **4m**[3b] are known compounds.



Dimethyl 2-(4-methyl-*N*-(1-(*o*-tolyl)hept-2-yn-1-yl)phenylsulfonamido)maleate (4b): white solid; 0.74 g (in 3.3 mmol scale); 45% yield; mp 104–105 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.85 (d, *J* = 8.1 Hz, 2H), 7.49 (d, *J* = 7.6 Hz, 1H), 7.32 (d, *J* = 8.0 Hz, 2H), 7.23 – 7.08 (m, 3H), 6.41 (s, 1H), 6.32 (s, 1H), 3.65 (s, 3H), 3.58 (s, 3H), 2.57 (s, 3H), 2.44 (s, 3H), 2.07 – 1.92 (m, 2H), 1.34 – 1.23 (m, 4H), 0.86 (t, *J* = 6.8 Hz, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 164.8, 164.0, 144.3, 138.5, 137.9, 135.3, 131.9, 131.0, 130.2, 129.3, 129.1, 128.8, 125.4, 123.5, 90.4, 75.1, 53.7, 52.6, 52.2, 30.3, 22.1, 21.7, 19.4, 18.5, 13.6; HRMS calcd for $C_{27}H_{32}NO_6S$ $[M+H]^+$ 498.1945, found 498.1931.

Dimethyl 2-(4-methyl-*N*-(1-(*m*-tolyl)hept-2-yn-1-yl)phenylsulfonamido)maleate (4c): white solid; 0.72 g (in 5.0 mmol scale); 29% yield; mp 101–102 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.89 (d, *J* = 8.3 Hz, 2H), 7.36 – 7.31 (m, 4H), 7.20 (t, *J* = 7.9 Hz, 1H), 7.08 (d, *J* = 7.5 Hz, 1H), 6.25 (s, 1H), 6.04 (s, 1H), 3.76 (s, 3H), 3.59 (s, 3H), 2.45 (s, 3H), 2.33 (s, 3H), 2.08 – 1.98 (m, 2H), 1.34 – 1.23 (m, 4H), 0.87 (t, *J* = 7.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.1, 164.2, 144.5, 139.9, 138.2, 135.5, 134.3, 129.6, 129.2, 128.6, 128.3, 124.9, 116.3, 90.6, 74.0, 54.8, 52.9, 51.9, 30.3, 22.0, 21.7, 21.5, 18.4, 13.6; HRMS calcd for $C_{27}H_{32}NO_6S$ $[M+H]^+$ 498.1945, found 498.1936.

Dimethyl 2-(4-methyl-*N*-(1-(*p*-tolyl)hept-2-yn-1-yl)phenylsulfonamido)maleate (4d): white solid; 1.26 g (in 5.0 mmol scale); 51% yield; mp 102–103 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.89 (d, *J* = 8.3 Hz, 2H), 7.43 (d, *J* = 8.0 Hz, 2H), 7.34 (d, *J* = 8.2 Hz, 2H), 7.12 (d, *J* = 8.0 Hz, 2H), 6.25 (s, 1H), 6.05 (s, 1H), 3.76 (s, 3H), 3.59 (s, 3H), 2.44 (s, 3H), 2.31 (s, 3H), 2.11 – 1.94 (m, 2H), 1.36 – 1.20 (m, 4H), 0.86 (t, *J* = 7.0 Hz, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 165.1, 164.3, 144.5, 139.9, 138.2, 135.5, 131.4, 129.6, 129.2, 128.6, 127.8, 116.1, 90.5, 74.0, 54.6, 52.9, 51.9, 30.3, 22.1, 21.7, 21.2, 18.4, 13.6; HRMS calcd for $C_{27}H_{32}NO_6S$ $[M+H]^+$ 498.1945, found 498.1933.

Dimethyl 2-(*N*-(1-(2-methoxyphenyl)hept-2-yn-1-yl)-4-methylphenylsulfonamido)-maleate (4e): white solid; 1.23 g (in 5.0 mmol scale); 48% yield; mp 100–101 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.82 (d, *J* = 8.3 Hz, 2H), 7.52 – 7.45 (m, 1H), 7.28 (d, *J* = 8.4 Hz, 3H), 6.91 – 6.79 (m, 2H), 6.53 (s, 1H), 6.31 (s, 1H), 3.84 (s, 3H), 3.65 (s, 3H), 3.57 (s, 3H), 2.43 (s, 3H), 2.09 (dq, *J* = 4.8, 3.3, 2.3 Hz, 2H), 1.35 (dqd, *J* = 15.3, 7.7, 7.0, 2.6 Hz, 4H), 0.88 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.1, 164.0, 157.6, 143.8, 138.9, 136.4, 130.9, 130.5, 129.2, 128.5, 122.7, 122.1, 119.7, 110.8, 89.5, 75.4, 55.6, 52.5, 52.1, 51.2, 30.5, 22.1, 21.7, 18.5, 13.6; HRMS calcd for $C_{27}H_{35}N_2O_7S$ $[M+H]^+$ 531.2159, found 531.2161.

Dimethyl 2-(*N*-(1-(3-methoxyphenyl)hept-2-yn-1-yl)-4-methylphenylsulfonamido)-maleate (4f): white solid; 0.39 g (in 5.0 mmol scale); 15% yield; mp 94–95 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.90 (d, *J* = 8.3 Hz, 2H), 7.35 (d, *J* = 8.2 Hz, 2H), 7.23 (t, *J* = 7.9 Hz, 1H), 7.15 (d, *J* = 7.7 Hz, 1H), 7.11 (s, 1H), 6.25 (s, 1H), 6.04 (s, 1H), 3.80 (s, 6H), 3.59 (s, 3H), 2.45 (s, 3H), 2.10 – 1.93 (m, 2H), 1.37 – 1.21 (m, 4H), 0.86 (t, *J* = 7.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.1, 164.3, 159.8, 144.7, 140.1, 135.9, 135.3, 129.6, 129.4, 128.6, 120.1, 115.4, 114.8, 112.5, 90.7, 73.8, 55.4, 54.6, 53.0, 51.9, 30.3, 22.1, 21.8, 18.4, 13.7; HRMS calcd for $C_{27}H_{32}NO_7S$ $[M+H]^+$ 514.1894, found 514.1899.

Dimethyl 2-(*N*-(1-(2-fluorophenyl)hept-2-yn-1-yl)-4-methylphenylsulfonamido)-maleate (4g): white solid; 1.13 g (in 5.0 mmol scale); 45% yield; mp 95–96 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.83 (d, *J* = 8.3 Hz, 2H), 7.54 – 7.45 (m, 1H), 7.31 (d, *J* = 8.0 Hz, 3H), 7.11 – 7.00 (m, 2H), 6.52 (t, *J* = 2.0 Hz, 1H), 6.38 (s, 1H), 3.68 (s, 3H), 3.54 (s, 3H), 2.44 (s, 3H), 2.14 – 2.02 (m, 2H), 1.40 – 1.23 (m, 4H), 0.88 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.8, 163.8, 160.9 (d, *J* = 252.8 Hz), 144.2, 137.6, 135.8, 131.1, 131.0 (d, *J* = 5.9 Hz), 129.4, 128.6, 124.9, 123.6 (d, *J* = 3.7 Hz), 122.3 (d, *J* = 12.8 Hz), 115.7 (d, *J* = 21.0 Hz), 90.2, 74.2, 52.6, 52.2, 50.0 (d, *J* = 3.9 Hz), 30.3, 22.1, 21.7, 18.4, 13.6; ^{19}F NMR (376 MHz, $CDCl_3$) δ -100.00; HRMS calcd for $C_{26}H_{29}FNO_6S$ $[M+H]^+$ 502.1694, found 502.1682.

Dimethyl 2-(*N*-(1-(4-fluorophenyl)hept-2-yn-1-yl)-4-methylphenylsulfonamido)-maleate (4h): white solid; 0.25g (in 5.0 mmol scale); 10% yield; mp 95–96 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.88 (d, *J* = 8.3 Hz, 2H), 7.55 (dd, *J* = 8.3, 5.3 Hz, 2H), 7.35 (d, *J* = 8.1 Hz, 2H), 7.02 (t, *J* = 8.6 Hz, 2H), 6.26 (s, 1H), 6.05 (s, 1H), 3.78 (s, 3H), 3.61 (s, 3H), 2.46 (s, 3H), 2.09 – 1.95 (m, 2H), 1.35 – 1.20 (m, 4H), 0.87 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.9, 164.2, 162.8 (d, *J* = 247.5 Hz), 144.7, 139.7, 135.3, 130.2 (d, *J* = 3.0 Hz), 129.8 (d, *J* = 8.4 Hz), 129.7, 128.5, 116.7, 115.4 (d, *J* = 21.8 Hz), 91.0, 73.8, 54.2, 53.0, 52.1, 30.3, 22.1, 21.8, 18.4, 13.6; ^{19}F NMR (376 MHz, $CDCl_3$) δ -113.61; HRMS calcd for $C_{26}H_{29}FNO_6S$ $[M+H]^+$ 502.1694, found 502.1690.

Dimethyl 2-(*N*-(1-(4-chlorophenyl)hept-2-yn-1-yl)-4-methyl phenylsulfonamido)-maleate (4i): white solid; 1.45 g (in 5.0 mmol scale); 56% yield; mp 87–88 °C;^{1}H NMR (400 MHz, $CDCl_3$) δ 7.88 (d, *J* = 8.2 Hz, 2H), 7.51 (d, *J* = 8.4 Hz, 2H), 7.35 (d, *J* = 8.1 Hz, 2H), 7.30 (d, *J* = 8.5 Hz, 2H), 6.24 (s, 1H), 6.05 (s, 1H), 3.77 (s, 3H), 3.61 (s, 3H), 2.45 (s, 3H), 2.09 – 1.98 (m, 2H), 1.34 – 1.22 (m, 4H), 0.86 (t, *J* = 7.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.8, 164.1, 144.7, 139.8, 135.2, 134.5, 133.1, 129.6, 129.3, 128.7, 128.5, 116.6, 91.2, 73.5, 54.2, 52.9, 52.0, 30.2, 22.0, 21.7, 18.4, 13.6; HRMS calcd for $C_{26}H_{29}ClNO_6S$ $[M+H]^+$ 518.1399, found 518.1387.

Dimethyl 2-(*N*-(1-(4-bromophenyl)hept-2-yn-1-yl)-4-methylphenylsulfonamido)-maleate (4j): white solid; 0.44 g (in 2.6 mmol scale); 30% yield; mp 87–89 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.88 (d, *J* = 8.3 Hz, 2H), 7.49 – 7.41 (m, 4H), 7.35 (d, *J* = 8.2 Hz, 2H), 6.22 (s, 1H), 6.04 (s, 1H), 3.78 (s, 3H), 3.62 (s, 3H), 2.46 (s, 3H), 2.08 – 1.98 (m, 2H), 1.34 – 1.23 (m, 4H), 0.87 (t, *J* = 7.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.9, 164.2, 144.8, 139.8, 135.3, 133.7, 131.7, 129.7, 129.6, 128.6, 122.8, 116.7, 91.2,

73.5, 54.3, 53.0, 52.1, 30.3, 22.1, 21.8, 18.5, 13.6; HRMS calcd for $C_{26}H_{29}BrNO_6S$ $[M+H]^+$ 562.0893, found 562.0884.

Dimethyl 2-(4-methyl-*N*-(1-(2-(trifluoromethyl)phenyl)-hept-2-yn-1-yl)phenyl-sulfonamido)maleate (4k): white solid; 1.41 g (in 5.0 mmol scale); 51% yield; mp 72–73 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.79 (d, *J* = 8.2 Hz, 2H), 7.73 (d, *J* = 7.8 Hz, 1H), 7.68 (d, *J* = 7.7 Hz, 1H), 7.49 (t, *J* = 7.4 Hz, 1H), 7.42 (t, *J* = 7.6 Hz, 1H), 7.30 (d, *J* = 8.2 Hz, 2H), 6.64 (s, 1H), 6.47 (s, 1H), 3.75 (s, 3H), 3.37 (s, 3H), 2.43 (s, 3H), 2.14 – 2.03 (m, 2H), 1.41 – 1.24 (m, 4H), 0.87 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.6, 163.2, 144.0, 135.2, 135.0, 133.6, 131.8, 131.3, 130.9, 128.9, 128.8, 128.6, 128.3, 126.5 (q, *J* = 5.8 Hz), 123.7 (q, *J* = 274.6 Hz), 90.4, 75.2, 52.2, 52.0, 51.5 (q, *J* = 2.5 Hz), 29.9, 21.8, 21.4, 18.2, 13.3; ^{19}F NMR (376 MHz, $CDCl_3$) δ -58.82; HRMS calcd for $C_{27}H_{29}F_3NO_6S$ $[M+H]^+$ 552.1662, found 552.1651.

Dimethyl 2-(4-methyl-*N*-(1-(naphthalen-2-yl)hept-2-yn-1-yl)phenylsulfonamido)-maleate (4l): white solid;1.00 g (in 5.0 mmol scale); 38% yield; mp 138–139 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.00 (s, 1H), 7.92 (d, *J* = 8.3 Hz, 2H), 7.85 – 7.78 (m, 3H), 7.67 (dd, *J* = 8.6, 1.5 Hz, 1H), 7.50 – 7.43 (m, 2H), 7.35 (d, *J* = 8.1 Hz, 2H), 6.45 (s, 1H), 6.12 (s, 1H), 3.72 (s, 3H), 3.53 (s, 3H), 2.45 (s, 3H), 2.16 – 2.01 (m, 2H), 1.41 – 1.25 (m, 4H), 0.90 (t, *J* = 7.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.0, 164.2, 144.6, 139.9, 135.5, 133.3, 133.0, 132.0, 129.6, 128.6, 128.5, 128.4, 127.8, 127.5, 126.6, 126.3, 125.2, 116.5, 91.0, 74.0, 55.0, 52.9, 51.9, 30.4, 22.1, 21.8, 18.5, 13.7; HRMS calcd for $C_{30}H_{32}NO_6S$ $[M+H]^+$ 534.1945, found 534.1921.

Dimethyl 2-(*N*-(1,4-diphenylbut-2-yn-1-yl)-4-methylphenyl-sulfonamido)maleate (4n): white solid; 0.17 g (in 5.0 mmol scale); 7% yield; mp 85–86 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.87 (d, *J* = 8.3 Hz, 2H), 7.58 (d, *J* = 7.6 Hz, 2H), 7.39 – 7.26 (m, 6H), 7.22 (d, *J* = 8.2 Hz, 2H), 7.14 (d, *J* = 7.0 Hz, 2H), 6.39 (s, 1H), 6.02 (s, 1H), 3.75 (s, 3H), 3.59 (s, 3H), 3.47 (s, 2H), 2.34 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.9, 164.2, 144.7, 139.7, 135.6, 135.2, 134.1, 129.6, 128.7, 128.61, 128.59, 128.5, 127.9, 126.9, 116.7, 88.1, 76.0, 54.7, 53.0, 52.0, 25.1, 21.7; HRMS calcd for $C_{29}H_{28}NO_6S$ $[M+H]^+$ 518.1632, found 518.1617.

Dimethyl 2-(*N*-(1-(4-fluorophenyl)hept-2-yn-1-yl)phenyl-sulfonamido)maleate (4o): white solid; 0.31 g (in 4.0 mmol scale); 16% yield; mp 97–98 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.03 – 7.98 (m, 2H), 7.65 (t, *J* = 7.4 Hz, 1H), 7.60 – 7.52 (m, 4H), 7.03 (t, *J* = 8.6 Hz, 2H), 6.27 (s, 1H), 6.07 (s, 1H), 3.77 (s, 3H), 3.62 (s, 3H), 2.05 – 1.96 (m, 2H), 1.33 – 1.24 (m, 4H), 0.86 (t, *J* = 7.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.8, 164.1, 162.8 (d, *J* = 247.5 Hz), 139.4, 138.2, 133.7, 130.1 (d, *J* = 3.0 Hz), 129.8 (d, *J* = 8.5 Hz), 129.0, 128.5, 117.6, 115.4 (d, *J* = 21.8 Hz), 91.2, 73.6, 54.3, 53.0, 52.1, 30.2, 22.0, 18.4, 13.6; ^{19}F NMR (376 MHz, $CDCl_3$) δ -113.49; HRMS calcd for $C_{25}H_{27}FNO_6S$ $[M+H]^+$ 488.1538, found 488.1524.

Dimethyl 2-(4-chloro-*N*-(1-(4-fluorophenyl)hept-2-yn-1-yl)phenylsulfonamido)-maleate (4p): white solid; 0.37 g (in 7.0 mmol scale); 10% yield; mp 104–105 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.94 (d, *J* = 8.6 Hz, 2H), 7.58 – 7.50 (m, 4H), 7.03 (t, *J* = 8.6 Hz, 2H), 6.25 (s, 1H), 6.09 (s, 1H), 3.76 (s, 3H), 3.63 (s, 3H), 2.10 – 1.99 (m, 2H), 1.35 – 1.24 (m, 4H), 0.89 (t, *J* = 7.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.6, 164.0, 162.8 (d, *J* = 247.9 Hz), 140.4, 139.1, 136.6, 129.9, 129.8, 129.3, 118.3, 115.6, 115.4, 91.3, 73.6, 54.4, 53.0, 52.1, 30.2, 22.1, 18.4, 13.6; ^{19}F NMR (376 MHz, $CDCl_3$) δ -113.23; HRMS calcd for $C_{25}H_{26}ClFNO_6S$ $[M+H]^+$ 522.1148, found 522.1150.

General Procedure for Synthesis of Pyrroles 5. To a glass pressure tube (15 mL) equipped with a magnetic stirrer bar, starting material **4** (0.3 mmol), Cs_2CO_3 (117.3 mg, 0.36 mmol, 1.2 equiv), and THF (1 mL) were added. The pressure tube was closed with a Teflon cap and the resulting mixture was stirred at 80 °C under argon protection for 12 hours. After cooling down to room temperature, the solvent was removed under vacuum. The residue was directly purified by silica gel flash chromatography eluting with petroleum ether/ethyl acetate (10 : 1, v/v) to give the desired pyrroles **5**.

(*E*)-Dimethyl 4-(pent-1-en-1-yl)-5-phenyl-1*H*-pyrrole-2,3-dicarboxylate (5a): white solid; 84.7 mg; 86% yield; mp 99–100 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.54 (s, 1H), 7.48 (d, *J* = 7.1 Hz, 2H), 7.42 (t, *J* = 7.2 Hz, 2H), 7.39 – 7.33 (m, 1H), 6.28 (d, *J* = 16.0 Hz, 1H), 5.90 – 5.78 (m, 1H), 3.91 (s, 3H), 3.78 (s, 3H), 2.13 – 2.04 (m, 2H), 1.46 – 1.35 (m, 2H), 0.90 (t, *J* = 7.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.2, 160.8, 133.4, 131.3, 128.9, 128.8, 128.4, 128.3, 121.3, 120.4, 120.0, 119.9, 52.5, 52.2, 35.6, 22.6, 13.7; HRMS calcd for $C_{19}H_{22}NO_4$ $[M+H]^+$ 328.1543, found 328.1552.

(*E*)-Dimethyl 4-(pent-1-en-1-yl)-5-(*o*-tolyl)-1*H*-pyrrole-2,3-dicarboxylate (5b): yellow oil; 10.2 mg; 10% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.13 (s, 1H), 7.35 – 7.27 (m, 2H), 7.26 – 7.21 (m, 2H), 6.09 (d, *J* = 16.1 Hz, 1H), 5.62 – 5.53 (m, 1H), 3.93 (s, 3H), 3.79 (s, 3H), 2.21 (s, 3H), 2.01 – 1.94 (m, 2H), 1.33 – 1.26 (m, 2H), 0.81 (t, *J* = 7.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.1, 160.6, 137.9, 132.9, 132.2, 131.0, 130.8, 130.6, 129.3, 126.1, 121.0, 120.3, 120.0, 119.8, 52.5, 52.1, 35.6, 22.6, 20.1, 13.6; HRMS calcd for $C_{20}H_{24}NO_4$ $[M+H]^+$ 342.1700, found 342.1695.

(*E*)-dimethyl 4-(pent-1-en-1-yl)-5-(*m*-tolyl)-1*H*-pyrrole-2,3-dicarboxylate (5c): white solid; 81.9 mg; 80% yield; mp 78–79 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.08 (s, 1H), 7.35 – 7.27 (m, 3H), 7.19 (d, *J* = 7.0 Hz, 1H), 6.29 (d, *J* = 16.0 Hz, 1H), 5.91 – 5.76 (m, 1H), 3.91 (s, 3H), 3.85 (s, 3H), 2.39 (s, 3H), 2.19 – 2.02 (m, 2H), 1.49 – 1.32 (m, 2H), 0.91 (t, *J* = 6.9 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.2, 160.7, 138.6, 133.7, 133.2, 131.2, 129.2, 128.9, 128.8, 125.5, 121.3, 120.5, 119.9, 119.7, 52.5, 52.1, 35.6, 22.5, 21.5, 13.7; HRMS calcd for $C_{20}H_{24}NO_4$ $[M+H]^+$ 342.1700, found 342.1700.

(*E*)-Dimethyl 4-(pent-1-en-1-yl)-5-(*p*-tolyl)-1*H*-pyrrole-2,3-dicarboxylate (5d): white solid; 71.0 mg; 69% yield; mp 109–110°C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.37 (s, 1H), 7.37 (d, *J* = 8.1 Hz, 2H), 7.22 (d, *J* = 8.0 Hz, 2H), 6.31 – 6.23 (m, 1H), 5.89 – 5.78 (m, 1H), 3.90 (s, 3H), 3.80 (s, 3H), 2.38 (s, 3H), 2.13 – 2.04 (m, 2H), 1.47 – 1.35 (m, 2H), 0.90 (t, *J* = 7.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.3, 160.7, 138.5, 133.6, 133.1, 129.6, 128.4, 128.2, 121.3, 120.5, 119.7, 119.6, 52.5, 52.1, 35.6, 22.6, 21.4, 13.7; HRMS calcd for $C_{20}H_{24}NO_4$ $[M+H]^+$ 342.1700, found 342.1696.

(*E*)-dimethyl5-(4-methoxyphenyl)-4-(pent-1-en-1-yl)-1*H*-pyrrole-2,3-dicarboxylate (5f): white solid; 96.7 mg; 90% yield; mp 93–94 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.70 (s, 1H), 7.32 (t, *J*

= 7.9 Hz, 1H), 7.06 (d, *J* = 7.7 Hz, 1H), 7.02 (s, 1H), 6.89 (dd, *J* = 8.2, 2.1 Hz, 1H), 6.29 (d, *J* = 16.1 Hz, 1H), 5.90 – 5.79 (m, 1H), 3.90 (s, 3H), 3.80 (s, 3H), 3.77 (s, 3H), 2.13 – 2.04 (m, 2H), 1.47 – 1.34 (m, 2H), 0.90 (t, *J* = 7.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.2, 160.8, 159.8, 133.4, 133.3, 132.5, 129.9, 121.2, 120.7, 120.4, 119.9, 119.7, 114.1, 113.8, 55.4, 52.5, 52.2, 35.6, 22.5, 13.7; HRMS calcd for $C_{20}H_{24}NO_5$ $[M+H]^+$ 358.1649, found 358.1645.

(*E*)-Dimethyl 5-(2-fluorophenyl)-4-(pent-1-en-1-yl)-1*H*-pyrrole-2,3-dicarboxylate (5g): white solid; 85.3 mg; 82% yield; mp 72–73 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.30 (s, 1H), 7.51 (t, *J* = 7.5 Hz, 1H), 7.36 (dd, *J* = 13.8, 6.9 Hz, 1H), 7.24 – 7.14 (m, 2H), 6.24 (d, *J* = 16.0 Hz, 1H), 5.87 – 5.76 (m, 1H), 3.92 (s, 3H), 3.86 (s, 3H), 2.13 – 2.04 (m, 2H), 1.46 – 1.34 (m, 2H), 0.90 (t, *J* = 7.3 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.0, 160.4, 159.8 (d, *J* = 248.6 Hz), 133.8, 131.4 (d, *J* = 2.4 Hz), 130.3 (d, *J* = 8.4 Hz), 126.8, 124.5 (d, *J* = 3.4 Hz), 121.7, 120.8, 120.5, 120.3, 118.9 (d, *J* = 13.6 Hz), 116.4 (d, *J* = 21.9 Hz), 52.5, 52.2, 35.6, 22.5, 13.7; ^{19}F NMR (376 MHz, $CDCl_3$) δ -114.95; HRMS calcd for $C_{19}H_{21}FNO_4$ $[M+H]^+$ 346.1449, found 346.1451.

(*E*)-Dimethyl 5-(4-fluorophenyl)-4-(pent-1-en-1-yl)-1*H*-pyrrole-2,3-dicarboxylate (5h): white solid; 84.7 mg, 81.7 mg, 80.7 mg from **2h**, **2o**, **2p**, respectively; 82%, 79%, 78% yield from **2h**, **2o**, **2p**, respectively; mp 120–121 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.64 (s, 1H), 7.49 – 7.42 (m, 2H), 7.16 – 7.08 (m, 2H), 6.22 (d, *J* = 16.1 Hz, 1H), 5.86 – 5.76 (m, 1H), 3.91 (s, 3H), 3.78 (s, 3H), 2.12 – 2.04 (m, 2H), 1.46 – 1.34 (m, 2H), 0.90 (t, *J* = 7.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.1, 162.8 (d, *J* = 249.0 Hz), 160.9, 133.7, 132.6, 130.3 (d, *J* = 8.2 Hz), 127.4 (d, *J* = 3.4 Hz), 121.3, 120.1, 120.0, 119.8, 116.0 (d, *J* = 21.7 Hz), 52.5, 52.2, 35.6, 22.5, 13.7; ^{19}F NMR (376 MHz, $CDCl_3$) δ -112.52; HRMS calcd for $C_{19}H_{21}FNO_4$ $[M+H]^+$ 346.1449, found 346.1451.

(*E*)-Dimethyl 5-(4-chlorophenyl)-4-(pent-1-en-1-yl)-1*H*-pyrrole-2,3-dicarboxylate (5i): white solid; 94.3 mg; 87% yield; mp 132–134 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.83 (s, 1H), 7.43 (d, *J* = 8.5 Hz, 2H), 7.37 (d, *J* = 8.5 Hz, 2H), 6.22 (d, *J* = 16.1 Hz, 1H), 5.87 – 5.77 (m, 1H), 3.90 (s, 3H), 3.76 (s, 3H), 2.12 – 2.03 (m, 2H), 1.46 – 1.35 (m, 2H), 0.90 (t, *J* = 7.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.1, 160.9, 134.4, 133.9, 132.3, 129.68, 129.65, 129.0, 121.4, 120.3, 120.1, 120.0, 52.5, 52.2, 35.6, 22.5, 13.7; HRMS calcd for $C_{19}H_{21}ClNO_4$ $[M+H]^+$ 362.1154, found 362.1146.

(*E*)-Dimethyl 5-(4-bromophenyl)-4-(pent-1-en-1-yl)-1*H*-pyrrole-2,3-dicarboxylate (5j): white solid;89.6 mg; 74% yield; mp 139–140 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.67 (s, 1H), 7.54 (d, *J* = 8.5 Hz, 2H), 7.36 (d, *J* = 8.5 Hz, 2H), 6.22 (d, *J* = 16.1 Hz, 1H), 5.88 – 5.78 (m, 1H), 3.90 (s, 3H), 3.78 (s, 3H), 2.12 – 2.03 (m, 2H), 1.47 – 1.34 (m, 2H), 0.90 (t, *J* = 7.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.0, 160.8, 134.1, 132.2, 132.0, 130.1, 129.9, 122.6, 121.4, 120.3, 120.2, 120.0, 52.5, 52.3, 35.6, 22.5, 13.7; HRMS calcd for $C_{19}H_{21}BrNO_4$ $[M+H]^+$ 406.0648, found 406.0641.

(*E*)-Dimethyl 4-(pent-1-en-1-yl)-5-(2-(trifluoromethyl)-phenyl)-1*H*-pyrrole-2,3-dicarboxylate (5k): yellow oil; 83.2 mg; 70% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.37 (s, 1H), 7.79 (d, *J* = 7.7 Hz, 1H), 7.64 – 7.48 (m, 2H), 7.44 (d, *J* = 7.4 Hz, 1H), 6.08 (d, *J* = 16.1 Hz, 1H), 5.58 – 5.42 (m, 1H), 3.91 (s, 3H), 3.77 (s, 3H), 2.01 – 1.88 (m, 2H), 1.33 – 1.21 (m, 2H), 0.79 (t, *J* = 7.3 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.7, 160.4, 133.8, 133.4, 131.9, 130.1 (q, *J* = 30.3 Hz), 129.9 (q, *J* = 2.0 Hz), 129.3, 129.2, 126.6 (q, *J* = 5.2 Hz), 123.8 (q, *J* = 273.7 Hz), 122.1, 120.4, 119.8, 119.7, 52.4, 52.1, 35.5, 22.5, 13.5; ^{19}F NMR (376 MHz, $CDCl_3$) δ -59.15; HRMS calcd for $C_{20}H_{21}F_3NO_4$ $[M+H]^+$ 396.1417, found 396.1419.

(*E*)-Dimethyl 5-(naphthalen-2-yl)-4-(pent-1-en-1-yl)-1*H*-pyrrole-2,3-dicarboxylate (5l): white solid; 89.8 mg; 79% yield; mp 111–112 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.45 (s, 1H), 7.93 (s, 1H), 7.89 – 7.84 (m, 3H), 7.60 (d, *J* = 8.2 Hz, 1H), 7.55 – 7.48 (m, 2H), 6.36 (d, *J* = 16.1 Hz, 1H), 5.94 – 5.80 (m, 1H), 3.93 (s, 3H), 3.80 (s, 3H), 2.12 –2.07 (m, 2H), 1.48 – 1.35 (m, 2H), 0.91 (t, *J* = 7.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.2, 160.8, 133.8, 133.3, 133.0, 128.7, 128.6, 128.2, 127.9, 127.5, 126.80, 126.77, 125.9, 121.4, 120.41, 120.37, 120.1, 100.1, 52.5, 52.2, 35.6, 22.5, 13.7; HRMS calcd for $C_{23}H_{24}NO_4$ $[M+H]^+$ 378.1700, found 378.1701.

(*E*)-Dimethyl 4-(but-1-en-1-yl)-5-phenyl-1*H*-pyrrole-2,3-dicarboxylate (5m): white solid; 76.7 mg; 81% yield; mp 106–107 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.47 (s, 1H), 7.51 – 7.46 (m, 2H), 7.46 – 7.39 (m, 2H), 7.39 – 7.33 (m, 1H), 6.32 – 6.25 (m, 1H), 5.92 – 5.83 (m, 1H), 3.91 (s, 3H), 3.79 (s, 3H), 2.17 – 2.07 (m, 2H), 1.00 (t, *J* = 7.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.2, 160.8, 135.0, 133.5, 131.3, 128.9, 128.5, 128.3, 121.2, 119.91, 119.87, 119.2, 52.5, 52.2, 26.6, 13.7; HRMS calcd for $C_{18}H_{20}NO_4$ $[M+H]^+$ 314.1387, found 314.1384.

(Z/*E*)-dimethyl 5-phenyl-4-styryl-1*H*-pyrrole-2,3-dicarboxylate (5n): *Z*/*E* = 1:1.4 mixture; white solid; 23.1 mg; 20% yield; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 9.50 (s, 2.38H), 7.51 (d, *J* = 7.0 Hz, 2.88H), 7.44 (dt, *J* = 13.9, 7.4 Hz, 6.41H), 7.39 – 7.26 (m, 9.21H), 7.22 (d, *J* = 7.2 Hz, 1.43H), 7.09 (t, *J* = 2.6 Hz, 4.92H), 7.02 (d, *J* = 16.5 Hz, 1.46H), 6.77 (d, *J* = 16.5 Hz, 1.43H), 6.61 (d, *J* = 11.9 Hz, 1.00H), 6.50 (d, *J* = 11.9 Hz, 1.00H), 3.95 (s, 4.29H), 3.84 (s, 4.30H), 3.80 (s, 3.20H), 3.57 (s, 3.01H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.1, 165.5, 160.8, 160.6, 137.7, 137.1, 134.8, 133.4, 131.0, 130.4, 129.5, 129.1, 128.83, 128.77, 128.7, 128.6, 128.5, 128.3, 128.1, 127.5, 127.3, 127.2, 127.1, 126.4, 122.1, 121.1, 120.4, 119.7, 119.5, 119.4, 52.7, 52.34, 52.25, 52.0; HRMS calcd for $C_{22}H_{20}NO_4$ $[M+H]^+$ 362.1387, found 362.1386.

Dimethyl 4-benzyl-6-phenylpyridine-2,3-dicarboxylate (6n): colorless oil; 10 mg; 9% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.94 (dd, *J* = 7.6, 1.8 Hz, 2H), 7.62 (s, 1H), 7.44 (m, 3H), 7.32 (t, *J* = 7.3 Hz, 2H), 7.27 (m, 1H), 7.19 (d, *J* = 7.1 Hz, 2H), 4.14 (s, 2H), 3.99 (s, 3H), 3.88 (s, 3H).^{13}C NMR (100 MHz, $CDCl_3$) δ 168.0, 166.0, 158.2, 150.2, 146.7, 137.84, 137.80, 130.0, 129.4, 129.2, 129.02, 128.96, 127.5, 127.1, 124.1, 53.3, 52.9, 38.8; HRMS calcd for $C_{22}H_{20}NO_4$ $[M+H]^+$ 362.1387, found 362.1400.

Procedure for Synthesis of Intermediate Pa. To a glass Schlenk tube (10 mL) equipped with a magnetic stirrer bar, 3-aza-1,5-enyne **4a** (0.1 mmol), Cs_2CO_3 (39.1 mg, 0.12 mmol, 1.2 equiv) and THF (1 mL) were added. The resulting mixture was stirred at 40 °C for 30 min under argon protection. After cooling down to room temperature, the solvent was removed under vacuum. The residue was directly purified by silica gel flash column

chromatography eluting with petroleum ether/ethyl acetate (20 : 1, v/v) to give the desired intermediate **Pa**.

Dimethyl 2-((*Z*)-(1-phenylhept-2-yn-1-ylidene)amino)-maleate (Pa): yellow oil; 2.7 mg; 8% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 (d, *J* = 7.5 Hz, 2H), 7.43 – 7.28 (m, 3H), 5.46 (s, 1H), 3.79 (s, 3H), 3.67 (s, 3H), 2.42 (t, *J* = 6.9 Hz, 2H), 1.58 – 1.48 (m, 2H), 1.45 – 1.33 (m, 2H), 0.85 (t, *J* = 7.3 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.9, 165.1, 156.2, 152.5, 136.1, 132.1, 128.8, 128.4, 105.5, 104.4, 73.8, 52.8, 51.8, 30.0, 22.0, 19.3, 13.5; HRMS calcd for $C_{19}H_{22}NO_4$ $[M+H]^+$ 328.1543, found 328.1560.

Procedure for Synthesis of Pyrrole 5a-*Z*/*E* and Pyridine 6a from Intermediate Pa. To a glass Schlenk tube (10 mL) equipped with a magnetic stirrer bar, intermediate **Pa** (0.2 mmol; **Pa** used here was obtained by accumulation through carrying out the above mentioned reaction several times), Cs_2CO_3 (13.0 mg, 0.04 mmol, 20 mol%) and THF (2 mL) were added. The resulting mixture was stirred at 80 °C under argon protection for 12 h. After cooling down to room temperature, the solvent was removed under vacuum. The residue was directly purified by silica gel flash column chromatography eluting with petroleum ether/ethyl acetate (20 : 1, v/v) to give the desired pyrrole **5a-*Z*/*E*** and pyridine **6a**.

(*Z*/*E*)-dimethyl 4-(pent-1-en-1-yl)-5-phenyl-1*H*-pyrrole-2,3-dicarboxylate (5a-*Z*/*E*, *Z*/*E* = 1:1): white solid; 13.0 mg (0.2 mmol); 20% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.29 (s, 1H), 9.14 (s, 1H), 7.55 – 7.51 (m, 2H), 7.49 – 7.37 (m, 7H), 7.36 – 7.32 (m, 1H), 6.44 – 6.17 (m, 2H), 5.84 (dt, *J* = 16.0, 7.0 Hz, 1H), 5.68 (dt, *J* = 11.2, 7.3 Hz, 1H), 3.92 (s, 3H), 3.88 (s, 3H), 3.87 (s, 3H), 3.85 (s, 3H), 2.09 (qd, *J* = 7.2, 1.5 Hz, 2H), 1.76 (qd, *J* = 7.3, 1.7 Hz, 2H), 1.41 (h, *J* = 7.3 Hz, 2H), 1.17 (h, *J* = 7.3 Hz, 2H), 0.90 (t, *J* = 7.4 Hz, 3H), 0.72 (t, *J* = 7.3 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.2, 166.0, 160.7, 160.6, 139.4, 136.2, 133.6, 131.5, 131.3, 129.02, 128.96, 128.5, 128.3, 128.2, 127.6, 127.1, 122.7, 122.5, 120.5, 120.3, 120.0, 119.91, 119.87, 119.8, 52.6, 52.3, 52.2, 35.6, 31.0, 22.6, 22.2, 13.8, 13.7 [*Note*: two peaks (2 CO_2CH_3) overlapped at 52.22 ppm]; HRMS calcd for $C_{19}H_{22}NO_4$ $[M+H]^+$ 328.1543, found 328.1552.

Dimethyl 4-butyl-6-phenylpyridine-2,3-dicarboxylate (6a): known compound[3d]; 12.2 mg; 19% yield; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.07 – 7.97 (m, 2H), 7.74 (s, 1H), 7.48 (dq, *J* = 6.8, 5.8, 5.1 Hz, 3H), 3.99 (s, 3H), 3.97 (s, 3H), 2.80 – 2.70 (m, 2H), 1.70 – 1.62 (m, 2H), 1.41 (h, *J* = 7.3 Hz, 2H), 0.95 (t, *J* = 7.3 Hz, 3H).

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