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CuI-catalyzed Intramolecular Aminocyanation of Terminal Alkynes in *N*-(2-Ethynylphenyl)-*N*-sulfonylcyanamides *via* Cu-vinylidene Intermediates

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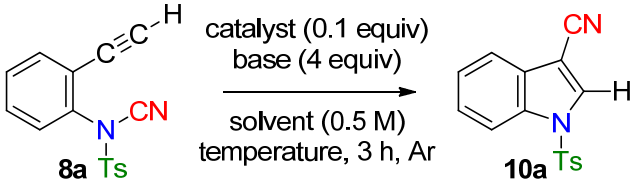
Table 1. Optimization of the reaction conditions

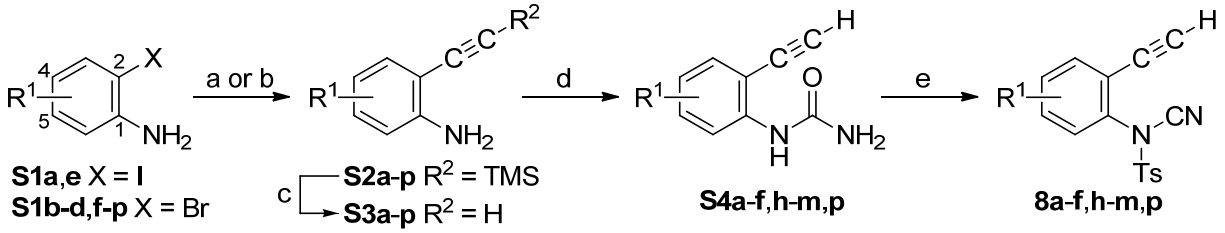


entry	base (4 equiv)	solvent (0.5 M)	catalyst (0.1 equiv)	temperature (^{o}C)	result[a] (%)
1	Et_3N	DMF	CuI	80	67
2	DIPEA	DMF	CuI	80	65
3	DBU	DMF	CuI	80	N.D.[b]
4	DABCO	DMF	CuI	80	0
5	NMM	DMF	CuI	80	63
6	pyridine	DMF	CuI	80	34
7	Na_2CO_3	DMF	CuI	80	67[c]
8	K_2CO_3	DMF	CuI	80	25
9	K_3PO_4	DMF	CuI	80	55
10	NaOAc	DMF	CuI	80	51
11	Na_2CO_3	DMF	CuBr	80	46
12	Na_2CO_3	DMF	CuCl	80	N.R.[d]
13	Na_2CO_3	DMF	CuCN	80	66[c]
14	Na_2CO_3	MeCN	CuI	reflux	52
15	Na_2CO_3	1,4-dioxane	CuI	80	88[c]
16	Na_2CO_3	1,2-DCE	CuI	reflux	15
17	Na_2CO_3	THF	CuI	reflux	59
18	Na_2CO_3	toluene	CuI	80	46
19	Na_2CO_3	DME	CuI	80	61
20	Na_2CO_3	DMSO	CuI	80	20
21	Na_2CO_3	1,4-dioxane	CuI / proline	80	78[c]
22	Na_2CO_3	1,4-dioxane	CuI / 1,10-Phen	80	N.R.[d]
23	-----	1,4-dioxane	CuI	80	N.R.[d]
24	Na_2CO_3	1,4-dioxane	-----	80	N.R.[d]

[a] unless specified otherwise, the yields were determined by ^{1}H NMR analysis of the crude products using 1,3,5-trimethoxybenzene as an internal standard; [b] N.D. = no desired product; [c] isolated yield; [d] N.R. = no reaction

Reaction Summary

Scheme S1

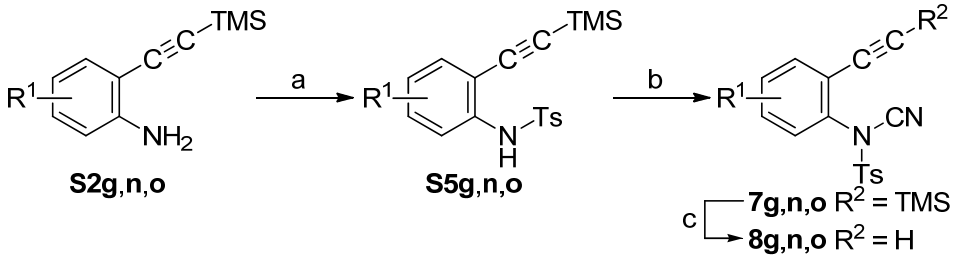


reagents and conditions
(a) X = I: trimethylsilylacetylene (1.2 equiv), $Pd(PPh_3)_2Cl_2$ (2 mol%), CuI (2 mol%), Et_3N / THF (1 : 1, *v*/*v*, 0.5 M), rt, Ar, 1 d; (b) X = Br: trimethylsilylacetylene (1.5 equiv), $Pd(PPh_3)_2Cl_2$ (2 mol%), CuI (2 mol%), PPh_3 (5 mol%), Et_3N / toluene (1 : 4, *v*/*v*, 0.2 M), 100 °C, Ar, 1 d; (c) TBAF (1 M in THF, containing *ca.* 5% H_2O, 1 equiv), THF (0.5 M), 0 °C, 3 ~ 15 min; (d) NaNCO (3 equiv), AcOH / H_2O (3 : 1, *v*/*v*, 0.25 M), rt, 15 min ~ 3 h; (e) TsCl (3 equiv), pyridine (0.5 M), 0 °C ~ rt, 3 ~ 24 h

	R^1 =	**S2**	**S3**	**S4**	**8**		R^1 =	**S2**	**S3**	**S4**	**8**
a	H	95%	N.I.	77%	43%	**h**	4-OMe	54%	N.I.	73%	74%
b	5-OMe	47%	N.I.	58%	43%	**i**	4-Me	74%	N.I.	57%	65%
c	5-Me	57%	N.I.	50%	39%	**j**	4-*i*-Pr	53%	N.I.	64%	43%
d	5-F	95%	N.I.	46%	26%	**k**	4-*t*-Bu	63%	N.I.	87%	52%
e	5-Cl	66%	N.I.	73%	28%	**l**	4-F	54%	N.I.	68%	37%
f	5-CF_3	N.I.	21%	71%	22%	**m**	4-Cl	70%	N.I.	65%	19%
g	5-NO_2	29%	N.I.	< 5%		**n**	4-CF_3	65%	N.I.	< 5%	
						o	4-NO_2	63%	N.I.	< 5%	
						p	4,6-di-F	66%	N.I.	49%	45%

N.I. = not isolated

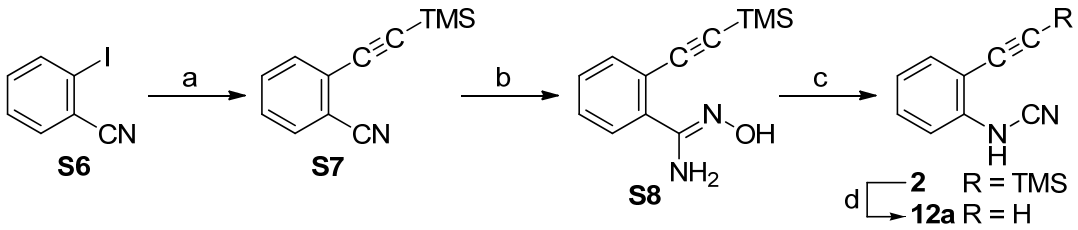
Scheme S2



reagents and conditions
(a) TsCl (1.2 equiv), pyridine (2 equiv), DCM (0.5 M), 0 °C ~ rt, 12 h; (b) BrCN (1.3 equiv), Et_3N (2 equiv), ether (0.2 M), 0 °C, 3 h; (c) TBAF (1 M in THF, containing *ca.* 5% H_2O, 1 equiv), THF (0.5 M), 0 °C, < 3 min

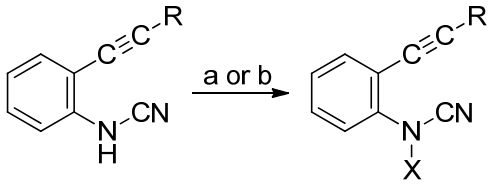
	R =	**S5**	**7**	**8**
g	5-NO_2	48%	49%	43%
n	4-CF_3	71%	33%	38%
o	4-NO_2	26%	77%	23%

Scheme S3



reagents and conditions
(a) trimethylsilylacetylene (1.2 equiv), $Pd(PPh_3)_2Cl_2$ (2 mol%), CuI (2 mol%), Et_3N / THF (1 : 1, *v*/*v*, 0.25 M), rt, Ar, 1 d, 78%; (b) NH_2OH (50 *wt*% aqueous solution, 2.0 equiv), EtOH (0.4 M), reflux, 4 h, 55%; (c) TsCl (1.1 equiv), pyridine (1.0 M), 0 °C ~ rt, 2 h, 93%; (d) TBAF (1 M in THF, containing *ca.* 5% H_2O, 1 equiv), THF (0.5 M), 0 °C, < 3 min, 37%

Scheme S4

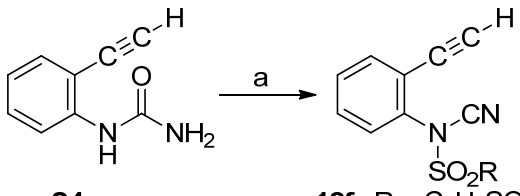


2 R = TMS — **7a** R = TMS, X = Ts (68% from **2**)

12a R = H	**12c** R = H, X = Ac (87% from **12a**)
	12d Bz (60% from **12a**)
	12e Boc (47% from **12a**)
	12g 4-$NO_2C_6H_4SO_2$ (32% from **12a**)
	12i 4-$AcNHC_6H_4SO_2$ (65% from **12a**)

reagents and conditions
(a) X = Ac, Bz, Ts, 4-$NO_2C_6H_4SO_2$, or 4-$AcNHC_6H_4SO_2$: X-Cl (1.5 equiv), DIPEA (3 equiv), MeCN (0.25 M), 0 °C ~ rt; (b) X = Boc: Boc_2O (1.8 equiv), DIPEA (3 equiv), MeCN (0.25 M), 0 °C ~ rt

Scheme S5

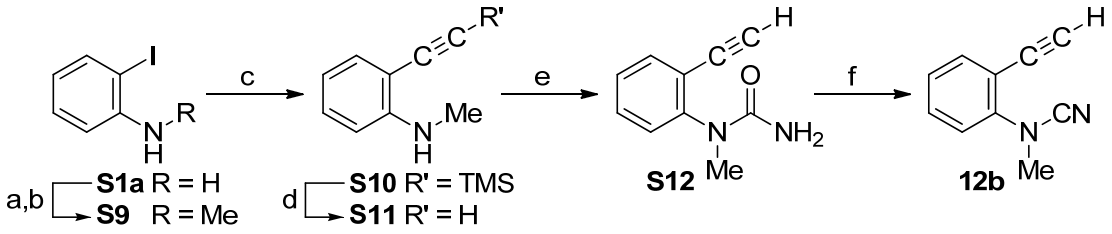


S4a

12f R = $C_6H_5SO_2$ (20%)
12h R = 4-$MeOC_6H_4SO_2$ (28%)
12j R = $MeSO_2$ (20%)

reagents and conditions
(a) RSO_2Cl (3 equiv), pyridine (0.33 M), 0 °C ~ rt, 3 h

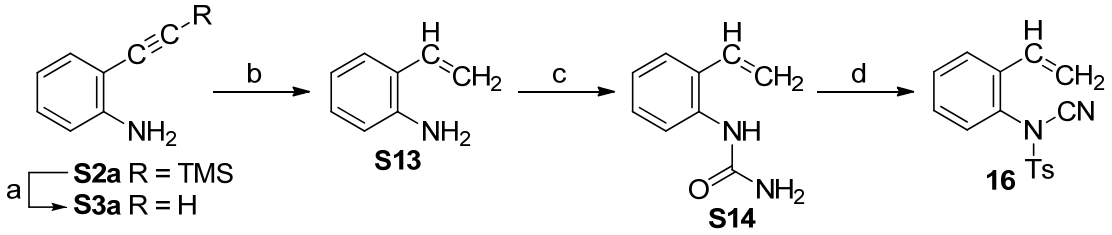
Scheme S6



reagents and conditions

(a) premixed HCOOH (3.5 equiv) with Ac_2O (1.2 equiv), DCM (0.33 M), rt, 11 h; (b) $NaBH_4$ (4 equiv), $BF_3{\cdot}OEt_2$ (5 equiv), THF (0.13 M), 0 ^oC ~ rt, 1 d, 81% (after two steps from **S1a**); (c) trimethylsilylacetylene (1.2 equiv), $Pd(PPh_3)_2Cl_2$ (2 mol%), CuI (2 mol%), Et_3N / THF (1 : 1, *v*/*v*, 0.5 M), rt, Ar, 1 d, 90%; (d) K_2CO_3 (1 equiv), MeOH, rt, 1 h; (e) NaNCO (3 equiv), AcOH / H_2O (3 : 1, *v*/*v*, 0.25 M), rt, 2.5 h, 59% (after two steps from **S10**); (f) TsCl (1.5 equiv), pyridine (1 M), 0 ^oC ~ rt, 1 h, 83%

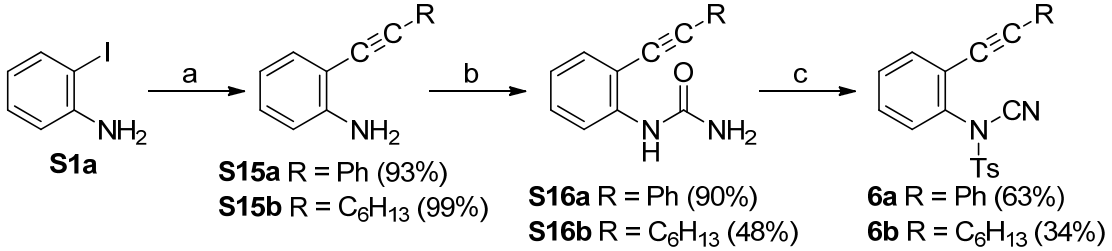
Scheme S7



reagents and conditions

(a) K_2CO_3 (1 equiv), MeOH, rt, 1 h; (b) Lindlar catalyst (10 mol%), MeOH (0.25 M), H_2 (1 atm), rt, 4.5 h, 45% (after two steps from **S2a**); (c) NaNCO (3 equiv), AcOH / H_2O (3 : 1, *v*/*v*, 0.25 M), rt, 4 h, 81%; (d) TsCl (3 equiv), pyridine (0.5 M), 0 ^oC ~ rt, 1 h, 68%

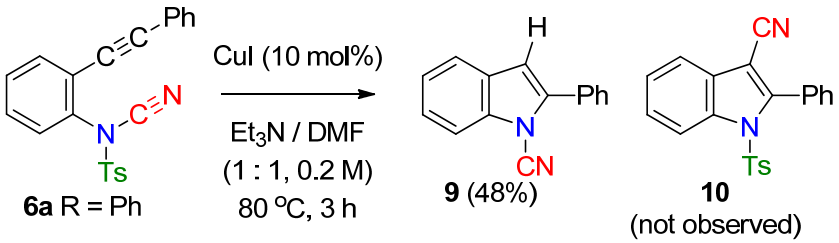
Scheme S8



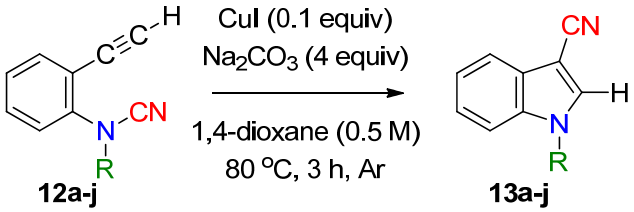
reagents and conditions

(a) phenylacetylene or 1-octyne (1.5 equiv), $Pd(PPh_3)_2Cl_2$ (2 mol%), CuI (2 mol%), Et_3N / THF (1 : 1, *v*/*v*, 0.5 M), rt, Ar, 1 d; (b) NaNCO (3 equiv), AcOH / H_2O (3 : 1, *v*/*v*, 0.25 M), rt, 5 h; (c) TsCl (3 equiv), pyridine (0.5 M), 0 ^oC ~ rt, 1 h

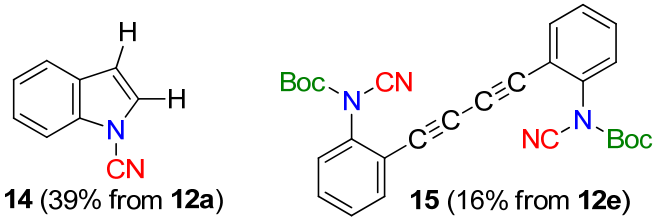
Scheme 3



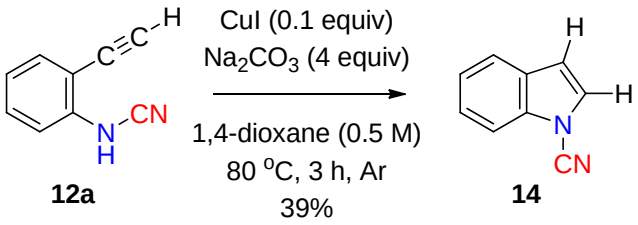
Scheme 4



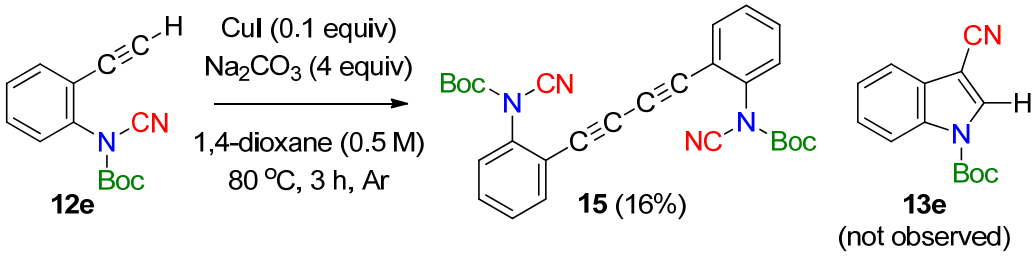
13a	R = H	(N.D.)	**13f**	R = $C_6H_5SO_2$	(65%)
13b	R = Me	(N.D.)	**13g**	R = 4-$NO_2C_6H_4SO_2$	(77%)
13c	R = Ac	(N.D.)	**13h**	R = 4-$MeOC_6H_4SO_2$	(65%)
13d	R = Bz	(N.D.)	**13i**	R = 4-$AcNHC_6H_4SO_2$	(67%)
13e	R = Boc	(N.D.)	**13j**	R = $MeSO_2$	(75%)



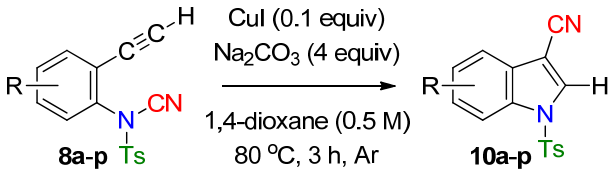
Scheme 4a

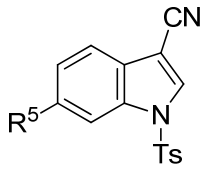


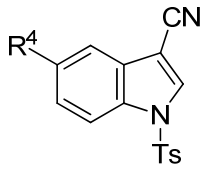
Scheme 4e

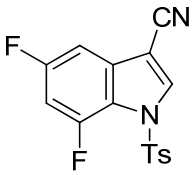


Scheme 5



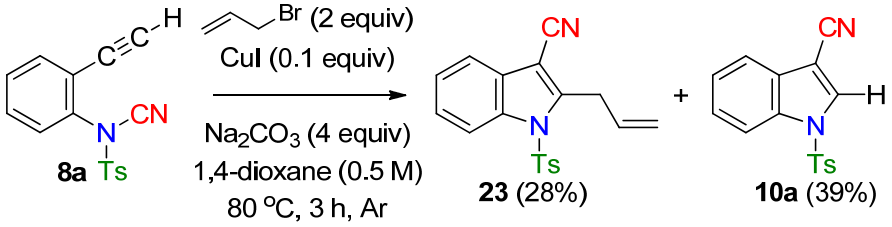






10a	R^5 = H	88%	**10h**	R^4 = OMe	61%	**10p**	34% (53%)[a]
10b	OMe	49%	**10i**	Me	59%	([a] time = 17 h)	
10c	Me	70%	**10j**	*i*-Pr	74%		
10d	F	59%	**10k**	*t*-Bu	83%		
10e	Cl	79%	**10l**	F	66%		
10f	CF_3	60%	**10m**	Cl	63%		
10g	NO_2	73%	**10n**	CF_3	58%		
			10o	NO_2	53%		

Scheme 7(E)

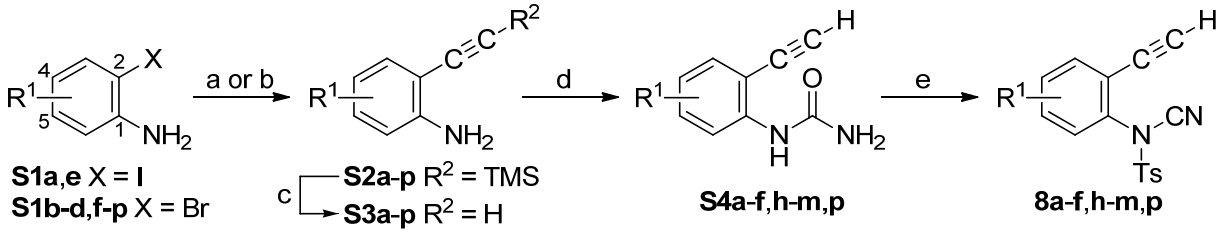


EXPERIMENTAL SECTION

General chemical procedures

The chemical shift values are reported in δ values (parts per million, ppm) relative to the standard chemical shift for the hydrogen residue peak and carbon-13 peak in the deuterated solvent, $CDCl_3$, or DMSO-d_6.[1] The coupling constant (*J*) values are expressed in hertz (Hz). The numbers of protons directly attached to the individual carbons were determined by ^{13}C NMR DEPT experiments. Thin-layer chromatography (TLC) was performed on silica gel plates. Compounds on TLC were visualized by illumination under UV light (254 nm), or dipped into 10% phosphomolybdic acid in ethanol followed by charring on a hot plate. Solvent systems are expressed as a volumetric ratio (*v* / *v*) of the less polar component to the more polar component. Silica gel (230-400 mesh) was used for flash column chromatography and this technique has been described by W. C. Still *et al.*[2] Evaporations were carried out under reduced pressure (water aspirator or vacuum pump) with the bath temperature below 50 ^{o}C unless specified otherwise. Materials obtained from commercial suppliers were used without further purification.

Scheme S1



reagents and conditions
(a) X = I: trimethylsilylacetylene (1.2 equiv), $Pd(PPh_3)_2Cl_2$ (2 mol%), CuI (2 mol%), Et_3N / THF (1 : 1, *v*/*v*, 0.5 M), rt, Ar, 1 d; (b) X = Br: trimethylsilylacetylene (1.5 equiv), $Pd(PPh_3)_2Cl_2$ (2 mol%), CuI (2 mol%), PPh_3 (5 mol%), Et_3N / toluene (1 : 4, *v*/*v*, 0.2 M), 100 °C, Ar, 1 d; (c) TBAF (1 M in THF, containing *ca.* 5% H_2O, 1 equiv), THF (0.5 M), 0 °C, 3 ~ 15 min; (d) NaNCO (3 equiv), AcOH / H_2O (3 : 1, *v*/*v*, 0.25 M), rt, 15 min ~ 3 h; (e) TsCl (3 equiv), pyridine (0.5 M), 0 °C ~ rt, 3 ~ 24 h

	R^1 =	**S2**	**S3**	**S4**	**8**		R^1 =	**S2**	**S3**	**S4**	**8**
a	H	95%	N.I.	77%	43%	**h**	4-OMe	54%	N.I.	73%	74%
b	5-OMe	47%	N.I.	58%	43%	**i**	4-Me	74%	N.I.	57%	65%
c	5-Me	57%	N.I.	50%	39%	**j**	4-*i*-Pr	53%	N.I.	64%	43%
d	5-F	95%	N.I.	46%	26%	**k**	4-*t*-Bu	63%	N.I.	87%	52%
e	5-Cl	66%	N.I.	73%	28%	**l**	4-F	54%	N.I.	68%	37%
f	5-CF_3	N.I.	21%	71%	22%	**m**	4-Cl	70%	N.I.	65%	19%
g	5-NO_2	29%	N.I.	< 5%		**n**	4-CF_3	65%	N.I.	< 5%	
						o	4-NO_2	63%	N.I.	< 5%	
						p	4,6-di-F	66%	N.I.	49%	45%

N.I. = not isolated

*[General procedure S1] Preparation of 2-alkynylanilines (**S2a,e, S15a,b, S7, S10**) from 2-iodoanilines (**S1a,e, S6, S9**, respectively) via Sonogashira reaction*[3]
To a mixture of $Pd(PPh_3)_2Cl_2$ (0.02 equiv), CuI (0.02 equiv) and 2-iodoaniline (1 equiv) in Et_3N / THF (1 : 1, *v*/*v*, 0.5 M) under Ar atmosphere at room temperature was added trimethylsilylacetylene or terminal alkynes (1.2 equiv). The reaction mixture was stirred at room temperature for 1 d. The solid was removed by filtration and the solvent was evaporated under reduced pressure. The residue was purified by flash column chromatography.

*[General procedure S2] Preparation of 2-alkynylanilines (**S2b-d,f-p**) from 2-bromoanilines (**S1b-d,f-p**) via Sonogashira reaction*[4]
To a mixture of $Pd(PPh_3)_2Cl_2$ (0.02 equiv), CuI (0.02 equiv), PPh_3 (0.05 equiv) and 2-bromoaniline (1 equiv) in Et_3N / toluene (1 : 4, *v*/*v*, 0.2 M) under Ar atmosphere at room temperature was added trimethylsilylacetylene (1.5 equiv). The reaction mixture was stirred at 100 °C for 1 d. The solid was removed by filtration and the solvent was evaporated under reduced pressure. The residue was purified by flash column chromatography.

[General procedure S3a] Preparation of 2-ethynylanilines from 2-(2-trimethylsilylethynyl)anilines by the reaction with TBAF in THF
To a solution of 2-(2-trimethylsilylethynyl)aniline (1 equiv) in THF (0.5 M) was add-

ed TBAF (1 M in THF, containing *ca.* 5% H_2O, 1 equiv) at 0 °C. The solution was stirred at 0 °C for 3 ~ 15 min and then the solvent was immediately evaporated under reduced pressure. The residue was purified by flash column chromatography, or used for the subsequent reaction without further purification.

[General procedure S3b] Preparation of 2-ethynylanilines from 2-(2-trimethylsilylethynyl)anilines by the reaction with K_2CO_3 in MeOH

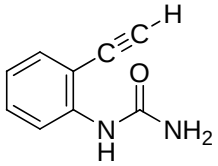
To a solution of 2-(2-trimethylsilylethynyl)aniline (1 equiv) in MeOH (0.33 M) was added K_2CO_3 (1 equiv). The solution was stirred at room temperature for 1 h. The solid was removed by filtration and the solvent was evaporated under reduced pressure. The residue was purified by flash column chromatography, or used for the subsequent reaction without further purification.

*[General procedure S4] Preparation of N-(2-alkynylphenyl)ureas (**S4a-f,h-m,p, S12, S14, S16a,b**) from 2-alkynylanililines*[5] *(**S3a-f,h-m,p, S11, S13, S15a,b**, respectively)*

To a solution of 2-alkynylanililine (1 equiv) in aqueous AcOH (H_2O / AcOH = 1 : 3, *v*/*v*, 0.25 M) was added sodium cyanate (3 equiv). The solution was stirred at room temperature for 15 min ~ 3 h. The reaction mixture was diluted with EtOAc. The solution was washed with saturated aqueous Na_2CO_3 solution, saturated aqueous NaCl solution and dried over anhydrous $MgSO_4$. The solvent was evaporated under reduced pressure and the resulting residue was purified by flash column chromatography.

*[General procedure S5] Preparation of N-tosyl-N-(2-alkynylphenyl)cyanamides (**8a-f,h-m,p, 12b,f,h,j, 6a,b, 16**) from N-(2-alkynylphenyl)ureas*[6] *(**S4a-f,h-m,p, S12, S16a,b, S14**, respectively)*

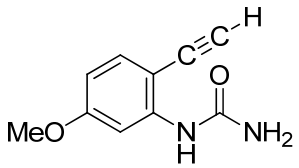
To a freshly prepared solution of TsCl (3 equiv) in pyridine (0.5 M of *N*-(2-alkynylphenyl)urea) at 0 °C was added *N*-(2-alkynylphenyl)urea (1 equiv). The solution was stirred under Ar atmosphere for 3 ~ 24 h while the reaction temperature was allowed to rise to room temperature. The solvent was evaporated under reduced pressure and the residue was purified by flash column chromatography.



S4a

***N*-(2-Ethynylphenyl)urea**[7] **(S4a)**

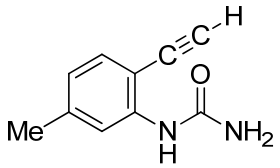
Compound **S4a** was prepared from 2-ethynylaniline (**S3a**) by *General procedure S4*. The product (**S4a,** solid, 2.5499 g, 15.92 mmol, 81%) was purified by flash column chromatography (Hex / EtOAc = 6 : 4, R_f = 0.15). m.p. 160–162 °C (*lit.*169–171 °C);[7] ^{1}H NMR (DMSO-d_6, 400 MHz) δ 8.10 (d, 1H, *J* = 8.4 Hz), 7.89 (br, 1H, NH), 7.37 (dd, 1H, *J* = 7.6, 1.2 Hz), 7.28 (dt, 1H, *J* = 7.8, 1.6 Hz), 6.91 (dt, 1H, *J* = 7.6, 0.8 Hz), 6.44 (br, 2H, NH_2), 4.55 (s, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ 155.6, 141.7, 132.2 (CH), 129.4 (CH), 121.1 (CH), 119.0 (CH), 109.9, 86.9 (CH), 79.7; MS (ESI^+) *m/z* 161 (100) (M+H); HRMS (ESI^+, TOF) calcd for $C_9H_8N_2O$: 161.0715 (M+H). Found: 161.0716.



S4b

***N*-(2-Ethynyl-5-methoxyphenyl)urea (S4b)**

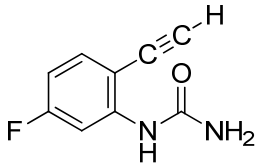
Compound **S4b** was prepared from 2-ethynyl-5-methoxyaniline (**S3b**) by *General procedure S4*. The product (**S4b**, white solid, 0.4486 g, 2.36 mmol, 58%, R_f = 0.15 (Hex / EtOAc = 5 : 5) was purified by flash column chromatography (Hex / EtOAc = 7 : 3). m.p. 183–184 ^oC; ^1H NMR (DMSO-d_6, 400 MHz) δ 7.85 (br, 1H, NH), 7.81 (d, 1H, J = 2.6 Hz), 7.28 (d, 1H, J = 8.6 Hz), 6.51 (dd, 1H, J = 8.6, 2.6 Hz), 6.50 (br, 2H, NH_2), 4.42 (s, 1H), 3.72 (s, 3H, Me); ^{13}C NMR (DMSO-d_6, 100 MHz) δ 160.0, 155.6, 143.1, 133.3 (CH), 107.1 (CH), 104.2 (CH), 102.1, 85.6 (CH), 79.7, 55.1 (CH_3); MS (EI, 20 eV) *m/z* 104 (25), 132 (28), 147 (100), 190 (49) (M^+); HRMS (EI, sector) calcd for $C_{10}H_{10}N_2O_2$: 190.0742. Found: 190.0748.



S4c

***N*-(2-Ethynyl-5-methylphenyl)urea (S4c)**

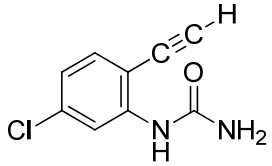
Compound **S4c** was prepared from 2-ethynyl-5-methylaniline (**S3c**) by *General procedure S4*. The product (**S4c**, solid, 0.7036 g, 4.039 mmol, 50%, R_f = 0.16 (Hex / EtOAc = 6 : 4)) was purified by flash column chromatography (Hex / EtOAc = 7 : 3). m.p. 184–186 ^oC; ^1H NMR (DMSO-d_6, 400 MHz) δ 7.90 (s, 1H), 7.83 (br, 1H, NH), 7.24 (d, 1H, J = 7.8 Hz), 6.74 (d, 1H, J = 7.9 Hz), 6.40 (br, 2H, NH_2), 4.40 (s, 1H), 2.25 (s, 3H, Me); ^{13}C NMR (DMSO-d_6, 100 MHz) δ 155.9, 141.6, 139.5, 132.2 (CH), 122.4 (CH), 119.7 (CH), 107.5, 86.4 (CH), 80.0, 21.7 (CH_3); MS (ESI^+) *m/z* 175 (100) (M+H); HRMS (ESI^+, TOF) calcd for $C_{10}H_{11}N_2O$: 175.0871 (M+H). Found: 175.0876.



S4d

***N*-(2-Ethynyl-5-fluorophenyl)urea (S4d)**

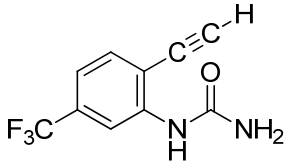
Compound **S4d** was prepared from 2-ethynyl-5-fluoroaniline (**S3d**) by *General procedure S4*. The product (**S4d**, yellow solid, 1.5426 g, 8.658 mmol, 46%, R_f = 0.25 (Hex / EtOAc = 5 : 5) was purified by flash column chromatography (Hex / EtOAc = 7 : 3). m.p. 184–185 ^oC; ^1H NMR (DMSO-d_6, 400 MHz) δ 8.07 (br, 1H, NH), 8.03 (dd, 1H, J = 12.7, 2.7 Hz), 7.42 (dd, 1H, J = 8.5, 6.7 Hz), 6.75 (dt, 1H, J = 8.4, 2.7 Hz), 6.63 (br, 2H, NH_2), 4.56 (s, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ 162.3 (d, J = 244 Hz), 155.5, 143.7 (d, J = 12.8 Hz), 134.1 (d, J = 10.3 Hz, CH), 108.1 (d, J = 22.9 Hz, CH), 105.8 (d, J = 2.8 Hz), 105.3 (d, J = 28.7 Hz, CH), 87.0 (CH), 78.7; ^{19}F NMR(DMSO-d_6, 376 MHz) δ -108; MS (EI, 20 eV) *m/z* 108 (48), 135 (100), 178 (37) (M^+); HRMS (EI, sector) calcd for $C_9H_7FN_2O$: 178.0542. Found: 178.0542.



S4e

***N*-(2-Ethynyl-5-chlorophenyl)urea (S4e)**

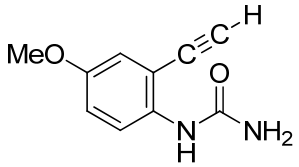
Compound **S4e** was prepared from 2-ethynyl-5-chloroaniline (**S3e**) by *General procedure S4*. The product (**S4e**, white solid, 1.8626 g, 9.570 mmol, 87%, R_f = 0.18 (Hex / EtOAc = 5 : 5)) was purified by flash column chromatography (Hex / EtOAc = 7 : 3). m.p. 200–201 ^{o}C; ^{1}H NMR (DMSO-d_6, 400 MHz) δ 8.27 (d, 1H, J = 2.1 Hz), 8.06 (br, 1H, NH), 7.38 (d, 1H, J = 8.3 Hz), 6.95 (dd, 1H, J = 8.3, 2.2 Hz), 6.62 (br, 2H, NH_2), 4.62 (s, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ 155.5, 143.0, 134.1, 133.7 (CH), 121.0 (CH), 118.1 (CH), 108.5, 88.1 (CH), 78.6; MS (EI, 70 eV) *m/z* 66 (83), 84 (89), 151 (100), 194 (45) (M^+), 196 (14) (M^++2); HRMS (EI, sector) calcd for $C_9H_7ClN_2O$: 194.0247. Found: 194.0245.



S4f

***N*-(2-Ethynyl-5-trifluoromethylphenyl)urea (S4f)**

Compound **S4f** was prepared from 2-ethynyl-5-trifluoromethylaniline (**S3f**) by *General procedure S4*. The product (**S4f**, solid, 1.0296 g, 4.512 mmol, 48%, R_f = 0.25 (Hex / EtOAc = 7 : 3)) was purified by flash column chromatography (Hex / EtOAc = 6 : 4). m.p. 183–185 ^{o}C; ^{1}H NMR (DMSO-d_6, 400 MHz) δ 8.57 (d, 1H, J = 1.2 Hz), 8.18 (br, 1H, NH), 7.59 (d, 1H, J = 8.0 Hz), 7.23 (dd, 1H, J = 8.4, 1.6 Hz), 6.66 (br, 2H, NH_2), 4.82 (s, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ 155.5, 142.4, 133.3 (CH), 129.4 (q, J = 31 Hz), 123.9 (q, J = 271 Hz), 117.2 (q, J = 4.0 Hz, CH), 114.6 (q, J = 4.0 Hz, CH), 113.4, 89.7 (CH), 78.3; ^{19}F NMR (DMSO-d_6, 376 MHz) δ -61.7; MS (EI, 70 eV) *m/z* 58 (29), 184 (74), 185 (100), 192 (45), 207 (40), 228 (56) (M^+); HRMS (EI, sector) calcd for $C_{10}H_7F_3N_2O$: 228.0510. Found: 228.0512.

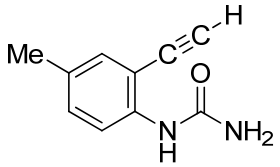


S4h

***N*-(2-Ethynyl-4-methoxyphenyl)urea (S4h)**

Compound **S4h** was prepared from 2-ethynyl-4-methoxyaniline (**S3h**) by *General procedure S4*. The product (**S4h**, solid, 0.5181 g, 2.724 mmol, 73%) was purified by flash column chromatography (Hex / EtOAc = 5 : 5, R_f = 0.08). m.p. 168–170 ^{o}C; ^{1}H NMR (DMSO-d_6, 400 MHz) δ 7.90 (d, 1H, J = 8.6 Hz), 7.76 (br, 1H, NH), 6.92 (s, 1H), 6.90 (dd, 1H, J = 8.6, 2.8 Hz), 6.27 (br, 2H, NH_2), 4.55 (s, 1H), 3.70 (s, 3H, OMe); ^{13}C NMR (DMSO-d_6, 100 MHz) δ 155.9, 153.5, 135.2, 121.4 (CH), 116.14 (CH), 116.07 (CH), 111.6, 86.6 (CH), 79.9, 55.3 (CH_3); MS (ESI^+) *m/z* 191 (100) (M+H); HRMS (ESI^+, TOF) calcd for $C_{10}H_{11}N_2O_2$: 191.0821 (M+H). Found:

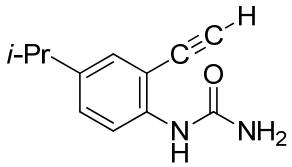
191.0822.



S4i

***N*-(2-Ethynyl-4-methylphenyl)urea (S4i)**

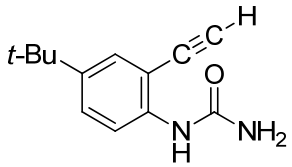
Compound **S4i** was prepared from 2-ethynyl-4-methylaniline (**S3i**) by *General procedure S4*. The product (**S4i**, solid, 1.9265 g, 11.19 mmol, 89%) was purified by flash column chromatography (Hex / EtOAc = 5 : 5, R_f = 0.15). m.p. 165–167 °C; ^{1}H NMR (DMSO-d_6, 400 MHz) δ 7.95 (d, 1H, *J* = 8.4 Hz), 7.80 (br, 1H, NH), 7.18 (d, 1H, *J* = 1.6 Hz), 7.09 (dd, 1H, *J* = 8.4, 2.0 Hz), 6.36 (br, 2H, NH_2), 4.50 (s, 1H), 2.20 (s, 3H, Me); ^{13}C NMR (DMSO-d_6, 100 MHz) δ 155.7, 139.3, 132.2 (CH), 130.1 (C+CH), 119.2 (CH), 110.0, 86.5 (CH), 79.9, 19.9 (CH_3); MS (EI, 70 eV) *m/z* 130 (95), 131 (100), 174 (52) (M^+); HRMS (EI, sector) calcd for $C_{10}H_{10}N_2O$: 174.0793 (M^+). Found: 174.0796.



S4j

***N*-(2-Ethynyl-4-(*i*-propyl)phenyl)urea (S4j)**

Compound **S4j** was prepared from 2-ethynyl-4-(*i*-propyl)aniline (**S3j**) by *General procedure S4*. The product (**S4j**, white solid, 0.6847 g, 3.39 mmol, 64%, R_f = 0.18 (Hex / EtOAc = 5 : 5)) was purified by flash column chromatography (Hex / EtOAc = 7 : 3). m.p. 191–192 °C; ^{1}H NMR (DMSO-d_6, 400 MHz) δ 7.97 (d, 1H, *J* = 8.6 Hz), 7.82 (br, 1H, NH), 7.22 (d, 1H, *J* = 2.1 Hz), 7.16 (dd, 1H, *J* = 8.6, 2.2 Hz), 6.35 (br, 2H, NH2), 4.50 (s, 1H), 2.79 (sept, 1H, *J* = 6.9 Hz, CH), 1.15 (d, 6H, *J* = 7.2 Hz, Me); ^{13}C NMR (DMSO-d_6, 100 MHz) δ 155.7, 141.3, 139.6, 129.6 (CH), 127.6 (CH), 119.4 (CH), 110.0, 86.4 (CH), 80.1, 32.4 (CH), 23.7 (CH3); MS (EI, 20 eV) *m/z* 144 (100), 159 (20), 202 (13) (M^+); HRMS (EI, sector) calcd for $C_{12}H_{14}N_2O$: 202.1106. Found: 202.1106.

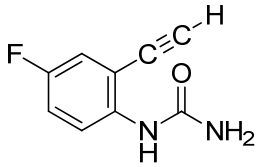


S4k

***N*-(2-Ethynyl-4-(*t*-butyl)phenyl)urea (S4k)**

Compound **S4k** was prepared from 2-ethynyl-4-(*t*-butyl)aniline (**S3k**) by *General procedure S4*. The product (**S4k**, solid, 1.5248 g, 7.050 mmol, 87%, R_f = 0.16 (Hex / EtOAc = 6 : 4)) was purified by flash column chromatography (Hex / EtOAc = 8 : 2). m.p. 200–203 °C; ^{1}H NMR (DMSO-d_6, 400 MHz) δ 7.96 (d, 1H, *J* = 9.2 Hz), 7.84 (br, 1H, NH), 7.33–7.30 (m, 2H), 6.35 (br, 2H, NH_2), 4.46 (s, 1H), 1.23 (s, 9H, *t*-Bu); ^{13}C NMR (DMSO-d_6, 100 MHz) δ 155.8, 143.7, 139.3, 128.6 (CH), 126.7 (CH), 119.3 (CH), 109.9, 86.3 (CH), 80.3, 33.8, 31.0 (CH_3); MS (ESI$^+$) *m/z* 217 (100) (M+H);

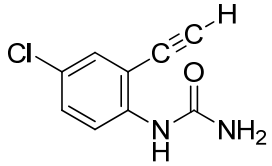
HRMS (ESI$^+$, TOF) calcd for $C_{13}H_{17}N_2O$: 217.1341 (M+H). Found: 217.1338.



S4l

***N*-(2-Ethynyl-4-fluorophenyl)urea (S4l)**

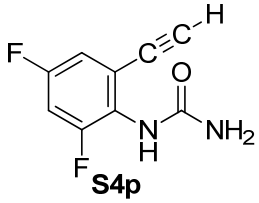
Compound **S4l** was prepared from 2-ethynyl-4-fluoroaniline (**S3l**) by *General procedure S4*. The product (**S4l**, solid, 1.2873 g, 7.225 mmol, 68%, R_f = 0.08 (Hex / EtOAc = 6 : 4)) was purified by flash column chromatography (Hex / EtOAc = 7 : 3). m.p. 187–189 ^oC; ^1H NMR (DMSO-d_6, 400 MHz) δ 8.06 (dd, 1H, J = 9.2, 5.4 Hz), 7.93 (br, 1H, NH), 7.23 (dd, 1H, J = 9.0, 3.0 Hz), 7.16 (dt, 1H, J = 8.7, 3.1 Hz), 6.41 (br, 2H, NH_2), 4.64 (s, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ 156.1 (d, J = 238 Hz), 155.7, 138.3 (d, J = 2 Hz), 121.1 (d, J = 8 Hz, CH), 118.0 (d, J = 24 Hz, CH), 116.5 (d, J = 22 Hz, CH), 111.6 (d, J = 9 Hz), 87.8 (CH), 78.6 (d, J = 3 Hz); ^{19}F NMR (DMSO-d_6, 376 MHz) δ -121.9; MS (EI, 70 eV) *m/z* 66 (60), 84 (67), 107 (41), 108 (53), 135 (100), 178 (37) (M^+); HRMS (EI, sector) calcd for $C_9H_7FN_2O$: 178.0542. Found: 178.0539.



S4m

***N*-(2-Ethynyl-4-chlorophenyl)urea (S4m)**

Compound **S4m** was prepared from 2-ethynyl-4-chloroaniline (**S3m**) by *General procedure S4*. The product (**S4m**, yellow solid, 1.0532 g, 5.411 mmol, 65%, R_f = 0.18 (Hex / EtOAc = 5 : 5)) was purified by flash column chromatography (Hex / EtOAc = 7 : 3). m.p. 197–198 ^oC; ^1H NMR (DMSO-d_6, 400 MHz) δ 8.14 (d, 1H, J = 9.0 Hz), 7.99 (br, 1H, NH), 7.42 (d, 1H, J = 2.6 Hz), 7.33 (dd, 1H, J = 9.1, 2.6 Hz), 6.52 (br, 2H, NH_2), 4.68 (s, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ 155.5, 140.8, 131.2 (CH), 129.4 (CH), 124.5, 120.4 (CH), 111.6, 88.3 (CH), 78.3; MS (EI, 20 eV) *m/z* 89 (87), 151 (100), 194 (17) (M^+), 196 (5) (M+2); HRMS (EI, sector) calcd for $C_9H_7ClN_2O$: 194.0247. Found: 194.0244.

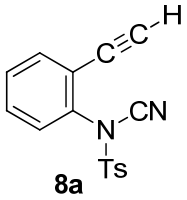


S4p

***N*-(2-Ethynyl-4,6-difluorophenyl)urea (S4p)**

Compound **S4p** was prepared from 2-ethynyl-4,6-difluoroaniline (**S3p**) by *General procedure S4*. The product (**S4p**, solid, 0.4950 g, 2.52 mmol, 80%, R_f = 0.08 (Hex / EtOAc = 5 : 5)) was purified by flash column chromatography (Hex / EtOAc = 6 : 4). m.p. 201–202 ^oC; ^1H NMR (DMSO-d_6, 400 MHz) δ 7.85 (br, 1H, NH), 7.35 (ddd, 1H, J = 8.8, 2.8, 1.2 Hz), 7.21 (ddd, 1H, J = 8.8, 2.8, 1.6 Hz), 6.00 (br, 2H, NH_2), 4.58 (s, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ 158.9 (dd, J = 243, 13 Hz), 157.7 (dd, J =

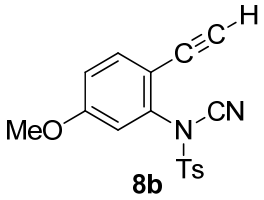
247, 14 Hz), 155.7, 125.8 (dd, *J* = 14, 3.0 Hz), 122.2 (dd, *J* = 12, 5.0 Hz), 114.5 (dd, *J* = 24, 4.0 Hz, CH), 105.7 (t, *J* = 26 Hz, CH), 86.9 (CH), 78.9; ^{19}F NMR ((DMSO-d_6, 376 MHz) δ -113.3 (d, *J* = 7.5 Hz), -113.8 (d, *J* = 7.5 Hz); MS (ESI$^+$) *m/z* 197 (15) (M+H), 219 (100, M+Na); HRMS (ESI$^+$, TOF) calcd for $C_9H_6F_2N_2NaO$: 219.0346 (M+Na). Found: 219.0337.



8a

***N*-Tosyl-*N*-(2-ethynylphenyl)cyanamide (8a)**

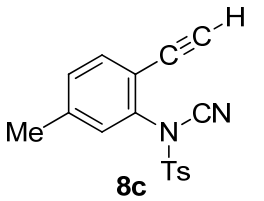
Compound **8a** was prepared from compound **S4a** by *General procedure S5*. The product (**8a**, solid, 0.5727 g, 1.93 mmol, 27%, R_f = 0.25 (Hex / EtOAc = 8 : 2)) was purified by flash column chromatography (Hex / EtOAc = 9 : 1). m.p. 85–86 ^{o}C (Hex / EtOAc); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.70 (d, 2H, *J* = 8.4 Hz, Ts), 7.52–7.50 (m, 1H), 7.45–7.42 (m, 2H), 7.38–7.35 (m, 1H), 7.35 (d, 2H, *J* = 8.4 Hz, Ts), 3.03 (s, 1H), 2.49 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 146.9, 134.9, 134.3 (CH), 133.2, 130.7 (CH), 130.4 (CH), 130.2 (CH), 129.8 (CH), 128.8 (CH), 122.1, 107.4, 84.7 (CH), 77.2, 22.0 (CH_3); MS (EI, 70 eV) *m/z* 91 (100), 155 (100), 248 (100), 267 (52), 271 (49), 296 (52) (M$^+$); HRMS (EI, sector) calcd for $C_{16}H_{12}N_2O_2S$: 296.0619. Found: 296.0619; IR (cm^{-1}) 3282, 3071, 2926, 2231, 2113, 1596, 1484, 1448.



8b

***N*-Tosyl-*N*-(2-ethynyl-5-methoxyphenyl)cyanamide (8b)**

Compound **8b** was prepared from compound **S4b** by *General procedure S5*. The product (**8b**, white soild, 0.2712 g, 0.831 mmol, 46%, R_f = 0.18 (Hex / EtOAc = 8 : 2)) was purified by flash column chromatography (Hex / EtOAc = 95 : 5). m.p. 128–129 ^{o}C; ^{1}H NMR (DMSO-d_6, 400 MHz) δ 7.71 (d, 2H, *J* = 8.4 Hz, Ts), 7.527 (d, 2H, *J* = 8.8 Hz, Ts), 7.525 (d, 1H, *J* = 7.3 Hz), 7.14 (dd, 1H, *J* = 8.7, 2.6 Hz), 6.93 (d, 1H, *J* = 2.6 Hz), 4.13 (s, 1H), 3.78 (s, 3H, OMe), 2.45 (s, 3H, Me); ^{13}C NMR (DMSO-d_6, 100 MHz) δ 160.1, 147.2, 134.98, 134.96 (CH), 132.1, 130.7 (CH), 128.3 (CH), 117.2 (CH), 115.1 (CH), 113.3, 107.0, 86.0 (CH), 76.9, 55.9 (CH_3), 21.3 (CH_3); MS (EI, 20 eV) *m/z* 187 (83), 326 (100) (M$^+$); HRMS (EI, sector) calcd for $C_{17}H_{14}N_2O_3S$: 326.0725. Found: 326.0717; IR (cm^{-1}) 3284, 2925, 2854, 2234, 2111, 1608, 1563, 1505, 1463, 1444.

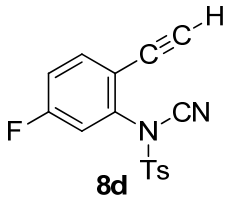


8c

***N*-Tosyl-*N*-(2-ethynyl-5-methylphenyl)cyanamide (8c)**

Compound **8c** was prepared from compound **S4c** by *General procedure S5*. The

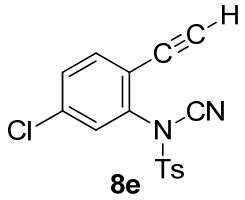
product (**8c**, solid, 0.4711 g, 1.52 mmol, 39%, R_f = 0.11 (Hex / EtOAc = 9: 1)) was purified by flash column chromatography (Hex / EtOAc = 95 : 5). m.p. 164–166 °C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.70 (d, 2H, *J* = 8.4 Hz, Ts), 7.37 (d, 1H, *J* = 8.0 Hz), 7.35 (d, 2H, *J* = 8.8 Hz, Ts), 7.22 (d, 1H, *J* = 8.1 Hz), 7.19 (s, 1H), 2.94 (s, 1H), 2.48 (s, 3H, Me), 2.39 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 146.8, 141.2, 134.9, 134.1 (CH), 133.5, 131.5 (CH), 130.5 (CH), 130.4 (CH), 129.0 (CH), 119.0, 107.6, 83.8 (CH), 77.4, 22.0 (CH_3), 21.5 (CH_3); MS (ESI$^+$) *m/z* 333 (100) (M+Na); HRMS (ESI$^+$, TOF) calcd for $C_{17}H_{15}N_2O_2S$: 311.0854 (M+H). Found: 311.0853; IR (cm^{-1}) 3287, 2925, 2235, 2113, 1608, 1596, 1499, 1410.



8d

***N*-Tosyl-*N*-(2-ethynyl-5-fluorophenyl)cyanamide (8d)**

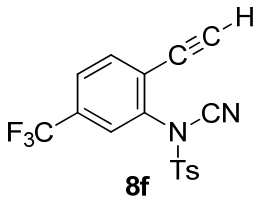
Compound **8d** was prepared from compound **S4d** by *General procedure S5*. The product (**8d**, white soild, 0.2496 g, 0.794 mmol, 26%, R_f = 0.25 (Hex / EtOAc = 8 : 2)) was purified by flash column chromatography (Hex / EtOAc = 95 : 5). m.p. 146–147 °C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.71 (d, 2H, *J* = 8.3 Hz, Ts), 7.48 (dd, 1H, *J* = 8.5, 5.9 Hz), 7.37 (d, 2H, *J* = 8.2 Hz, Ts), 7.19–7.13 (m, 2H), 3.01 (s, 1H), 2.49 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 162.2 (d, *J* = 255 Hz), 147.0, 136.1 (d, *J* = 10.3 Hz), 135.4 (d, *J* = 9.0 Hz, CH),132.9, 130.3 (CH), 128.7 (CH), 118.2 (d, *J* = 21.8 Hz, CH), 118.1 (d, *J* = 4.1 Hz), 117.5 (d, *J* = 24.5 Hz, CH), 106.7, 84.5 (d, *J* = 1.4 Hz, CH), 76.1, 21.8 (CH_3); ^{19} F NMR ($CDCl_3$, 376 MHz) δ -106; MS (ESI$^+$) *m/z* 239 (100), 315 (56) (M+H); HRMS (ESI$^+$, TOF) calcd for $C_{16}H_{12}FN_2O_2S$: 315.0604 (M+H). Found: 315.0598; IR (cm^{-1}) 3288, 2925, 2232, 2117, 1596, 1495, 1419.



8e

***N*-Tosyl-*N*-(2-ethynyl-5-chlorophenyl)cyanamide (8e)**

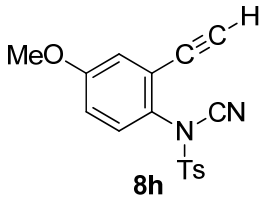
Compound **8e** was prepared from compound **S4e** by *General procedure S5*. The product (**8e**, white solid, 0.0338 g, 0.10 mmol, 28%, R_f = 0.28 (Hex / EtOAc = 8 : 2)) was purified by flash column chromatography (Hex / EtOAc = 95 : 5). m.p. 145–147 °C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.71 (d, 2H, *J* = 8.3 Hz, Ts), 7.45–7.36 (m, 5H), 3.07 (s, 1H), 2.49 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 147.0, 135.7, 135.6, 134.8 (CH), 132.9, 130.9 (CH), 130.3 (CH), 130.0 (CH), 128.7 (CH), 120.4, 106.7, 85.6 (CH), 76.2, 21.8 (CH_3); MS (EI, 20 eV) *m/z* 91 (100), 155 (91), 330 (15) (M^+), 332 (5) (M+2); HRMS (EI, sector) calcd for $C_{16}H_{11}ClN_2O_2S$: 330.0230. Found: 330.0217; IR (cm^{-1}) 3291, 3101, 2923, 2235, 2118, 1593, 1472, 1403.



8f

***N*-Tosyl-*N*-(2-ethynyl-5-trifluoromethylphenyl)cyanamide (8f)**

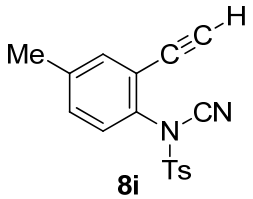
Compound **8f** was prepared from compound **S4f** by *General procedure S5*. The product (**8f**, white soild, 0.1939 g, 0.532 mmol, 22%, R_f = 0.23 (Hex / EtOAc = 8 : 2)) was purified by flash column chromatography (Hex / EtOAc = 95 : 5). m.p. 124–125 ^oC; ^1H NMR ($CDCl_3$, 400 MHz) δ 7.71 (d, 2H, *J* = 8.4 Hz, Ts), 7.69 (dd, 1H, *J* = 7.6, 0.8 Hz), 7.64 (d, 1H, *J* = 8.2 Hz), 7.58 (s, 1H), 7.39 (d, 2H, *J* = 8.2 Hz, Ts), 3.21 (s, 1H), 2.50 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 147.2, 135.5, 134.8 (CH), 132.8, 132.1 (q, *J* = 34.1 Hz), 130.4 (CH), 128.7 (CH), 127.2 (q, *J* = 3.5 Hz, CH), 126.8 (q, *J* = 3.8 Hz, CH), 125.7, 122.6 (q, *J* = 273 Hz), 106.7, 87.3 (CH), 76.1, 21.8 (CH_3); MS (EI, 20 eV) *m/z* 91 (77), 155 (100), 364 (12) (M^+); HRMS (EI, sector) calcd for $C_{17}H_{11}F_3N_2O_2S$: 364.0493. Found: 364.0492; IR (cm^{-1}) 3286, 2926, 2854, 2240, 2119, 1598.



8h

***N*-Tosyl-*N*-(2-ethynyl-4-methoxyphenyl)cyanamide (8h)**

Compound **8h** was prepared from compound **S4h** by *General procedure S5*. The product (**8h**, oil, 0.3228 g, 0.989 mmol, 74%) was purified by flash column chromatography (Hex / EtOAc = 8 : 2 , R_f = 0.15). ^1H NMR ($CDCl_3$, 400 MHz) δ 7.68 (d, 2H, *J* = 8.4 Hz, Ts), 7.35 (d, 2H, *J* = 8.0 Hz, Ts), 7.23 (d, 1H, *J* = 8.8 Hz), 6.96 (d, 1H, *J* = 3.2 Hz), 6.92 (dd, 1H, *J* = 8.8, 2.8 Hz), 3.81 (s, 3H, Me), 2.99 (s, 1H), 2.48 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 160.8, 146.8, 133.3, 131.1 (CH), 130.4 (CH), 128.9 (CH), 127.7, 123.3, 118.7 (CH), 116.3 (CH), 107.7, 84.2 (CH), 77.4, 55.9 (CH_3), 22.0 (CH_3); MS (ESI^+) *m/z* 349 (100) (M+Na); HRMS (ESI^+, TOF) calcd for $C_{17}H_{14}NaO_3N_2S$: 349.0623 (M+Na). Found: 349.0610; IR (cm^{-1}) 3279, 2943, 2844, 2231, 2114, 1597, 1574, 1486.

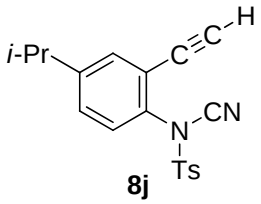


8i

***N*-Tosyl-*N*-(2-ethynyl-4-methylphenyl)cyanamide (8i)**

Compound **8i** was prepared from compound **S4i** by *General procedure S5*. The product (**8i**, oil, 0.8054 g, 2.60 mmol, 65%, R_f = 0.2 (Hex / EtOAc = 8 : 2)) was purified by flash column chromatography (Hex / EtOAc = 95 : 5). ^1H NMR ($CDCl_3$, 400 MHz) δ 7.67 (d, 2H, *J* = 8.4 Hz, Ts), 7.34 (d, 2H, *J* = 8.1 Hz, Ts), 7.29 (s, 1H), 7.207 (s, 1H), 7.205 (s, 1H), 2.99 (s, 1H), 2.46 (s, 3H, Me), 2.34 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 146.6, 141.1, 134.5 (CH), 133.1, 132.2, 130.8 (CH), 130.1 (CH), 129.3 (CH), 128.6 (CH), 121.5, 107.4, 83.9 (CH), 77.2, 21.7 (CH_3), 20.9 (CH_3); MS (EI, 70 eV)

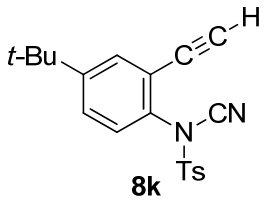
m/z 155 (100), 246 (45), 262 (47), 310 (43) (M^+); HRMS (EI, sector) calcd for $C_{17}H_{14}N_2O_2S$: 310.0776. Found: 310.0780; IR (cm^{-1}) 3252, 3056, 2926, 2238, 2109, 1918, 1596, 1488.



8j

***N*-Tosyl-*N*-(2-ethynyl-4-(*i*-propyl)phenyl)cyanamide (8j)**

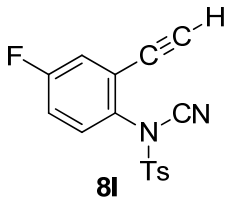
Compound **8j** was prepared from compound **S4j** by *General procedure S5*. The product (**8j**, white soild, 0.2883 g, 0.852 mmol, 43%, R_f = 0.38 (Hex / EtOAc = 8 : 2)) was purified by flash column chromatography (Hex / EtOAc = 95 : 5). m.p. 104–106 ^oC; ^1H NMR ($CDCl_3$, 400 MHz) δ 7.72 (dd, 2H, *J* = 6.6 Hz, 1.8 Hz, Ts), 7.36 (d, 2H, *J* = 7.2 Hz, Ts), 7.35 (d, 1H, *J* = 2.0 Hz), 7.27 (dd, 1H, *J* = 8.4, 2.0 Hz), 7.24 (d, 1H, *J* = 8.4 Hz), 2.99 (s, 1H), 2.91 (sept, 1H, *J* = 6.8 Hz, CH), 2.48 (s, 3H, Me), 1.24 (d, 6H, *J* = 7.2 Hz, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 151.8, 146.5, 133.4, 132.5 (CH), 132.1, 130.2 (CH), 129.5 (CH), 128.7 (CH), 128.4 (CH), 121.7, 107.4, 83.7 (CH), 77.6, 33.7 (CH), 23.5 (CH_3), 21.8 (CH_3); MS (ESI^+) *m/z* 251 (21), 297 (26), 339 (M+H); HRMS (ESI^+, TOF) calcd for $C_{19}H_{19}N_2O_2S$: 339.1167 (M+H). Found: 339.1161; IR (cm^{-1}) 3284, 2965, 2233, 2113, 1596, 1488, 1463.



8k

***N*-Tosyl-*N*-(2-ethynyl-4-(*t*-butyl)phenyl)cyanamide (8k)**

Compound **8k** was prepared from compound **S4k** by *General procedure S5*. The product (**8k**, solid, 0.5436 g, 1.54 mmol, 52%) was purified by flash column chromatography (Hex / EtOAc = 9 : 1, R_f = 0.15). m.p. 106–108 ^oC; ^1H NMR ($CDCl_3$, 400 MHz) δ 7.72 (d, 2H, *J* = 8.4 Hz, Ts), 7.50 (d, 1H, *J* = 2.3 Hz), 7.43 (dd, 1H, *J* = 8.5, 2.3 Hz), 7.36 (d, 2H, *J* = 8.2 Hz, Ts), 7.24 (d, 1H, *J* = 8.6 Hz), 3.00 (s, 1H), 2.49 (s, 3H, Me), 1.31 (s, 9H, *t*-Bu); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 154.3, 146.7, 133.6, 132.5, 131.5 (CH), 130.4 (CH), 129.4 (CH), 128.9 (CH), 127.7 (CH), 121.5, 107.7, 83.8 (CH), 78.0, 35.1, 31.2 (CH_3), 22.0 (CH_3); MS (ESI^+) *m/z* 375 (100) (M+Na); HRMS (ESI^+, TOF) calcd for $C_{20}H_{21}N_2O_2S$: 353.1324 (M+H). Found: 353.1330; IR (cm^{-1}) 3282, 2966, 2872, 2234, 2112, 1596, 1493, 1467.

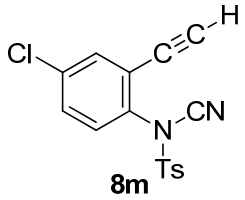


8l

***N*-Tosyl-*N*-(2-ethynyl-4-fluorophenyl)cyanamide (8l)**

Compound **8l** was prepared from compound **S4l** by *General procedure S5*. The product (**8l**, solid, 0.5880 g, 1.87 mmol, 37%) was purified by flash column chromatography (Hex / EtOAc = 9 : 1, R_f = 0.1). m.p. 106–108 ^oC; ^1H NMR ($CDCl_3$, 400 MHz)

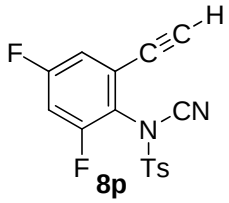
δ 7.69 (d, 2H, *J* = 8.4 Hz, Ts), 7.37 (d, 2H, *J* = 8.4 Hz, Ts), 7.35 (dd, 1H, *J* = 9.2, 4.8 Hz), 7.19 (dd, 1H, *J* = 8.4, 2.8 Hz), 7.14 (ddd, 1H, *J* = 8.8, 7.6, 2.8 Hz), 3.08 (s, 1H), 2.49 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 163.0 (d, *J* = 252 Hz), 147.1, 133.2, 132.0 (d, *J* = 10 Hz, CH), 131.2 (d, *J* = 3Hz), 130.5 (CH), 129.0 (CH), 124.2 (d, *J* = 9 Hz), 121.0 (d, *J* = 24 Hz, CH), 117.8 (d, *J* = 23 Hz, CH), 107.3, 85.8 (CH), 76.3, 22.0 (CH_3); ^{19}F NMR ($CDCl_3$, 376 MHz) δ -108.1; MS (EI, 70 eV) *m/z* 91 (100), 155 (91), 266 (21), 314 (23) (M^+); HRMS (EI, sector) calcd for $C_{16}H_{11}FN_2O_2S$: 314.0525. Found: 314.0526; IR (cm^{-1}) 3270, 3063, 2924, 2238, 2120, 1929, 1584.



8m

***N*-Tosyl-*N*-(2-ethynyl-4-chlorophenyl)cyanamide (8m)**

Compound **8m** was prepared from compound **S4m** by *General procedure S5*. The product (**8m**, white soild, 0.1312 g, 0.397 mmol, 19%, R_f = 0.33 (Hex / EtOAc = 8 : 2)) was purified by flash column chromatography (Hex / EtOAc = 95 : 5). m.p. 126–128 ^{o}C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.68 (d, 2H, *J* = 8.3 Hz, Ts), 7.46 (d, 1H, *J* = 2.3 Hz), 7.40 (dd, 1H, *J* = 8.6, 2.4 Hz), 7.36 (d, 2H, *J* = 8.1 Hz, Ts), 7.30 (d, 1H, *J* = 8.6 Hz), 3.09 (s, 1H), 2.48 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 146.9, 136.6, 133.8 (CH), 133.3, 132.8, 130.8 (CH), 130.3 (2xCH), 128.6 (CH), 123.3, 106.8, 85.8 (CH), 75.9, 21.8 (CH_3); MS (EI, 70 eV) *m/z* 65 (61), 91 (100), 92 (53), 139 (47), 155 (82), 156 (47), 282 (51), 330 (30) (M^+), 332 (12) (M+2); HRMS (EI, sector) calcd for $C_{16}H_{11}ClN_2O_2S$: 330.0230. Found: 330.0229; IR (cm^{-1}) 3246, 3076, 2926, 2229, 2111, 1595, 1479.

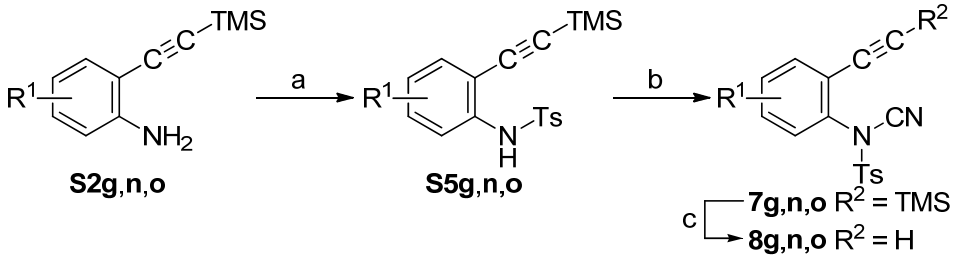


8p

***N*-Tosyl-*N*-(2-ethynyl-4,6-difluorophenyl)cyanamide (8p)**

Compound **8p** was prepared from compound **S4p** by *General procedure S5*. The product (white soild, 0.1490 g, 0.448 mmol, 45%, R_f = 0.25 (Hex / EtOAc = 8 : 2)) was purified by flash column chromatography (Hex / EtOAc = 95 : 5). m.p. 118–119 ^{o}C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.81 (d, 2H, *J* = 8.4 Hz, Ts), 7.40 (d, 2H, *J* = 8.3 Hz, Ts), 7.08 (dt, 1H, *J* = 8.0, 2.2 Hz), 6.98 (dt, 1H, *J* = 8.6, 2.8 Hz), 3.20 (s, 1H), 2.50 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 163.2 (dd, *J* = 255, 13.1 Hz), 159.4 (dd, *J* = 258, 14.1 Hz), 147.0, 133.4, 130.3 (CH), 128.8 (CH),126.0 (d, *J* = 14.1 Hz), 120.1 (dd, *J* = 14.6, 4.5 Hz), 116.7 (dd, *J* = 24.7, 3.5 Hz, CH), 106.8, 106.6 (dd, *J* = 26.2, 24.1 Hz, CH), 86.6 (CH), 75.8, 21.9 (CH_3); ^{19}F NMR ($CDCl_3$, 376 MHz) δ -103.0 (d, *J* = 10.5 Hz), -109.8 (d, *J* = 10.2 Hz); MS (EI, 20 eV) *m/z* 91 (100), 155 (91), 284 (6), 332 (4) (M^+); HRMS (EI, sector) calcd for $C_{16}H_{10}F_2N_2S$: 332.0431. Found: 332.0428; IR (cm^{-1}) 3292, 3094, 2926, 2855, 2238, 2119, 1613, 1588, 1469, 1439.

Scheme S2

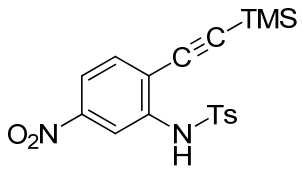


reagents and conditions
(a) TsCl (1.2 equiv), pyridine (2 equiv), DCM (0.5 M), 0 °C ~ rt, 12 h; (b) BrCN (1.3 equiv), Et_3N (2 equiv), ether (0.2 M), 0 °C, 3 h; (c) TBAF (1 M in THF, containing *ca.* 5% H_2O, 1 equiv), THF (0.5 M), 0 °C, < 3 min

	R =	**S5**	**7**	**8**
g	5-NO_2	48%	49%	43%
n	4-CF_3	71%	33%	38%
o	4-NO_2	26%	77%	23%

*[General procedure S6] Preparation of N-tosyl-2-(2-trimethylsilylethynyl)anilines (**S5g,n,o**) from 2-(2-trimethylsilylethynyl)anilines*[8] *(**S2g,n,o**)*
To a solution of 2-(2-trimethylsilylethynyl)aniline (1 equiv) and pyridine (2 equiv) in CH_2Cl_2 (0.5 M) at 0 °C was added TsCl (1.2 equiv). The solution was stirred for 12 h while the reaction temperature was allowed to rise to room temperature. The solution was diluted with CH_2Cl_2, washed with H_2O and saturated aqueous NaCl solution, and dried over anhydrous $MgSO_4$. The solvent was removed under reduced pressure, and the residue was purified by flash column chromatography.

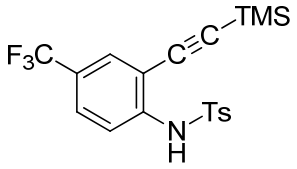
*[General procedure S7] Preparation of N-tosyl-N-(2-(2-trimethylsilylethynyl))cyanamides (**7g,n,o**) from N-tosyl-2-(2-trimethylsilylethynyl)anilines*[8] *(**S5g,n,o**)*
To a solution of *N*-tosyl-2-(2-trimethylsilylethynyl)aniline (1 equiv) in ethyl ether (0.2 M) at 0 °C was added BrCN (1.5 equiv, ***caution:*** *toxic and hydrolyzed readily to release hydrogen cyanide*) in one portion. The solution was stirred at 0 °C and Et_3N (2.0 equiv) was added dropwise. After the addition was completed, the reaction mixture was stirred for 3 h while the reaction temperature was allowed to rise to room temperature. The solid was removed by filteration, and the solution was diluted with EtOAc. The solution was washed with saturated aqueous Na_2CO_3 solution, saturated aqueous NaCl solution, and dried over anhydrous $MgSO_4$. The solvent was evaporated under reduced pressure, and the residue was purified by flash column chromatography.



S5g

***N*-Tosyl-2-(2-trimethylsilylethynyl)-5-nitroaniline (S5g)**

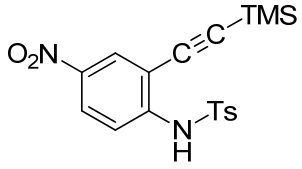
Compound **S5g** was prepared from 2-(2-trimethylsilylethynyl)-5-nitroaniline (**S3g**) by *General procedure S6*. The product (**S5g**, oil, 0.5660 g, 1.46 mmol, 48%) was purified by flash column chromatography (Hex / $CHCl_3$ = 7 : 3, R_f = 0.08). ^{1}H NMR ($CDCl_3$, 400 MHz) δ 8.42 (d, 1H, *J* = 2.0 Hz), 7.84 (dd, 1H, *J* = 8.4, 2.4 Hz), 7.73 (d, 2H, *J* = 8.4 Hz, Ts), 7.45 (d, 1H, *J* = 8.4 Hz), 7.39 (br, 1H, NH), 7.27 (d, 2H, *J* = 8.0 Hz, Ts), 2.39 (s, 3H, Me), 0.31 (s, 9H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 148.2, 145.0, 139.4, 135.8, 132.8 (CH), 130.2 (CH), 127.6 (CH), 119.5, 118.7 (CH), 113.5 (CH), 108.4, 97.9, 21.8 (CH_3), -0.13 (CH_3); MS (EI, 70 eV) *m/z* 91 (28), 373 (100), 388 (76) (M^+); HRMS (EI, sector) calcd for $C_{18}H_{20}N_2O_4SSi$: 388.0913. Found: 388.0912.



S5n

***N*-Tosyl-2-(2-trimethylsilylethynyl)-4-trifluoromethylaniline (S5n)**

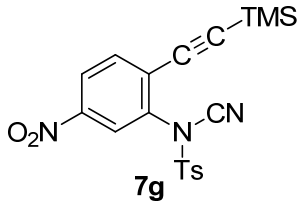
Compound **S5n** was prepared from 2-(2-trimethylsilylethynyl)-4-trifluoromethyl aniline (**S3n**) by *General procedure S6*. The product (**S5n**, oil, 2.1713 g, 5.276 mmol, 89%, R_f = 0.28 (Hex / EtOAc = 95 : 5)) was purified by flash column chromatography (Hex / EtOAc = 99 : 1). ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.72 (d, 2H, *J* = 8.4 Hz, Ts), 7.70 (d, 1H, *J* = 8.8 Hz), 7.59 (s, 1H), 7.51 (dd, 1H, *J* = 8.8, 1.2 Hz), 7.43 (br, 1H, NH), 7.28 (d, 2H, *J* = 7.6 Hz, Ts), 2.42 (s, 3H, Me), 0.32 (s, 9H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 144.8, 141.2, 136.1, 130.1 (CH), 129.4 (q, *J* = 4.0 Hz, CH), 127.4 (CH), 126.8 (q, *J* = 4.0 Hz, CH), 126.3 (q, *J* = 33 Hz), 123.7 (q, *J* = 270 Hz), 118.6 (CH), 114.0, 104.7, 98.2, 21.8 (CH_3), -0.04 (CH_3); ^{19}F NMR ($CDCl_3$, 376 MHz) δ -62.5; MS (EI, 70 eV) *m/z* 396 (100), 397 (26), 411 (72) (M^+); HRMS (EI, sector) calcd for $C_{19}H_{20}F_3NO_2SSi$: 411.0936. Found: 411.0933.



S5o

***N*-Tosyl-2-(2-trimethylsilylethynyl)-4-nitroaniline (S5o)**

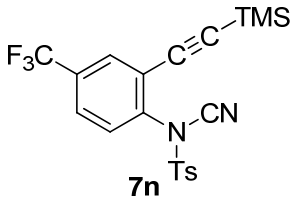
Compound **S5o** was prepared from 2-(2-trimethylsilylethynyl)-4-nitroaniline (**S3o**) by *General procedure S6*. The product (**S5o**, oil, 0.3054 g, 0.786 mmol, 26%) was purified by flash column chromatography (Hex / EtOAc = 95 : 5, R_f = 0.18). ^{1}H NMR ($CDCl_3$, 400 MHz) δ 8.19 (d, 1H, *J* = 2.7 Hz), 8.09 (dd, 1H, *J* = 9.1, 2.5 Hz), 7.73 (d, 2H, *J* = 8.3 Hz, Ts), 7.67 (d, 1H, *J* = 9.2 Hz), 7.61 (br, 1H, NH), 7.28 (d, 2H, *J* = 8.2 Hz, Ts), 2.39 (s, 3H, Me), 0.31 (s, 9H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 145.2, 143.6, 143.3, 135.7, 130.3 (CH), 127.8 (CH), 127.5 (CH), 125.3 (CH), 117.4 (CH), 113.7, 106.0, 97.2, 21.8 (CH_3), -0.12 (CH_3); MS (EI, 70 eV) *m/z* 91 (21), 155 (22), 316 (25), 373 (100), 388 (87) (M^+); HRMS (EI, sector) calcd for $C_{18}H_{20}N_2O_4SSi$: 388.0913. Found: 388.0912.



7g

***N*-Tosyl-*N*-(2-(2-trimethylsilylethynyl)-5-nitrophenyl)cyanamide (7g)**

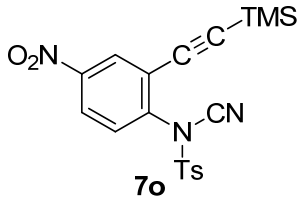
Compound **7g** was prepared from compound **S5g** by *General procedure S7*. The product (**7g**, oil, 0.2948 g, 0.713 mmol, 49%, R_f = 0.13 (Hex / EtOAc = 9 : 1)) was purified by flash column chromatography (Hex / EtOAc = 95 : 5). ^{1}H NMR ($CDCl_3$, 400 MHz) δ 8.26 (dd, 1H, *J* = 8.4, 2.0 Hz), 8.17 (d, 1H, *J* = 2.0 Hz), 7.72 (d, 2H, *J* = 8.4 Hz, Ts), 7.66 (d, 1H, *J* = 8.8 Hz), 7.40 (d, 2H, *J* = 8.0 Hz, Ts), 2.51 (s, 3H, Me), 0.226 (s, 9H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 147.4, 147.3, 135.6, 134.7 (CH), 133.4, 130.8 (CH), 129.4, 128.8 (CH), 125.1 (CH), 124.7 (CH), 110.9, 106.3, 96.6, 22.1 (CH_3), -0.43 (CH_3); MS (EI, 70 eV) *m/z* 92 (100), 155 (100), 228 (44), 398 (98), 399 (98), 400 (86), 413 (65) (M^+); HRMS (EI, sector) calcd for $C_{19}H_{19}N_3O_4SSi$: 413.0866. Found: 413.0867; IR (cm^{-1}) 2962, 2231, 1596, 1527, 1391.



7n

***N*-Tosyl-*N*-(2-(2-trimethylsilylethynyl)-4-trifluoromethylphenyl)cyanamide (7n)**

Compound **7n** was prepared from compound **S5n** by *General procedure S7*. The product (**7n**, solid, 0.5303 g, 1.21 mmol, 33%, R_f = 0.2 (Hex / EtOAc = 95 : 5)) was purified by flash column chromatography (Hex / EtOAc = 98 : 2). m.p. 113–115 ^{o}C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.74 (d, 1H, *J* = 1.8 Hz,Ar), 7.68 (d, 2H, *J* = 8.4 Hz, Ts), 7.63 (dd, 1H, *J* = 8.5, 2.0 Hz), 7.52 (d, 1H, *J* = 8.4 Hz), 7.37 (d, 2H, *J* = 8.1 Hz, Ts), 2.49 (s, 3H, Me), 0.20 (s, 9H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 147.1, 137.4, 133.5, 132.7 (q, *J* = 33 Hz), 131.1 (q, *J* = 4.0 Hz, CH), 130.6 (CH), 130.2 (CH), 128.8 (CH), 126.2 (q, *J* = 4.0 Hz, CH), 123.8, 123.1 (q, *J* = 271 Hz), 106.4 (q, *J* = 2.0 Hz), 96.7, 77.4, 22.0 (CH_3), -0.37 (CH_3); ^{19}F NMR ($CDCl_3$, 376 MHz) δ -63.2; MS (EI, 70 eV) *m/z* 91 (100), 139 (29), 155 (66), 251 (58), 267 (52), 421 (79), 422 (60), 423 (58), 436 (34) (M^+); HRMS (EI, sector) calcd for $C_{20}H_{19}F_3N_2O_2SSi$: 436.0889. Found: 436.0886; IR (cm^{-1}) 3068, 2963, 2240, 2166, 1596, 1493.

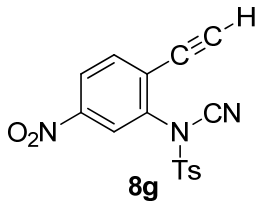


7o

***N*-Tosyl-*N*-(2-(2-trimethylsilylethynyl)-4-nitrophenyl)cyanamide (7o)**

Compound **7o** was prepared from compound **S5o** by *General procedure S7*. The product (**7o**, oil, 0.7405 g, 1.79 mmol, 77%) was purified by flash column chromatography (Hex / EtOAc = 95 : 5, R_f = 0.10). ^{1}H NMR ($CDCl_3$, 400 MHz) δ 8.29 (d, 1H, *J* = 2.8 Hz), 8.21 (dd, 1H, *J* = 9.2, 2.8 Hz), 7.66 (d, 2H, *J* = 8.4 Hz, Ts), 7.60 (d, 1H, *J* = 8.8 Hz), 7.37 (d, 2H, *J* = 8.4 Hz, Ts), 2.49 (s, 3H, Me), 0.19 (s, 9H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 148.3, 147.3, 139.3, 133.2, 130.7 (CH), 130.6 (CH), 128.9

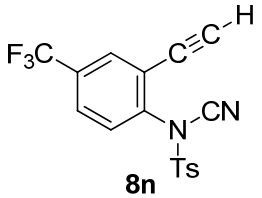
(CH), 128.7 (CH), 124.2, 124.1 (CH), 107.9, 105.9, 95.9, 22.0 (CH_3), -0.47 (CH_3); MS (EI, 70 eV) *m/z* 91 (100), 139 (41), 155 (100), 182 (55), 228 (66), 244 (60), 398 (100), 399 (100), 400 (97), 413 (64) (M^+); HRMS (EI, sector) calcd for $C_{19}H_{19}N_3O_4SSi$: 413.0866. Found: 413.0866; IR (cm^{-1}) 3091, 2962, 2239, 1596, 1574, 1533, 1477.



8g

***N*-Tosyl-*N*-(2-ethynyl-5-nitrophenyl)cyanamide (8g)**

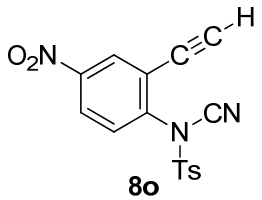
Compound **8g** was prepared from *compound* **7g** by *General procedure S3a*. The product (**8g**, solid, 0.1035 g, 0.3032 mmol, 43%) was purified by flash column chromatography (Hex / EtOAc = 8 : 2, R_f = 0.18). m.p. 159–161 ^oC; ^1H NMR ($CDCl_3$, 400 MHz) δ 8.30 (dd, 1H, *J* = 8.8, 2.4 Hz), 8.20 (d, 1H, *J* = 2.4 Hz), 7.73 (d, 2H, *J* = 8.4 Hz, Ts), 7.71 (d, 1H, *J* = 8.8 Hz), 7.41 (d, 2H, *J* = 8.4 Hz, Ts), 3.40 (s, 1H), 2.51 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 147.9, 147.7, 136.2, 135.2 (CH), 133.0, 130.8 (CH), 128.9 (CH), 128.6, 125.3 (CH), 125.1 (CH), 106.6, 90.1 (CH), 76.1, 22.1 (CH_3); MS (EI, 70 eV) 91 (100), 155 (100), 316 (56), 341 (26) (M^+); HRMS (EI, sector) calcd for $C_{16}H_{11}N_3O_4S$: 341.0470. Found: 341.0468; IR (cm^{-1}) 3281, 3102, 2925, 2231, 2116, 1595, 1529.



8n

***N*-Tosyl-*N*-(2-ethynyl-4-trifluoromethylphenyl)cyanamide (8n)**

Compound **8n** was prepared from *compound* **7n** by *General procedure S3a*. The product (**8n**, solid, 0.0734 g, 0.30 mmol, 43%, R_f = 0.18 (Hex / EtOAc = 9 : 1)) was purified by flash column chromatography (Hex / EtOAc = 95 : 5). m.p. 158–160 ^oC; ^1H NMR ($CDCl_3$, 400 MHz) δ 7.76 (s, 1H), 7.71 (d, 2H, *J* = 8.4 Hz,Ts), 7.69 (dd, 1H, *J* = 8.8, 1.6 Hz), 7.54 (d, 1H, *J* = 8.4 Hz), 7.39 (d, 2H, *J* = 8.0 Hz, Ts), 3.14 (s, 1H), 2.50 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 147.4, 138.0, 133.2, 133.0 (q, *J* = 34 Hz), 131.4 (q, *J* = 3.0 Hz, CH), 130.7 (2xCH), 128.9 (CH), 127.0 (q, *J* = 3.0 Hz, CH), 123.0, 122.97 (q, *J* = 272 Hz), 106.8, 86.7 (CH), 76.1, 22.1 (CH_3); ^{19}F NMR ($CDCl_3$, 376 MHz) δ -63.2; MS (EI, 70 eV) *m/z* 91 (93), 139 (25), 155 (100), 316 (82), 364 (32) (M^+); HRMS (EI, sector) calcd for $C_{17}H_{11}F_3N_2O_2S$: 364.0493. Found: 364.0493; IR (cm^{-1}) 3244, 2925, 2856, 2230, 2113, 1601.



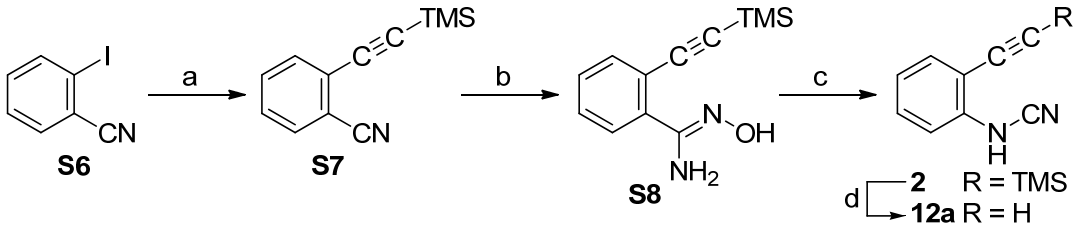
8o

***N*-Tosyl-*N*-(2-ethynyl-4-nitrophenyl)cyanamide (8o)**

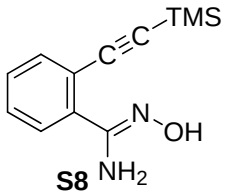
Compound **8o** was prepared from *compound* **7o** by *General procedure S3a*. The

product (**8o**, oil, 0.0538 g, 0.16 mmol, 23%) was purified by flash column chromatography (Hex / EtOAc = 85 : 15, R_f = 0.13). ^{1}H NMR ($CDCl_3$, 400 MHz) δ 8.34 (s, 1H, *J* = 2.4 Hz), 8.27 (dd, 1H, *J* = 8.8, 2.8 Hz), 7.71 (d, 2H, *J* = 8.4 Hz, Ts), 7.62 (d, 1H, *J* = 8.8 Hz), 7.39 (d, 2H, *J* = 8.0 Hz, Ts), 3.23 (s, 1H), 2.51 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 148.5, 147.7, 140.0, 132.9, 131.2 (CH), 130.8 (CH), 129.3 (CH), 128.9 (CH), 124.9 (CH), 123.6, 106.4, 87.8 (CH), 75.5, 22.1 (CH_3); MS (EI, 70 eV) *m/z* 91 (100), 155 (100), 293 (25), 341 (25) (M^+); HRMS (EI, sector) calcd for $C_{16}H_{11}N_3O_4S$: 341.0470. Found: 341.0470; IR (cm^{-1}) 3281, 3091, 2926, 2236, 2116, 1731, 1595, 1538, 1479.

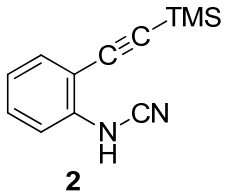
Scheme S3



reagents and conditions
(a) trimethylsilylacetylene (1.2 equiv), $Pd(PPh_3)_2Cl_2$ (2 mol%), CuI (2 mol%), Et_3N / THF (1 : 1, *v*/*v*, 0.25 M), rt, Ar, 1 d, 78%; (b) NH_2OH (50 *wt*% aqueous solution, 2.0 equiv), EtOH (0.4 M), reflux, 4 h, 55%; (c) TsCl (1.1 equiv), pyridine (1.0 M), 0 °C ~ rt, 2 h, 93%; (d) TBAF (1 M in THF, containing *ca.* 5% H_2O, 1 equiv), THF (0.5 M), 0 °C, < 3 min, 37%

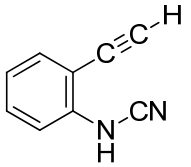


2-(2-Trimethylsilylethynyl)benzamidoxime (S8)
To a solution of 2-(2-trimethylsilylethynyl)benzonitrile[9] (**S7**, 1.6045 g, 8.050 mmol) in EtOH (20 mL) was added hydroxylamine (50wt% aqueous solution, 1.12 g, 16.95 mmol, 2.1 equiv).[10,11] The mixture was stirred at reflux temperature for 4 h under nitrogen. After cooling to room temperature, the reaction mixture was concentrated under reduced pressure and the residue was purified by flash column chromatography (Hex / EtOAc = 8 : 2, R_f = 0.1) to give the product (**S8**, solid, 1.0266 g, 4.418 mmol, 55%). m. p. 124–126 °C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 9.38 (br, 1H, OH), 7.68–7.64 (m, 1H), 7.53–7.50 (m, 1H), 7.36–7.31 (m, 2H), 5.40 (br, 2H, NH_2), 0.25 (s, 9H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 152.7, 134.4, 134.0 (CH), 129.4 (CH), 129.1 (CH), 128.8 (CH), 120.7, 103.3, 100.4, -0.09 (CH_3); MS (ESI^+) *m/z* 233 (100) (M+H); HRMS (ESI^+, TOF) calcd. for $C_{12}H_{17}N_2OSi$: 233.1110 (M+H). Found: 233.1111.



***N*-(2-(2-Trimethylsilylethynyl)phenyl)cyanamide (2)**
To the mixture of 2-(2-trimethylsilylethynyl)benzamidoxime (**S8**, 0.8584 g, 3.694 mmol) in pyridine (4.0 mL) at 0 °C was added TsCl (0.7781 g, 4.081 mmol, 1.1 equiv).[10] The mixture was stirred under nitrogen for 2 h while the reaction temperature was allowed to rise to room temperature. The reaction mixture was concentrated under reduced pressure and the residue was purified by flash column chromatography (Hex / EtOAc = 95 : 5, R_f = 0.2) to give the product (**2**, 0.7378 g, oil, 3.442 mmol, 93%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.40 (dd, 1H, *J* = 7.6, 1.2 Hz), 7.34 (dt, 1H, *J* = 8.0, 1.2 Hz), 7.21 (d, 1H, *J* = 8.0 Hz), 7.01 (dt, 1H, *J* = 7.6, 0.8 Hz), 6.65 (br, 1H, NH), 0.28 (s, 9H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 138.7, 132.6 (CH), 130.5 (CH),

123.2 (CH), 114.2 (CH), 110.3, 110.2, 103.4, 98.7, 0.05 (CH_3); MS (EI, 70 eV) *m/z* 127 (47), 199 (100), 214 (64) (M^+); HRMS (EI, sector) calcd. for $C_{12}H_{14}N_2Si$: 214.0926. Found: 214.0925; IR (cm^{-1}) 3250, 2961, 2242, 2158, 1579, 1499, 1422.

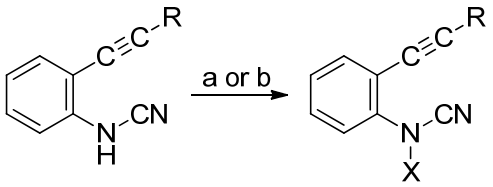


12a

***N*-(2-Ethynylphenyl)cyanamide (12a)**

Compound **12a** was prepared from *N*-(2-(2-trimethylsilylethynyl)phenyl)cyanamide (**2**) by *General procedure S3a*. The product (**12a**, solid, 0.1537 g, 1.081 mmol, 37%) was purified by flash column chromatography (Hex / EtOAc = 9 : 1, R_f = 0.12). m. p. 96-98 ^oC; ^1H NMR ($CDCl_3$, 400 MHz) δ 7.43 (dd, 1H, *J* = 7.6, 1.6 Hz), 7.38 (dt, 1H, *J* = 8.0, 1.6 Hz), 7.23 (d, 1H, *J* = 8.4 Hz), 7.02 (dt, 1H, *J* = 7.6, 1.2 Hz), 5.50 (br, 1H, NH), 3.51 (s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 139.7, 132.9 (CH), 130.8 (CH), 123.2 (CH), 114.6 (CH), 110.7, 109.1, 85.3 (CH), 78.3; MS (EI, 70 eV) *m/z* 115 (54), 142 (100) (M^+); HRMS (EI, sector) calcd for $C_9H_6N_2$: 142.0531. Found: 142.0531; IR (cm^{-1}) 3271, 3208, 2241, 1581, 1504, 1432.

Scheme S4

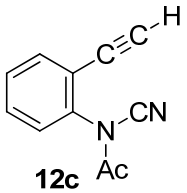


2 R = TMS **7a** R = TMS, X = Ts (68% from **2**)

12a R = H **12c** R = H, X = Ac (87% from **12a**)
12d Bz (60% from **12a**)
12e Boc (47% from **12a**)
12g 4-$NO_2C_6H_4SO_2$ (32% from **12a**)
12i 4-$AcNHC_6H_4SO_2$ (65% from **12a**)

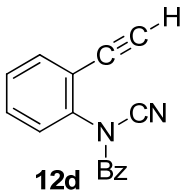
reagents and conditions
(a) X = Ac, Bz, Ts, 4-$NO_2C_6H_4SO_2$, or 4-$AcNHC_6H_4SO_2$: X-Cl (1.5 equiv), DIPEA (3 equiv), MeCN (0.25 M), 0 $^oC \sim$ rt; (b) X = Boc: Boc_2O (1.8 equiv), DIPEA (3 equiv), MeCN (0.25 M), 0 $^oC \sim$ rt

*[General procedure S8] Preparation of N-acyl-N-(2-ethynylphenyl)cyanamides (**12c-e**) and N-arylsulfonyl-N-(2-ethynylphenyl)cyanamides (**12g,i,7a**) from N-(2-ethynylphenyl)cyanamide (**12a,2**)*
To a solution of *N*-(2-ethynylphenyl)cyanamide (**12a**, 1 equiv) and DIPEA (3 equiv) in acetonitrile (0.25 M) at 0 ^oC was added acyl chloride, arylsulfonyl chloride or Boc_2O, respectively (X-Cl or Boc_2O, 1.5 equiv). The reaction mixture was stirred and monitored by TLC while the reaction temperature was allowed to rise to room temperature. The reaction mixture was concentrated under reduced pressure and the residue was purified by flash column chromatography.



12c

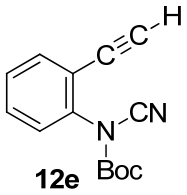
***N*-Acetyl-*N*-(2-ethynylphenyl)cyanamide (12c)**
Compound **12c** was prepared from compound **12a** by *General procedure S8* with acetyl chloride. The product (**12c**, oil, 0.8972 g, 4.874 mmol, 87%) was purified by flash column chromatography (Hex / EtOAc = 9 : 1, R_f = 0.15). ^1H NMR ($CDCl_3$, 400 MHz) δ 7.64 (dd, 1H, *J* = 7.2, 2.0 Hz), 7.51–7.44 (m, 2H), 7.37 (d, 1H, *J* = 7.2 Hz), 3.43 (s, 1H), 2.50 (br, 3H, Ac); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 169.1, 136.3, 134.3 (CH), 130.6 (CH), 130.3 (CH), 128.1 (CH), 121.7, 109.2, 84.7 (CH), 78.0, 21.9 (CH_3); MS (EI, 70 eV) *m/z* 88 (32), 89 (44), 114 (65), 115 (100), 142 (100), 143 (94), 184 (65) (M^+); HRMS (EI, sector) calcd for $C_{11}H_8N_2O$: 184.0637. Found: 184.0637; IR (cm^{-1}) 3277, 2237, 2112, 1739, 1504, 1487, 1446.



12d

***N*-Benzoyl-*N*-(2-ethynylphenyl)cyanamide (12d)**

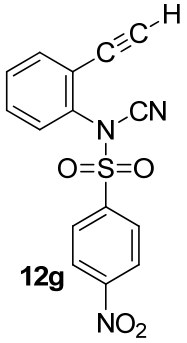
Compound **12d** was prepared from compound **12a** by *General procedure S8* with benzoyl chloride. The product (**12d**, solid, 0.1816 g, 0.737 mmol, 60%) was purified by flash column chromatography (Hex / EtOAc = 9 : 1, R_f = 0.15). m.p. 105–109 °C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.89 (d, 2H, *J* = 7.6 Hz, Bz), 7.64 (d, 1H, *J* = 8.0 Hz), 7.61 (t, 1H, *J* = 8.0 Hz), 7.51–7.42 (m, 5H), 3.41 (s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 167.9, 137.2, 134.3 (CH), 133.6 (CH), 130.7, 130.6 (CH), 130.0 (CH), 129.3 (CH), 128.8 (CH), 127.8 (CH), 121.4, 109.8, 84.7 (CH), 78.4; MS (EI, 70 eV) *m/z* 77 (100), 105 (100), 151 (58), 162 (64), 190 (30), 205 (44), 245 (34), 246 (70) (M^+); HRMS (EI, sector) calcd for $C_{16}H_{10}N_2O$: 246.0793. Found: 246.0794; IR (cm^{-1}) 3276, 2928, 2238, 2110, 1722, 1623, 1486, 1448.



12e

***N*-(*t*-Butoxycarbonyl)-*N*-(2-ethynylphenyl)cyanamide (12e)**

Compound **12e** was prepared from compound **12a** by *General procedure S8* with Boc_2O. The product (**12e**, oil, 0.0516 g, 0.217 mmol, 47%) was purified by flash column chromatography (Hex / EtOAc = 9 : 1, R_f = 0.25). ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.59 (d, 1H, *J* = 7.6 Hz), 7.46–7.37 (m, 3H), 3.40 (s, 1H), 1.53 (s, 9H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 150.0, 136.5, 134.0 (CH), 130.2 (CH), 129.8 (CH), 127.8 (CH), 121.6, 108.5, 86.6, 84.3 (CH), 78.3, 27.8 (CH_3); MS (ESI^+) *m/z* 265 (100) (M+Na); HRMS (ESI^+, TOF) calcd for $C_{14}H_{14}N_2NaO_2$: 265.0953 (M+Na). Found: 265.0951; IR (cm^{-1}) 3269, 2984, 2930, 2246, 2113, 1760, 1487, 1451.

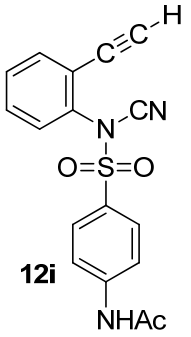


12g

***N*-(*p*-Nosyl)-*N*-(2-ethynylphenyl)cyanamide (12g)**

Compound **12g** was prepared from compound **12a** by *General procedure S8* with *p*-nitrobenzenesulfonyl chloride. The product (**12g**, solid, 0.1572 g, 0.480 mmol, 32%, R_f = 0.25 (Hex / EtOAc = 8 : 2)) was purified by flash column chromatography (Hex / EtOAc = 9 : 1). m.p. 177–179 °C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 8.40 (d, 2H, *J* = 8.8 Hz, Ns), 8.02 (d, 2H, *J* = 8.9 Hz, Ns), 7.54–7.46 (m, 4H), 2.98 (s, 1H, CH); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 151.6, 141.5, 134.6 (CH), 134.0, 131.1 (CH), 130.6 (CH), 130.14 (CH), 130.09 (CH), 124.8 (CH), 121.5, 106.2, 85.0 (CH), 76.8; MS (EI, 70 eV)

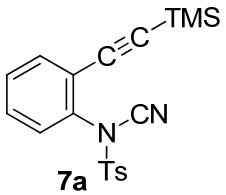
m/z 89 (49), 114 (76), 115 (87), 122 (73), 141 (100), 142 (100), 157 (31), 186 (43), 205 (74), 252 (25), 298 (85), 327 (17) (M^+); HRMS (EI, sector) calcd for $C_{15}H_9N_3O_4S$: 327.0314. Found: 327.0313; IR (cm^{-1}) 3249, 3107, 2924, 2233, 2109, 1532, 1406.



12i

***N*-(4-Acetamidobenzenesulfonyl)-*N*-(2-ethynylphenyl)cyanamide (12i)**

Compound **12i** was prepared from compound **12a** by *General procedure S8* with 4-acetamidobenzenesulfonyl chloride. The product (**12i**, solid, 0.1267 g, 0.373 mmol, 65%) was purified by flash column chromatography (Hex / EtOAc = 5 : 5, R_f = 0.1). m.p. 159 ^oC (decomp.); ^1H NMR (DMSO-d_6, 400 MHz) δ 10.57 (s, 1H, NH), 7.88 (d, 2H, *J* = 9.2 Hz), 7.73 (d, 2H, *J* = 8.8 Hz), 7.64–7.62 (m, 1H), 7.58–7.56 (m, 2H), 7.40–7.38 (m, 1H), 4.37 (s, 1H), 2.12 (s, 3H, Me); ^{13}C NMR (DMSO-d_6, 100 MHz) δ 170.4, 146.9, 135.1 (CH), 135.0, 132.2 (CH), 131.6 (CH), 130.9 (CH), 130.4 (CH), 128.6, 122.5, 120.1 (CH), 108.2, 88.8 (CH), 78.2, 25.2 (CH_3); MS (EI, 70 eV) *m/z* 92 (33), 108 (34), 134 (99), 142 (34), 198 (100), 199 (34), 291 (45), 339 (32) (M^+); HRMS (EI, sector) calcd for $C_{17}H_{13}N_3O_3S$: 339.0678. Found: 339.0679; IR (cm^{-1}) 3282, 3109, 2231, 2112, 1706, 1590, 1532, 1405.

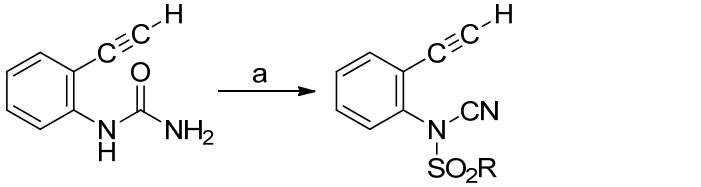


7a

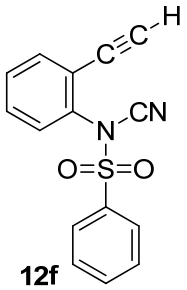
***N*-Tosyl-*N*-(2-(2-trimethylsilylethynyl)phenyl)cyanamide (7a)**

Compound **7a** was prepared from compound **2** by *General procedure S8* with TsCl. The product (**7a**, oil, 0.2049 g, 0.5560 mmol, 68%, R_f = 0.2 (Hex / EtOAc = 9 : 1)) was purified by flash column chromatography (Hex / EtOAc = 95 : 5 ~ 9 : 1). ^1H NMR ($CDCl_3$, 400 MHz) δ 7.65 (d, 2H, J = 8.3 Hz), 7.48-7.46 (m,1H), 7.41-7.37 (m, 2H), 7.35-7.31 (m, 3H), 2.46 (s, 3H), 0.19 (s, 9H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 146.5, 134.4, 133.9 (CH), 133.5, 130.3 (CH), 130.2 (CH), 129.5 (CH), 129.2 (CH), 128.6 (CH), 122.9, 106.9, 103.6, 98.0, 21.8 (CH_3), -0.37 (CH_3); MS (EI, 70 eV) *m/z* 91 (58), 155 (28), 183 (36), 198 (20), 353 (100), 368 (15) (M^+); HRMS (EI, sector) calcd for $C_{19}H_{20}N_2O_2SSi$: 368.1015. Found: 368.1016; IR (cm^{-1}) 3366, 3069, 2962, 2230, 2163, 1719, 1599.

Scheme S5

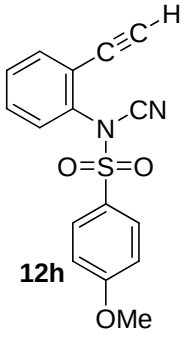


reagents and conditions
(a) RSO_2Cl (3 equiv), pyridine (0.33 M), 0 °C ~ rt, 3 h



***N*-Benzenesulfonyl-*N*-(2-ethynylphenyl)cyanamide (12f)**

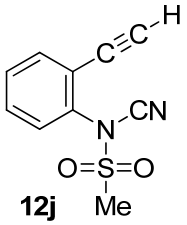
Compound **12f** was prepared from compound **S4a** by *General procedure S5* with benzenesulfonyl chloride. The product (**12f**, solid, 0.1805 g, 0.639 mmol, 20%) was purified by flash column chromatography (Hex / EtOAc = 8 : 2, R_f = 0.20). m.p. 80 °C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.81 (dd, 2H, *J* = 8.2, 1.0 Hz), 7.75 (dt, 1H, *J* = 7.5, 1.0 Hz), 7.57 (t, 2H, *J* = 7.7 Hz), 7.51–7.48 (m, 1H), 7.46–7.43 (m, 2H), 7.40–7.37 (m, 1H), 2.98 (s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 136.3, 135.4 (CH), 134.9, 134.4 (CH), 130.8 (CH), 130.3 (CH), 130.1 (CH), 129.9 (CH), 128.9 (CH), 122.1, 107.3, 84.8 (CH), 77.1; MS (EI, 70 eV) *m/z* 77 (97), 141 (95), 234 (100), 237 (47), 253 (85), 282 (39) (M^+); HRMS (EI, sector) calcd for $C_{15}H_{10}N_2O_2S$: 282.0463. Found: 282.0463; IR (cm^{-1}) 3281, 2231, 2114, 1483, 1450.



***N*-(4-Methoxybenzenesulfonyl)-*N*-(2-ethynylphenyl)cyanamide (12h)**

Compound **12h** was prepared from compound **S4a** by *General procedure S5* with 4-methoxybenzenesulfonyl chloride. The product (**12h**, solid, 0.2636 g, 0.844 mmol, 28%, R_f = 0.15 (Hex / EtOAc = 8 : 2)) was purified by flash column chromatography (Hex / EtOAc = 9 : 1). m.p. 110–113 °C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.72 (d, 2H, *J* = 9.0 Hz), 7.51–7.49 (m, 1H), 7.44–7.41 (m, 2H), 7.38–7.35 (m, 1H), 6.99 (d, 2H, *J* = 9.0 Hz), 3.90 (s, 3H, OMe), 3.08 (s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 165.3, 135.1,

134.4 (CH), 131.3 (CH), 130.6 (CH), 130.3 (CH), 129.9 (CH), 127.4, 122.1, 115.0 (CH), 107.6, 84.7 (CH), 77.4, 56.1 (CH_3); MS (EI, 70 eV) *m/z* 77 (74), 92 (63), 107 (100), 123 (77), 171 (100), 172 (62), 264 (96), 312 (67) (M^+); HRMS (EI, sector) calcd for $C_{16}H_{12}N_2O_3S$: 312.0569. Found: 312.0569; IR (cm^{-1}) 3280, 2948, 2845, 2230, 2113, 1594, 1576, 1498, 1484, 1447.

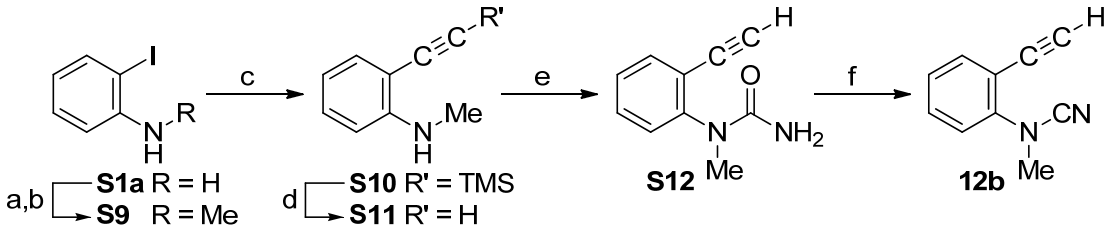


12j

***N*-Mesyl-*N*-(2-ethynylphenyl)cyanamide (12j)**

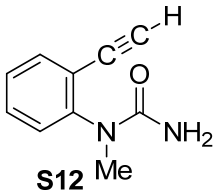
Compound **12j** was prepared from compound **S4a** by *General procedure S5* with methanesulfonyl chloride. The product (**12j**, oil, 0.1337 g, 0.607 mmol, 20%) was purified by flash column chromatography (Hex / EtOAc = 8 : 2, R_f = 0.13). ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.67–7.64 (m, 1H), 7.54–7.48 (m, 3H), 3.60 (s, 1H), 3.35 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 134.6 (C+CH), 131.1 (CH), 130.8 (CH), 130.3 (CH), 121.4, 106.8, 86.1 (CH), 78.2, 41.5 (CH_3); MS (EI, 70 eV) *m/z* 89 (60), 114 (80), 141 (81), 142 (100), 191 (72), 205 (80), 220 (60) (M^+); HRMS (EI, sector) calcd for $C_{10}H_8N_2O_2S$: 220.0306. Found: 220.0306; IR (cm^{-1}) 3283, 3030, 2932, 2234, 2113, 1708, 1565, 1501, 1484, 1447, 1412.

Scheme S6



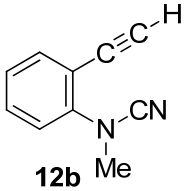
reagents and conditions

(a) premixed HCOOH (3.5 equiv) with Ac_2O (1.2 equiv), DCM (0.33 M), rt, 11 h; (b) $NaBH_4$ (4 equiv), $BF_3{\cdot}OEt_2$ (5 equiv), THF (0.13 M), 0 ^oC ~ rt, 1 d, 81% (after two steps from **S1a**); (c) trimethylsilylacetylene (1.2 equiv), $Pd(PPh_3)_2Cl_2$ (2 mol%), CuI (2 mol%), Et_3N / THF (1 : 1, *v*/*v*, 0.5 M), rt, Ar, 1 d, 90%; (d) K_2CO_3 (1 equiv), MeOH, rt, 1 h; (e) NaNCO (3 equiv), AcOH / H_2O (3 : 1, *v*/*v*, 0.25 M), rt, 2.5 h, 59% (after two steps from **S10**); (f) TsCl (1.5 equiv), pyridine (1 M), 0 ^oC ~ rt, 1 h, 83%



***N*-(2-Ethynylphenyl)-*N*-methylurea (S12)**

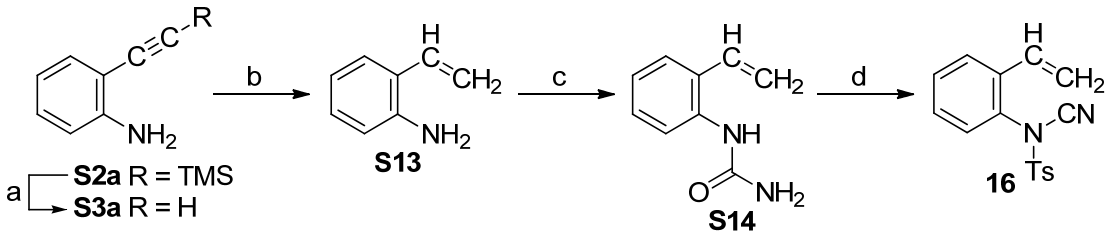
Compound **S12** was prepared from *N*-methyl-2-ethynylaniline[12] (**S11**) by *General procedure S4*. The product (**S12**, solid, 0.7543 g, 4.330 mmol, 59%) was purified by flash column chromatography (Hex / EtOAc = 4 : 6, R_f = 0.1). m.p. 132–134 ^oC; ^1H NMR (DMSO-d_6, 400 MHz) δ 7.53 (dd, 1H, *J* = 7.6, 1.4 Hz), 7.43 (dt, 1H, *J* = 7.6, 1.6 Hz), 7.30 (dt, 1H, *J* = 7.6, 1.2 Hz), 7.28 (d, 1H, *J* = 8.9 Hz), 5.64 (br, 2H, NH_2), 4.33 (s, 1H), 3.08 (s, 3H, Me); ^{13}C NMR (DMSO-d_6, 100 MHz) δ 157.3, 146.0, 133.5 (CH), 130.1 (CH), 129.1 (CH), 127.2 (CH), 121.1, 84.7 (CH), 80.4, 36.5 (CH_3); MS (ESI^+) *m/z* 175 (100) (M+H); HRMS (ESI^+, TOF) calcd for $C_{10}H_{11}N_2O$: 175.0871 (M+H). Found: 175.0871.



***N*-(2-Ethynylphenyl)-*N*-methylcyanamide (12b)**

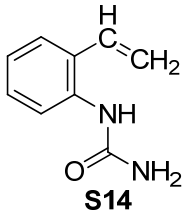
Compound **12b** was prepared from compound **S12** by *General procedure S5*. The product (**12b**, oil, 0.5594 g, 3.582 mmol, 83%) was purified by flash column chromatography (Hex / EtOAc = 9 : 1, R_f = 0.15). ^1H NMR ($CDCl_3$, 400 MHz) δ 7.52 (dd, 1H, *J* = 8.0, 1.6 Hz), 7.37 (dt, 1H, *J* = 8.0, 1.2 Hz), 7.30 (dd, 1H, *J* = 8.4, 1.2 Hz), 7.20 (dt, 1H, *J* = 7.6, 1.6 Hz), 3.48 (s, 1H), 3.42 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 143.3, 135.1 (CH), 130.3 (CH), 126.6 (CH), 122.5 (CH), 116.9, 115.5, 85.0 (CH), 79.4, 41.4 (CH_3); MS (ESI^+) *m/z* 157 (100) (M+H); HRMS (ESI^+, TOF) calcd for $C_{10}H_9N_2$: 157.0766 (M+H). Found: 157.0767; IR (cm^{-1}) 3286, 2947, 2221, 2108, 1598, 1571, 1488, 1448.

Scheme S7



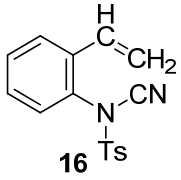
reagents and conditions

(a) K_2CO_3 (1 equiv), MeOH, rt, 1 h; (b) Lindlar catalyst (10 mol%), MeOH (0.25 M), H_2 (1 atm), rt, 4.5 h, 45% (after two steps from **S2a**); (c) NaNCO (3 equiv), AcOH / H_2O (3 : 1, *v*/*v*, 0.25 M), rt, 4 h, 81%; (d) TsCl (3 equiv), pyridine (0.5 M), 0 °C ~ rt, 1 h, 68%



***N*-(2-Vinylphenyl)urea (S14)**

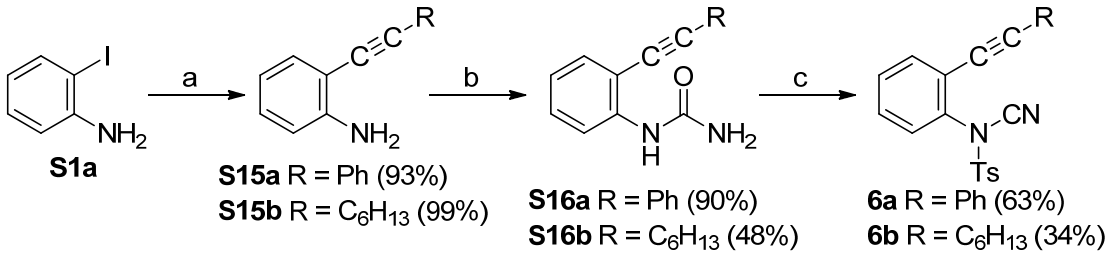
Compound **S14** was prepared from 2-vinylaniline[13] (**S13**) by *General procedure S4*. The product (**S14**, solid, 0.3230 g, 1.9915 mmol, 81%) was purified by flash column chromatography (Hex / EtOAc = 5 : 5, R_f = 0.13). m.p. 194–198 °C; ^{1}H NMR (DMSO-d_6, 400 MHz) δ 8.34 (br, 1H, NH), 7.71 (d, 1H, *J* = 8.2 Hz), 7.47 (dd, 1H, *J* = 7.6, 0.7 Hz), 7.17 (dt, 1H, *J* = 7.6, 1.1 Hz), 7.01 (dd, 1H, *J* = 17.6, 11.4 Hz), 6.98 (t, 1H, *J* = 7.2 Hz), 6.17 (br, 2H, NH_2), 5.69 (dd, 1H, *J* =17.3, 1.1 Hz), 5.28 (dd, 1H, *J* = 10.3, 1.0 Hz); ^{13}C NMR (DMSO-d_6, 100 MHz) δ 156.4, 137.0, 132.6 (CH), 128.4, 127.9 (CH), 125.5 (CH), 122.7 (CH), 122.6 (CH), 115.4 (CH_2); MS (ESI$^+$) *m/z* 163 (100) (M+H); HRMS (ESI$^+$, TOF) calcd for $C_9H_{11}N_2O$: 163.0871 (M+H). Found: 163.0871.



***N*-Tosyl-*N*-(2-vinylphenyl)cyanamide (16)**

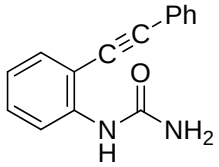
Compound **16** was prepared from compound **S14** by *General procedure S5*. The product (**16**, oil, 0.4023 g, 1.348 mmol, 68%) was purified by flash column chromatography (Hex / EtOAc = 9 : 1, R_f = 0.13). ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.69 (d, 2H, *J* = 8.4 Hz, Ts), 7.63 (dd, 1H, *J* = 8.0, 1.2 Hz), 7.43 (dt, 1H, *J* = 7.6, 0.8 Hz), 7.37 (d, 2H, *J* = 8.4 Hz, Ts), 7.25 (dt, 1H, *J* = 7.6, 0.8 Hz), 6.96 (dd, 1H, *J* = 8.0, 1.2 Hz), 6.69 (dd, 1H, *J* = 17.2, 10.8 Hz), 5.73 (d, 1H, *J* = 17.6 Hz), 5.30 (d, 1H, *J* = 10.8 Hz), 2.49 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 147.1, 137.3, 133.0, 131.6, 131.2 (CH), 130.5 (CH), 130.3 (CH), 129.1 (CH), 128.9 (CH), 128.8 (CH), 127.2 (CH), 118.5 (CH_2), 108.6, 22.0 (CH_3); MS (ESI$^+$) *m/z* 200 (24), 299 (100) (M+H); HRMS (ESI$^+$, TOF) calcd for $C_{16}H_{15}N_2O_2S$: 299.0854 (M+H). Found: 299.0856; IR (cm^{-1}) 3069, 2927, 2228, 1629, 1596, 1483, 1451.

Scheme S8



reagents and conditions

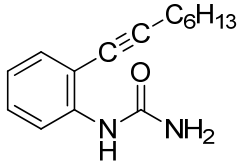
(a) phenylacetylene or 1-octyne (1.5 equiv), $Pd(PPh_3)_2Cl_2$ (2 mol%), CuI (2 mol%), Et_3N / THF (1 : 1, *v/v*, 0.5 M), rt, Ar, 1 d; (b) NaNCO (3 equiv), AcOH / H_2O (3 : 1, *v/v*, 0.25 M), rt, 5 h; (c) TsCl (3 equiv), pyridine (0.5 M), 0 °C ~ rt, 1 h



S16a

***N*-(2-(Phenylethynyl)phenyl)urea[5] (S16a)**

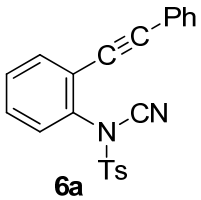
Compound **S16a** was prepared from 2-(phenylethynyl)aniline[14] (**S15a**) by *General procedure S4*. The product (**S16a**, solid, 1.2158 g, 5.146 mmol, 90%) was purified by flash column chromatography (Hex / EtOAc = 7 : 3, R_f = 0.05). m.p. 195–197 °C; ^{1}H NMR (DMSO-d_6, 400 MHz) δ 8.09 (d, 1H, *J* = 8.0 Hz), 7.94 (br, 1H, NH), 7.66–7.64 (m, 2H), 7.47–7.43 (m, 4H), 7.30 (dt, 1H, *J* = 8.8, 1.6 Hz), 6.97 (dt, 1H, *J* = 8.0, 0.8 Hz), 6.46 (br, 2H, NH_2); ^{13}C NMR (DMSO-d_6, 100 MHz) δ 155.6, 140.9, 132.0 (CH), 131.6 (CH), 129.3 (CH), 128.8 (CH), 128.6 (CH), 122.4, 121.4 (CH), 119.4 (CH), 110.9, 95.0, 85.4; MS (EI, 70 eV) *m/z* 84 (24), 165 (28), 193 (100), 236 (56) (M^+); HRMS (EI, sector) calcd for $C_{15}H_{12}N_2O$: 236.0950. Found: 236.0954.



S16b

***N*-(2-(Oct-1-ynyl)phenyl)urea (S16b)**

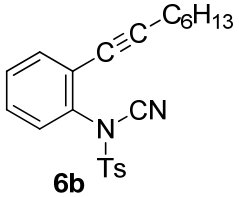
Compound **S16b** was prepared from 2-(oct-1-ynyl)aniline[15] (**S15b**) by *General procedure S4*. The product (**S16b**, solid, 0.8694 g, 3.558 mmol, 48%, R_f = 0.25 (Hex / EtOAc = 6 : 4) was purified by flash column chromatography (Hex / EtOAc = 8 : 2). m.p. 130–132 °C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.97 (d, 1H, *J* = 8.3 Hz), 7.67 (br, 1H, NH), 7.31 (dd, 1H, *J* = 7.6, 1.3 Hz), 7.16 (dt, 1H, *J* = 7.6, 1.3 Hz), 6.90 (dt, 1H, *J* = 7.6, 1.3 Hz), 5.65 (br, 2H, NH_2), 2.39 (t, 2H, *J* = 7.2 Hz, CH_2), 1.59–1.52 (m, 2H), 1.41–1.36 (m, 2H), 1.34–1.25 (m, 4H), 0.88 (t, 3H, *J* = 7.1 Hz, CH_3); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 157.1, 139.7, 132.1 (CH), 128.5 (CH), 122.5 (CH), 119.7 (CH), 113.7, 97.5, 76.3, 31.4 (CH_2), 28.7 (2xCH_2), 22.6 (CH_2), 19.6 (CH_2), 14.1 (CH_3); MS (ESI^+) *m/z* 245 (100) (M+H); HRMS (ESI^+, TOF) calcd for $C_{15}H_{21}N_2O$: 245.1654 (M+H). Found: 245.1651.



6a

***N*-Tosyl-*N*-(2-(phenylethynyl)phenyl)cyanamide[16] (6a)**

Compound **6a** was prepared from compound **S16a**[5] by *General procedure S5*. The product (**6a**, solid, 1.2109 g, 3.251 mmol, 63%) was purified by flash column chromatography (Hex / EtOAc = 9 : 1, R_f = 0.18). m.p. 104–110 °C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.64 (d, 2H, *J* = 8.4 Hz, Ts), 7.50–7.49 (m, 2H), 7.45–7.40 (m, 4H), 7.36–7.31 (m, 3H), 7.06 (d, 2H, *J* = 8.4 Hz, Ts), 2.20 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 146.6, 134.4, 133.6, 133.5 (CH), 132.0 (CH), 130.6 (CH), 130.4 (2xCH), 129.6 (CH), 129.2 (CH), 128.6 (CH), 128.4 (CH), 122.8, 122.4, 107.7, 97.0, 83.3, 21.8 (CH_3); MS (ESI$^+$) *m/z* 395 (100) (M+Na); HRMS (ESI$^+$, TOF) calcd for $C_{22}H_{17}N_2O_2S$: 373.1011 (M+H). Found: 373.1015; IR (cm^{-1}) 3064, 2924, 2226, 1596, 1497, 1447.

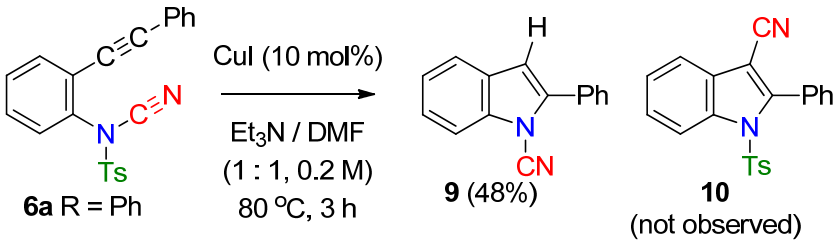


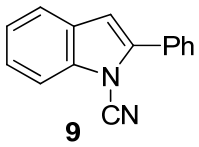
6b

***N*-Tosyl-*N*-(2-(oct-1-ynyl)phenyl)cyanamide (6b)**

Compound **6b** was prepared from compound **S16b** by *General procedure S5*. The product (**6b**, oil, 0.4173 g, 1.097 mmol, 34 %) was purified by flash column chromatography (Hex / EtOAc = 9 : 1, R_f = 0.20). ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.79 (d, 2H, *J* = 7.6 Hz, Ts), 7.40–7.31 (m, 6H), 2.47 (s, 3H, Me), 2.16 (t, 2H, *J* = 7.2 Hz), 1.51–1.44 (m, 2H), 1.41–1.26 (m, 6H), 0.90 (t, 3H, *J* = 7.2 Hz); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 146.4, 134.4, 134.0, 133.7 (CH), 130.5 (CH), 130.2 (CH), 129.6 (CH), 128.8 (CH), 128.7 (CH), 124.0, 107.5, 99.2, 74.7, 31.5 (CH_2), 28.9 (CH_2), 28.5 (CH_2), 22.7 (CH_2), 22.0 (CH_3), 19.7 (CH_2), 14.2 (CH_3); MS (ESI$^+$) *m/z* 381 (7) (M+H), 403 (100) (M+Na); HRMS (ESI$^+$, TOF) calcd for $C_{22}H_{25}N_2O_2S$: 381.1637 (M+H). Found: 381.1631; IR (cm^{-1}) 2931, 2859, 2232, 1597, 1487, 1448.

Scheme 3





9

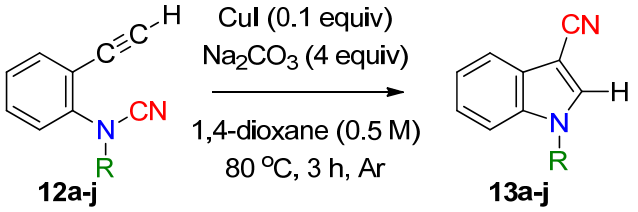
1-Cyano-2-phenylindole[17] **(9)**

A mixture of *N*-(2-(phenylethynyl)phenyl)-*N*-tosylcyanamide (**6a**, 0.0484 g, 0.130 mmol), CuI (0.0025 g, 0.013 mmol, 0.01 equiv) and triethylamine (0.5 mL) in DMF (0.5 mL) was stirred at 80 °C for 3 h. The mixture was diluted with EtOAc, and the organic solution was washed with *conc.* aqueous NH_4OH solution and saturated aqueous NaCl solution. The organic layer was dried over anhydrous $MgSO_4$ and the solvent was removed under reduced pressure. The residue was purified by flash column chromatography (Hex / EtOAc = 95 : 5, R_f = 0.3) to give the product (**9**, solid, 0.0232 g, 0.062 mmol, 48 %). An analytical sample was recrystallized from Hex / EtOAc. m.p. 88–90 °C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.74 (d, 2H, *J* = 6.8 Hz), 7.64 (dd, 2H, *J* = 8.0, 1.2 Hz), 7.55–7.45 (m, 3H), 7.42 (dt, 1H, *J* = 8.0, 1.2 Hz), 7.35 (t, 1H, *J* = 7.6 Hz), 6.79 (s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 139.8, 138.4, 129.8 (CH), 129.32 (CH), 129.30, 128.8, 127.8 (CH), 125.4 (CH), 124.7 (CH), 121.8 (CH), 111.8 (CH), 107.6, 107.3 (CH); MS (EI, 70 eV) *m/z* 190 (21), 218 (100) (M^+); HRMS (EI, sector) calcd for $C_{15}H_{12}N_2$: 218.0844. Found: 218.0843; IR (cm^{-1}) 3062, 2923, 2242, 1456.

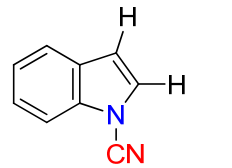
*[General procedure 1] Preparation of 3-cyano-1-tosylindoles (**10a-p**, **13f-j**) from N-(2-ethynylphenyl)-N-tosylcyanamides (**8a-p**, **12f-j**) ('standard condition')*

A mixture of *N*-(2-ethynylphenyl)-*N*-tosylcyanamide (**8,** 0.50 mmol), Na_2CO_3 (2 mmol, 4 equiv) and CuI (0.050 mmol, 0.1 equiv) in 1,4-dioxane (1.0 mL) was stirred at 80 °C under argon atmosphere for 3 h. After cooling to room temperature, the solution was diluted with EtOAc. The organic solution was washed with *conc.* aqueous NH_4OH solution, saturated aqueous NaCl solution, dried over anhydrous $MgSO_4$ and the solvent was removed under reduced pressure. The resulting residue was purified by flash column chromatography to give the corresponding 3-cyano-1-tosylindole (**10**).

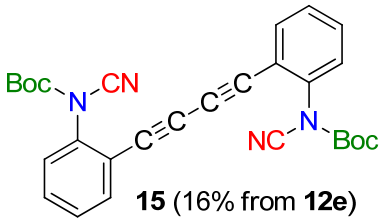
Scheme 4



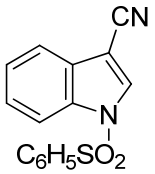
13a R = H (N.D.)
13b R = Me (N.D.)
13c R = Ac (N.D.)
13d R = Bz (N.D.)
13e R = Boc (N.D.)
13f R = $C_6H_5SO_2$ (65%)
13g R = 4-$NO_2C_6H_4SO_2$ (77%)
13h R = 4-$MeOC_6H_4SO_2$ (65%)
13i R = 4-$AcNHC_6H_4SO_2$ (67%)
13j R = $MeSO_2$ (75%)



14 (39% from **12a**)



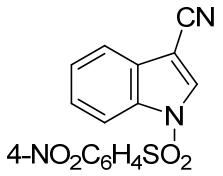
15 (16% from **12e**)



13f

1-Benzenesulfonyl-3-cyanoindole[18] **(13f)**

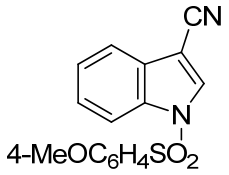
Compound **13f** was prepared from compound **12f** by *General procedure 1*. The product (**13f**, solid, 0.1176 g, 0.417 mmol, 65%) was purified by flash column chromatography (Hex / EtOAc = 9 : 1, R_f = 0.15). m.p. 148–150 °C (*lit*. 148–149 °C);[18] ^{1}H NMR ($CDCl_3$, 400 MHz) δ 8.11 (s, 1H), 8.01 (d, 2H, *J* = 8.4 Hz), 7.95 (d, 2H, *J* = 7.5 Hz), 7.70 (d, 1H, *J* = 7.8 Hz), 7.63 (t, 1H, *J* = 7.5 Hz), 7.53 (t, 2H, *J* = 7.8 Hz), 7.45 (dt, 1H, *J* = 7.9, 0.9 Hz), 7.38 (dt, 1H, *J* = 7.5, 0.68 Hz); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 137.4, 135.1 (CH), 133.9, 133.3 (CH), 130.0 (CH), 128.5, 127.4 (CH), 126.8 (CH), 125.1 (CH), 120.5 (CH), 114.0 (CH), 113.6, 94.2; MS (EI, 70 eV) *m/z* 77 (50), 141 (73), 282 (100) (M^+); HRMS (EI, sector) calcd for $C_{15}H_{10}N_2O_2S$: 282.0463. Found: 282.0463; IR (cm^{-1}) 3147, 2925, 2233, 1924, 1597, 1445.



13g

1-(4-Nitrobenzenesulfonyl)-3-cyanoindole (13g)

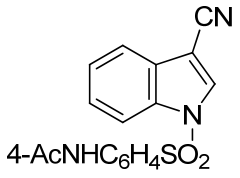
Compound **13g** was prepared from compound **12g** by *General procedure 1*. The product (**13g**, solid, 0.1117 g, 0.341 mmo1, 77%) was purified by flash column chromatography (Hex / EtOAc = 9 : 1, R_f = 0.17). m.p. 179–182 °C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 8.36 (d, 2H, *J* = 9.2 Hz, Ns), 8.14 (d, 2H, *J* = 9.2 Hz, Ns), 8.09 (s, 1H), 8.00 (d, 1H, *J* = 8.4 Hz), 7.73 (d, 1H, *J* = 7.6 Hz), 7.50 (dt, 1H, *J* = 7.2, 1.2 Hz), 7.43 (dt, 1H, *J* = 7.2, 0.8 Hz); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 151.5, 142.6, 133.8, 132.9 (CH), 128.7 (CH), 128.6, 127.5 (CH), 125.8 (CH), 125.2 (CH), 121.0 (CH), 113.8 (CH), 113.0, 95.7; MS (EI, 70 eV) *m/z* 114 (33), 122 (38), 141 (65), 186 (62), 327 (100) (M^+); HRMS (EI, sector) calcd for $C_{15}H_9N_3O_4S$: 327.0314. Found: 327.0313; IR (cm^{-1}) 3148, 3100, 2924, 2229, 1528.



13h

1-(4-Methoxybenzenesulfonyl)-3-cyanoindole (13h)

Compound **13h** was prepared from compound **12h** by *General procedure 1*. The product (**13h**, solid, 0.0837 g, 0.268 mmol, 65%) was purified by flash column chromatography (Hex / EtOAc = 9 : 1, R_f = 0.11). m.p. 103–105 °C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 8.10 (s, 1H), 7.99 (d, 1H, *J* = 8.4 Hz), 7.88 (d, 2H, *J* = 9.2 Hz), 7.68 (d, 1H, *J* = 7.6 Hz), 7.43 (dt, 1H, *J* = 7.6, 1.2 Hz), 7.36 (dt, 1H, *J* = 7.6, 0.8 Hz), 6.94 (d, 2H, *J* = 8.8 Hz), 3.82 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 164.8, 133.8, 133.3 (CH), 129.8 (CH), 128.53, 128.48, 126.6 (CH), 124.9 (CH), 120.4 (CH), 115.2 (CH), 113.9 (CH), 113.7, 93.6, 56.0 (CH_3); MS (EI, 70 eV) *m/z* 92 (28), 107 (43), 141 (25), 171 (100), 312 (64) (M^+); HRMS (EI, sector) calcd for $C_{16}H_{12}N_2O_3S$: 312.0569. Found: 312.0569; IR (cm^{-1}) 3138, 3067, 2927, 2845, 2231, 1594, 1576, 1543, 1497, 1448.

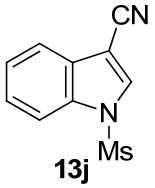


13i

1-(4-Acetamidobenzenesulfonyl)-3-cyanoindole (13i)

Compound **13i** was prepared from compound **12i** by *General procedure 1*. The product (**13i**, solid, 0.0688 g, 0.203 mmol, 67%) was purified by flash column chromatography (Hex / EtOAc = 5 : 5, R_f = 0.15). m.p. 217–219 °C; ^{1}H NMR (DMSO-d_6, 400 MHz) δ 10.46 (s, 1H, NH), 8.84 (s, 1H), 8.06 (d, 2H, *J* = 8.8 Hz), 8.00 (d, 1H, *J* = 8.0 Hz), 7.79 (d, 2H, *J* = 8.8 Hz), 7.70 (d, 1H, *J* = 8.0 Hz), 7.50 (t, 1H, *J* = 7.6 Hz), 7.43 (t, 1H, *J* = 7.6 Hz), 2.05 (s, 3H, Me); ^{13}C NMR (DMSO-d_6, 100 MHz) δ 169.3, 145.4, 135.5 (CH), 132.8, 128.9 (CH), 128.7, 127.7, 126.5 (CH), 124.9 (CH), 119.7 (CH), 119.0 (CH), 113.60 (CH), 113.56, 92.1, 24.1 (CH_3); MS (EI, 70 eV) *m/z* 92 (31), 134

(44), 142 (62), 198 (100), 218 (20), 339 (92) (M^+); HRMS (EI, sector) calcd for $C_{17}H_{13}N_3O_3S$: 339.0678, Found: 339.0679; IR (cm^{-1}) 3568, 3180, 3129, 3066, 2925, 2229, 1686, 1591, 1542, 1447, 1406.

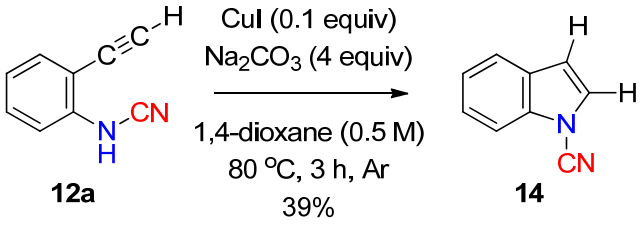


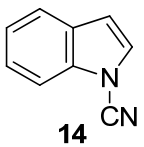
13j

1-Methanesulfonyl-3-cyanoindole[19] (13j)

Compound **13j** was prepared from compound **12j** by *General procedure 1*. The product (**13j**, solid, 0.0503 g, 0.228 mmol, 75%) was purified by flash column chromatography (Hex / EtOAc = 8 : 2, R_f = 0.24). m.p. 150–153 °C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.99 (s, 1H), 7.93 (d, 1H, *J* = 8.0 Hz), 7.80 (d, 1H, *J* = 7.6 Hz), 7.52 (t, 1H, *J* = 7.2 Hz), 7.47 (t, 1H, *J* = 8.8 Hz), 3.27 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 134.0, 133.1 (CH), 128.6, 127.1 (CH), 125.3 (CH), 120.8 (CH), 113.5 (CH), 113.4, 94.0, 42.1 (CH_3); MS (EI, 70 eV) *m/z* 114 (31), 141 (92), 142 (98), 220 (100) (M^+); HRMS (EI, sector) calcd for $C_{10}H_8N_2O_2S$: 220.0306. Found: 220.0306; IR (cm^{-1}) 3125, 3018, 2927, 2855, 2230, 1710, 1544, 1449.

Scheme 4a



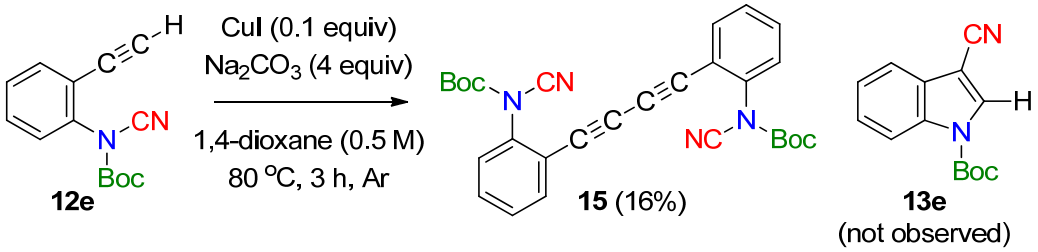


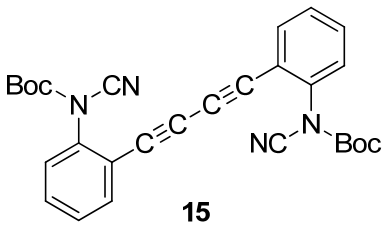
14

1-Cyanoindole[17] (14)

Compound **14** was obtained from the reaction of compound **12a** under the condition described in *General procedure 1*. The product (**14**, oil, 0.0174 g, 0.122 mmol, 39%) was purified by flash column chromatography (Hex / EtOac = 98 : 2; R_f = 0.16). ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.64 (dd, 1H, *J* = 7.6, 1.2 Hz), 7.62 (dd, 1H, *J* = 8.4, 0.8 Hz), 7.43 (dt, 1H, *J* = 7.6, 1.2 Hz), 7.34 (dt, 1H, *J* = 7.6, 0.8 Hz), 7.24 (d, 1H, *J* = 3.6 Hz), 6.71 (dd, 1H, *J* = 3.6, 0.8 Hz); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 137.0, 128.1, 126.3 (CH), 125.6 (CH), 124.3 (CH), 122.2 (CH), 111.6 (CH), 109.7 (CH), 107.8. The NMR spectroscopic data are consistent with the same compound previously reported in the literature.[17]

Scheme 4e



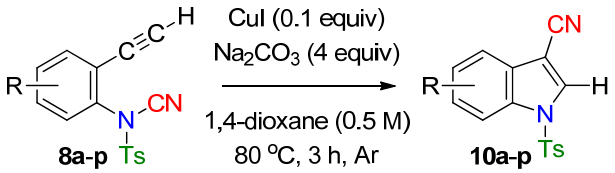


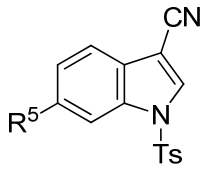
15

1,4-Bis(2-(*N*-*t*-butyloxycarbonyl-*N*-cyanoamino)phenyl)-1,3-butadiyne (15)

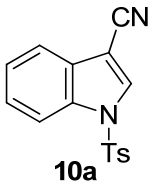
Compound **15** was obtained from the reaction of compound **12e** under the condition described in *General procedure 1*. The product (**15**, oil, 0.0191 g, 0.0395 mmol, 16%) was purified by flash column chromatography (Hex / EtOAc = 8 : 2; R_f = 0.20). ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.66–7.64 (m, 2H), 7.52–7.42 (m, 6H), 1.59 (s, 18H, CH_3); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 149.7, 137.2, 134.7 (CH), 131.0 (CH), 129.9 (CH), 127.7 (CH), 121.1, 108.5, 87.3, 79.4, 78.0, 28.0 (CH_3); MS (ESI^+) *m/z* 443 (48), 505 (100) (M+Na); HRMS (ESI^+, TOF) calcd for $C_{28}H_{26}N_4NaO_4$: 505.1852 (M+Na). Found: 505.1852; IR (cm^{-1}) 2925, 2854, 2244, 1762, 1458.

Scheme 5



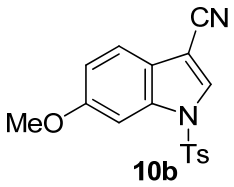


10a	R^5 = H	88%	**10h**	R^4 = OMe	61%	**10p**	34% (53%)[a]	
10b	OMe	49%	**10i**	Me	59%	([a] time = 17 h)		
10c	Me	70%	**10j**	*i*-Pr	74%			
10d	F	59%	**10k**	*t*-Bu	83%			
10e	Cl	79%	**10l**	F	66%			
10f	CF_3	60%	**10m**	Cl	63%			
10g	NO_2	73%	**10n**	CF_3	58%			
			10o	NO_2	53%			



1-Tosyl-3-cyanoindole[20] (10a)

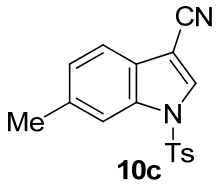
Compound **10a** was prepared from compound **8a** by *General procedure 1*. The product (**10a**, solid, 0.1422 g, 0.480 mmol, 88%) was purified by flash column chromatography (Hex / EtOAc = 9 : 1, R_f = 0.16). An analytical sample was recrystallized from Hex / EtOAc. m.p. 156–157 °C (*lit*. 157–158 °C);[20] ^{1}H NMR ($CDCl_3$, 400 MHz) δ 8.10 (s, 1H), 7.99 (d, 1H, *J* = 8.4 Hz), 7.83 (d, 2H, *J* = 8.4 Hz, Ts), 7.69 (d, 1H, *J* = 8.0 Hz), 7.44 (t, 1H, *J* = 7.8 Hz), 7.38 (t, 1H, *J* = 8.4 Hz), 7.30 (d, 2H, *J* = 8.2 Hz, Ts), 2.38 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 146.6, 134.4, 133.9, 133.3 (CH), 130.6 (CH), 128.6, 127.4 (CH), 126.7 (CH), 125.0 (CH), 120.5 (CH), 114.0 (CH), 113.8, 93.9, 21.9 (CH3); MS (EI, 70 eV) *m/z* 91 (75), 155 (84), 296 (100) (M^+); HRMS (EI, sector) calcd for $C_{16}H_{12}N_2O_2S$: 296.0619. Found: 296.0619; IR (cm^{-1}) 3148, 3056, 2927, 2234, 1924, 1596, 1546, 1447.



1-Tosyl-3-cyano-6-methoxyindole (10b)

Compound **10b** was prepared from compound **8b** by *General procedure 1*. The product (**10b**, yellow solid, 0.1087 g, 0.333 mmol, 49%, R_f = 0.33 (Hex / EtOAc = 8 : 2)) was purified by flash column chromatography (Hex / EtOAc = 95 : 5). m.p. 154–156 °C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.97 (s, 1H), 7.80 (d, 2H, *J* = 8.4 Hz, Ts), 7.52 (d, 1H, *J* = 8.8 Hz), 7.47 (d, 1H, *J* = 2.2 Hz), 7.30 (d, 2H, *J* = 8.4 Hz, Ts), 6.98 (dd, 1H, *J* = 8.8 Hz, 2.2 Hz), 3.88 (s, 3H, Me), 2.38 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ

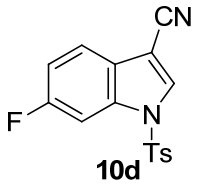
159.2, 146.3, 134.8, 134.1, 131.9 (CH), 130.3 (CH), 127.1 (CH), 121.8, 120.7 (CH), 114.0 (CH), 113.5, 97.8 (CH), 93.6, 55.8 (CH_3), 21.6 (CH_3); MS (EI, 20 eV) *m/z* 91 (20), 171 (100), 326 (28) (M^+); HRMS (EI, sector) calcd for $C_{17}H_{14}N_2O_3S$: 326.0725. Found: 326.0721; IR (cm^{-1}) 3142, 3068, 2926, 2854, 2232, 1616, 1596, 1543, 1495, 1436.



10c

1-Tosyl-3-cyano-6-methylindole (10c)

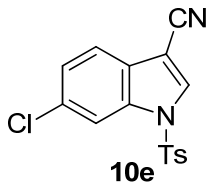
Compound **10c** was prepared from compound **8c** by *General procedure 1*. The product (**10c**, solid, 0.2063 g, 0.665 mmol, 70%, R_f = 0.23 (Hex / EtOAc = 9 : 1)) was purified by flash column chromatography (Hex / EtOAc = 95 : 5). m.p. 146–150 ^oC; ^1H NMR ($CDCl_3$, 400 MHz) δ 8.02 (s, 1H), 7.82 (d, 2H, *J* = 8.4 Hz, Ts), 7.79 (s, 1H), 7.55 (d, 1H, *J* = 8.1 Hz), 7.30 (d, 2H, *J* = 8.3 Hz, Ts), 7.19 (dd, 1H, *J* = 8.0, 0.6 Hz), 2.50 (s, 3H, Me), 2.38 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 146.4, 137.3, 134.5, 134.3, 132.7 (CH), 130.6 (CH), 127.4 (CH), 126.6 (CH), 126.3, 120.0 (CH), 113.9 (CH), 113.8, 93.8, 22.2 (CH_3), 21.9 (CH_3); MS (EI, 70 eV) *m/z* 91 (84), 155 (100), 310 (98) (M^+); HRMS (EI, sector) calcd for $C_{17}H_{14}N_2O_2S$: 310.0776. Found: 310.0777; IR (cm^{-1}) 3137, 2925, 2856, 2230, 1596, 1542, 1428



10d

1-Tosyl-3-cyano-6-fluoroindole (10d)

Compound **10d** was prepared from compound **8d** by *General procedure 1*. The product (**10d**, yellow solid, 0.1478 g, 0.470 mmol, 59%, R_f = 0.45 (Hex / EtOAc = 8 : 2)) was purified by flash column chromatography (Hex / EtOAc = 95 : 5). m.p. 159–160 ^oC; ^1H NMR ($CDCl_3$, 400 MHz) δ 8.08 (s, 1H), 7.83 (d, 2H, *J* = 8.4 Hz, Ts), 7.72 (dd, 1H, *J* = 9.2, 2.2 Hz), 7.62 (dd, 1H, *J* = 8.7, 5.1 Hz), 7.33 (d, 2H, *J* = 8.2 Hz, Ts), 7.14 (dt, 1H, *J* = 8.9, 2.2 Hz), 2.40 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 161.7 (d, *J* = 245.7 Hz), 146.6, 134.0, 133.8, 133.4 (d, *J* = 3.0 Hz, CH), 130.5 (CH), 127.2 (CH), 124.5, 121.3 (d, *J* = 10.0 Hz, CH), 113.6 (d, *J* = 24 Hz, CH), 113.1, 101.2 (d, *J* = 29 Hz, CH), 93.6, 21.7 (CH_3); ^{19}F NMR ($CDCl_3$, 376 MHz) δ -112.7; MS (EI, 20 eV) *m/z* 91 (100), 155 (88), 314 (27) (M^+); HRMS (EI, sector) calcd for $C_{16}H_{11}FN_2O_2S$: 314.0525. Found: 314.0519; IR (cm^{-1}) 3152, 3122, 2924, 2235, 1616, 1595, 1548, 1487, 1426.

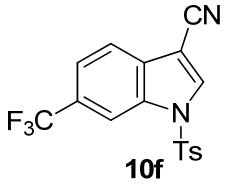


10e

1-Tosyl-3-cyano-6-chloroindole (10e)

Compound **10e** was prepared from compound **8e** by *General procedure 1*. The product (**10e**, yellow solid, 0.0267 g, 0.081 mmol, 79%, R_f = 0.43 (Hex / EtOAc = 8 : 2))

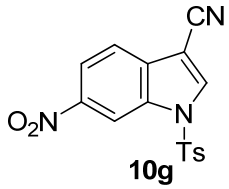
was purified by flash column chromatography (Hex / EtOAc = 95 : 5). m.p. 276–278 ^{o}C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 8.08 (s, 1H), 8.01 (d, 1H, *J* = 1.7 Hz), 7.83 (d, 2H, *J* = 8.4 Hz, Ts), 7.60 (d, 1H, *J* = 8.6 Hz), 7.35 (dd, 1H, *J* = 8.4, 2.0 Hz), 7.34 (d, 2H, *J* = 8.8 Hz, Ts), 2.41 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 146.7, 134.0, 133.8, 133.5 (CH), 132.8, 130.6 (CH), 127.2 (CH), 126.8, 125.6 (CH), 121.1(CH), 114.0 (CH), 113.0, 93.6, 21.7 (CH_3); MS (EI, 20 eV) *m/z* 91 (100), 155 (88), 330 (12) (M^+), 332 (4) (M+2); HRMS (EI, sector) calcd for $C_{16}H_{11}ClN_2O_2S$: 330.0230. Found: 330.0227; IR (cm^{-1}) 3138, 2928, 2854, 2234, 1596, 1422.



10f

1-Tosyl-3-cyano-6-trifluoromethylindole (10f)

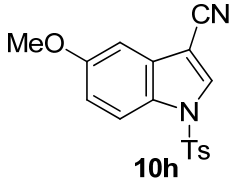
Compound **10f** was prepared from compound **8f** by *General procedure 1*. The product (**10f**, yellow solid, 0.0666 g, 0.183 mmol, 60%) was purified by flash column chromatography (Hex / EtOAc = 9 : 1, R_f = 0.18). m.p. 174–175 ^{o}C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 8.29 (s, 1H), 8.23 (s, 1H), 7.85 (d, 2H, *J* = 8.4 Hz, Ts), 7.82 (d, 1H, *J* = 8.4 Hz), 7.64 (d, 1H, *J* = 8.4 Hz), 7.35 (d, 2H, *J* = 8.4 Hz, Ts), 2.41 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 147.0, 135.3 (CH), 133.7, 132.9, 130.8, 130.6 (CH), 128.9 (q, *J* = 32.8 Hz), 127.3 (CH), 123.9 (q, *J* = 271 Hz), 121.6 (q, *J* = 3.5 Hz, CH), 121.0 (CH), 112.7, 111.4 (q, *J* = 4.4 Hz, CH), 93.6, 21.7 (CH_3); ^{19}F NMR ($CDCl_3$, 376 MHz) δ -61.5; MS (EI, 20 eV) *m/z* 91 (82), 155(100), 364 (13) (M^+); HRMS (EI, sector) calcd for $C_{17}H_{11}F_3N_2O_2S$: 364.0493. Found: 364.0493; IR (cm^{-1}) 3134, 2926, 2856, 2232, 1598, 1432



10g

1-Tosyl-3-cyano-6-nitroindole (10g)

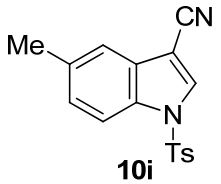
Compound **10g** was prepared from compound **8g** by *General procedure 1*. The product (**10g**, solid, 0.0760 g, 0.227 mmol, 73%) was purified by flash column chromatography (Hex / EtOAc = 9 : 1, R_f = 0.10). m.p. 196–198 ^{o}C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 8.91 (d, 1H, *J* = 2.0 Hz), 8.33 (s, 1H), 8.28 (dd, 1H, *J* = 8.8, 2.0 Hz), 7.89 (d, 2H, *J* = 8.4 Hz, Ts), 7.83 (d, 1H, *J* = 8.8 Hz), 7.37 (d, 2H, *J* = 8.4 Hz, Ts), 2.42 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 147.6, 146.7, 137.4 (CH), 133.7, 133.1, 132.9, 131.1 (CH), 127.7 (CH), 121.1 (CH), 120.2 (CH), 112.5, 110.6 (CH), 93.9 , 22.0 (CH_3); MS (EI, 70 eV) *m/z* 91 (100), 155 (100), 341 (47) (M^+); HRMS (EI, sector) calcd for $C_{16}H_{11}N_3O_4S$: 341.0470. Found: 341.0468; IR (cm^{-1}) 3124, 2924, 2856, 2232, 1745, 1594, 1520, 1462, 1428.



10h

1-Tosyl-3-cyano-5-methoxyindole (10h)

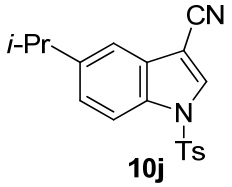
Compound **10h** was prepared from compound **8h** by *General procedure 1*. The product (**10h**, solid, 0.1069 g, 0.328 mmol, 61%) was purified by flash column chromatography (Hex / EtOAc = 9 : 1, R_f = 0.15). m.p. 156–158 °C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 8.03 (s, 1H), 7.86 (d, 1H, *J* = 9.0 Hz), 7.79 (d, 2H, *J* = 8.4 Hz, Ts), 7.29 (d, 2H, *J* = 8.4 Hz, Ts), 7.07 (d, 1H, *J* = 2.4 Hz), 7.03 (dd, 1H, *J* = 9.0, 2.5 Hz), 3.84 (s, 3H, Me), 2.38 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 157.8, 146.5, 134.4, 133.5 (CH), 130.6 (CH), 129.7, 128.4, 127.3 (CH), 116.8 (CH), 115.0 (CH), 113.8, 101.9 (CH), 93.7, 56.0 (CH_3), 21.9 (CH_3); MS (ESI$^-$) *m/z* 297 (23), 325 (100) (M-H); HRMS (ESI$^+$, TOF) calcd for $C_{17}H_{15}N_2O_3S$: 327.0803 (M+H). Found: 327.0801; IR (cm^{-1}) 3133, 2963, 2926, 2230, 1615, 1596, 1541, 1484, 1447.



10i

1-Tosyl-3-cyano-5-methylindole (10i)

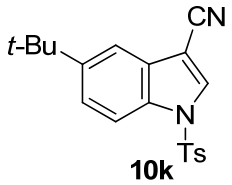
Compound **10i** was prepared from compound **8i** by *General procedure 1*. The product (**10i**, yellow solid, 0.2644 g, 0.852 mmol, 59%, R_f = 0.38 (Hex / EtOAc = 8 : 2)) was purified by flash column chromatography (Hex / EtOAc = 95 : 5). m.p. 149–150 °C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 8.03 (s, 1H), 7.84 (d, 1H, *J* = 8.6 Hz), 7.80 (d, 2H, *J* = 8.4 Hz, Ts), 7.45 (s, 1H, CH), 7.28 (d, 2H, *J* = 8.1 Hz, Ts), 7.24 (dd, 1H, *J* = 8.6 Hz, 1.4 Hz, CH), 2.43 (s, 3H, Me), 2.36 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 146.2, 134.8, 134.2, 133.0 (CH), 131.9, 130.3 (CH), 128.6, 128.0 (CH), 127.1 (CH), 119.9 (CH), 113.5, 113.4 (CH), 93.3, 21.6 (CH_3), 21.2 (CH_3); MS (EI, 70 eV) *m/z* 91 (75), 155 (94), 310 (100) (M^+); HRMS (EI, sector) calcd for $C_{17}H_{14}N_2O_2S$: 310.0776. Found: 310.0778; IR (cm^{-1}) 3139, 3069, 2924, 2870, 2231, 1732, 1596, 1543, 1456.



10j

1-Tosyl-3-cyano-5-(*i*-propyl)indole (10j)

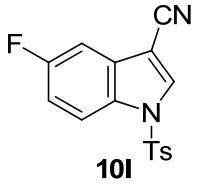
Compound **10j** was prepared from compound **8j** by *General procedure 1*. The product (**10j**, yellow solid, 0.2139 g, 0.632 mmol, 74%, R_f = 0.55 (Hex / EtOAc = 8 : 2)) was purified by flash column chromatography (Hex / EtOAc = 95 : 5). m.p. 106–108 °C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 8.05 (s, 1H), 7.89 (d, 1H, *J* = 8.6 Hz), 7.82 (d, 2H, *J* = 8.4 Hz, Ts), 7.51 (d, 1H, *J* = 1.5 Hz), 7.31 (dd, 1H, *J* = 8.4, 1.6 Hz), 7.30 (d, 2H, *J* = 8.1 Hz, Ts), 3.01 (sept, 1H, *J* = 6.9 Hz, CH), 2.38 (s, 3H, Me), 1.27 (d, 6H, *J* = 6.9 Hz, *i*-Pr); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 146.2, 146.0, 134.3, 133.0 (CH), 132.1, 130.3 (CH), 128.5, 127.2 (CH), 125.8 (CH), 117.3 (CH), 113.7, 113.5 (CH), 93.6, 34.0 (CH), 24.2 (CH_3), 21.7 (CH_3); MS (EI, 20 eV) *m/z* 155 (100), 323 (41), 338 (48) (M^+); HRMS (EI, sector) calcd for $C_{19}H_{18}N_2O_2S$: 338.1089. Found: 338.1086; IR (cm^{-1}) 3141, 2962, 2930, 2872, 2231, 1596, 1543, 1474, 1447.



10k

1-Tosyl-3-cyano-5-(*t*-butyl)indole (10k)

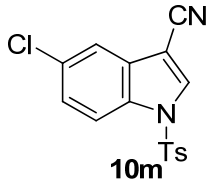
Compound **10k** was prepared from compound **8k** by *General procedure 1*. The product (**10k**, solid, 0.2532 g, 0.718 mmol, 83%, R_f = 0.25 (Hex / EtOAc = 9 : 1)) was purified by flash column chromatography (Hex / EtOAc = 95 : 5). m.p. 137–141 ^oC; ^1H NMR ($CDCl_3$, 400 MHz) δ 8.06 (s, 1H), 7.90 (d, 1H, *J* = 8.9 Hz), 7.84 (d, 2H, *J* = 8.4 Hz, Ts), 7.65 (d, 1H, *J* = 1.7 Hz), 7.50 (dd, 1H, *J* = 8.9, 1.8 Hz), 7.30 (d, 2H, *J* = 8.2 Hz, Ts), 2.38 (s, 3H, Me), 1.35 (s, 9H, *t*-Bu); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 148.5, 146.4, 134.4, 133.2 (CH), 131.9, 130.5 (CH), 128.4, 127.4 (CH), 124.9 (CH), 116.5 (CH), 114.0, 113.4 (CH), 93.9, 35.1, 31.7 (CH_3), 21.9 (CH_3); MS (ESI^+) *m/z* 114 (49), 173 (70), 217 (100), 261 (56), 305 (33), 338 (44), 353 (12) (M+H); HRMS (ESI^+, TOF) calcd for $C_{20}H_{21}N_2O_2S$: 353.1324 (M+H). Found: 353.1312; IR (cm^{-1}) 3139, 2964, 2870, 2231, 1738, 1596, 1544, 1464.



10l

1-Tosyl-3-cyano-5-fluoroindole (10l)

Compound **10l** was prepared from compound **8l** by *General procedure 1*. The product (**10l**, solid, 0.1887 g, 0.600 mmol, 66%, R_f = 0.20 (Hex / EtOAc = 9 : 1)) was purified by flash column chromatography (Hex / EtOAc = 95 : 5). m.p. 177–180 ^oC; ^1H NMR ($CDCl_3$, 400 MHz) δ 8.12 (s, 1H), 7.95 (dd, 1H, *J* = 9.2, 4.2 Hz), 7.81 (d, 2H, *J* = 8.4 Hz, Ts), 7.33 (dd, 1H, *J* = 7.5, 2.4 Hz), 7.32 (d, 2H, *J* = 8.5 Hz, Ts), 7.17 (dt, 1H, *J* = 9.0, 2.5 Hz), 2.39 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 160.4 (d, *J* = 243 Hz), 146.8, 134.7 (CH), 134.2, 130.7 (CH), 130.3, 129.7 (d, *J* = 10.0 Hz), 127.4 (CH), 115.34 (CH), 115.25 (d, *J* = 35 Hz, CH), 113.1, 106.3 (d, *J* = 25 Hz, CH), 93.8 (d, *J* = 4 Hz), 21.9 (CH_3); ^{19}F NMR ($CDCl_3$, 376 MHz) δ -116.4; MS (EI, 70 eV) *m/z* 93 (100), 155 (77), 314 (53) (M^+); HRMS (EI, sector) calcd for $C_{16}H_{11}FN_2O_2S$: 314.0525. Found: 314.0524; IR (cm^{-1}) 3149, 3084, 2930, 2233, 1618, 1593, 1540, 1475, 1449.

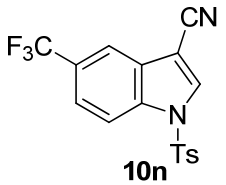


10m

1-Tosyl-3-cyano-5-chloroindole (10m)

Compound **10m** was prepared from compound **8m** by *General procedure 1*. The product (**10m**, yellow solid, 0.0812 g, 0.245 mmol, 63%, R_f = 0.23 (Hex / EtOAc = 9 : 1)) was purified by flash column chromatography (Hex / EtOAc = 95 : 5). m.p. 176–178 ^oC; ^1H NMR ($CDCl_3$, 400 MHz) δ 8.10 (s, 1H), 7.92 (d, 1H, *J* = 8.8 Hz), 7.81 (d, 2H, *J* = 8.4 Hz, Ts), 7.67 (d, 1H, *J* = 1.8 Hz), 7.40 (dd, 1H, *J* = 8.9, 2.0 Hz), 7.32 (d, 2H, *J* = 8.1 Hz, Ts), 2.40 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 146.7, 134.2 (CH), 133.9, 132.1, 131.1, 130.5 (CH), 129.5, 127.2 (CH), 127.0 (CH), 120.0 (CH), 114.9 (CH), 112.8, 93.2, 21.7 (CH_3); MS (EI, 20 eV) *m/z* 91 (100), 155 (100), 330 (21)

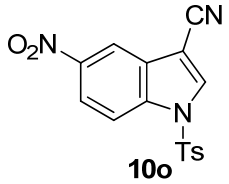
(M^+), 332 (7) (M+2); HRMS (EI, sector) calcd for $C_{16}H_{11}ClN_2O_2S$: 330.0230. Found: 330.0232; IR (cm^{-1}) 3133, 3067, 2922, 2855, 2231, 1594, 1574, 1543, 1448.



10n

1-Tosyl-3-cyano-5-trifluoromethylindole (10n)

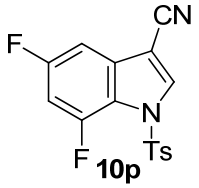
Compound **10n** was prepared from compound **8n** by *General procedure 1*. The product (**10n**, solid, 0.0747 g, 0.205 mmol, 58%, R_f = 0.23 (Hex / EtOAc = 9 : 1)) was purified by flash column chromatography (Hex / EtOAc = 95 : 5). m.p. 151–155 ^oC; ^1H NMR ($CDCl_3$, 400 MHz) δ 8.20 (s, 1H), 8.11 (d, 1H, *J* = 8.8 Hz), 8.00 (s, 1H), 7.84 (d, 2H, *J* = 8.4 Hz, Ts), 7.69 (dd, 1H, *J* = 8.8, 1.2 Hz), 7.34 (d, 2H, *J* = 8.0 Hz, Ts), 2.40 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 147.2, 135.3, 134.9 (CH), 134.0, 130.8 (CH), 128.4, 127.7 (q, *J* = 24 Hz), 127.5 (CH), 124.1 (q, *J* = 270 Hz), 123.5 (q, *J* = 4.0 Hz, CH), 118.2 (q, *J* = 4.0 Hz, CH), 114.6 (CH), 112.8, 94.3, 21.9 (CH_3); ^{19}F NMR ($CDCl_3$, 376 MHz) δ -61.6; MS (EI, 70 eV) *m/z* 91 (100), 155 (70), 364 (60) (M^+); HRMS (EI, sector) calcd for $C_{17}H_{11}F_3N_2O_2S$: 364.0493. Found: 364.0493; IR (cm^{-1}) 3142, 2925, 2236, 1596, 1449.



10o

1-Tosyl-3-cyano-5-nitroindole (10o)

Compound **10o** was prepared from compound **8o** by *General procedure 1*. The product (**10o**, solid, 0.0511 g, 0.150 mmo1, 53%) was purified by flash column chromatography (Hex / EtOAc = 9 : 1, R_f = 0.13). m.p. 210–213 ^oC; ^1H NMR ($CDCl_3$, 400 MHz) δ 8.64 (d, 1H, *J* = 2.4 Hz), 8.33 (dd, 1H, *J* = 8.8, 2.4 Hz), 8.26 (s, 1H), 8.14 (d, 1H, *J* = 9.2 Hz), 7.85 (d, 2H, *J* = 8.4 Hz, Ts), 7.36 (d, 2H, *J* = 8.4 Hz, Ts), 2.41 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 147.6, 145.4, 136.6, 136.0 (CH), 133.7, 131.0 (CH), 128.6, 127.6 (CH), 121.9 (CH), 117.0 (CH), 114.6 (CH), 112.3 , 94.9 , 22.0 (CH_3); MS (EI, 70 eV) *m/z* 91 (85), 155 (100), 341 (70) (M^+); HRMS (EI, sector) calcd for $C_{16}H_{11}N_3O_4S$: 341.0470. Found: 341.0470; IR (cm^{-1}) 3129, 2924, 2856, 2237, 1618, 1594, 1546, 1532, 1444.



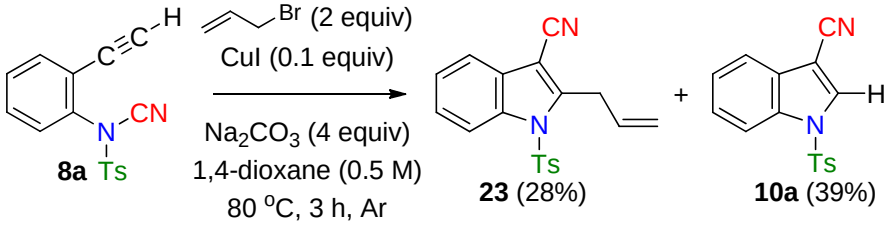
10p

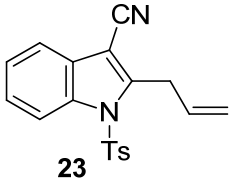
1-Tosyl-3-cyano-5,7-difluoroindole (10p)

Compound **10p** was prepared from compound **8p** by *General procedure 1*. The product (**10p**, yellow solid, 0.0467 g, 0.14 mmol, 34%, R_f = 0.4 (Hex / EtOAc = 8 : 2)) was purified by flash column chromatography (Hex / EtOAc = 95 : 5). m.p. 195–196 ^oC; ^1H NMR ($CDCl_3$, 400 MHz) δ 8.31 (s, 1H), 7.86 (d, 2H, *J* = 8.3, Hz, Ts), 7.36 (d, 2H, *J* = 8.2 Hz, Ts), 7.19 (dd, 1H, *J* = 7.5, 2.1 Hz), 6.88 (ddd, 1H, *J* = 11.5, 9.1, 2.3 Hz), 2.42 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 159.6 (dd, *J* = 247, 9.8 Hz),

149.2 (dd, J = 256, 13.3 Hz), 146.7, 136.6 (CH), 133.7, 132.4 (dd, J = 11.9, 4.8 Hz), 130.3 (CH), 128.2 (d, J = 2.8 Hz, CH), 118.2 (dd, J = 12.4, 2.3 Hz), 112.5, 102.7 (dd, J = 29.3 Hz, 23.3 Hz, CH), 102.0 (dd, J = 24.8, 4.5 Hz, CH), 92.9 (dd, J = 4.4, 2.8 Hz), 21.7 (CH_3); ^{19}F NMR ($CDCl_3$, 376 MHz) δ -113.0 (d, J = 5.6 Hz), -116.0 (d, J = 5.8 Hz); MS (EI, 20 eV) *m/z* 91 (100), 155 (83), 332 (8) (M^+); HRMS (EI, sector) calcd for $C_{16}H_{10}F_2N_2O_2S$: 332.0431. Found: 332.0428; IR (cm^{-1}) 3282, 3163, 3096, 2927, 2236, 1594, 1424.

Scheme 7(E)





1-Tosyl-2-allyl-3-cyanoindole (23)

To a mixture of *N*-(2-ethynylphenyl)-*N*-tosylcyanamide (**8a**, 0.0896, 0.302 mmol), CuI (0.0056 g, 0.029 mmol, 0.1 equiv), Na_2CO_3 (0.1282 g, 1.210 mmol, 4.0 equiv) in 1,4-dioxane (0.6 mL) under argon atmosphere was added allyl bromide (0.0759 g, 0.63 mmol, 2.0 equiv). The mixture was stirred at 80 °C under argon atmosphere for 3 h. The mixture was diluted with EtOAc, and the organic solution was washed with *conc.* aqueous NH_4OH solution and saturated aqueous NaCl solution. The organic layer was dried over anhydrous $MgSO_4$ and the solvent was removed under reduced pressure. The residue was purified by flash column chromatography (Hex / EtOAc = 95 : 5) to give the 1-tosyl-2-allyl-3-cyanoindole (**23**, solid, 0.0281 g, 0.0837 mmol, 28%, R_f = 0.25 (Hex / EtOAc = 9 : 1)) and 1-tosyl-3-cyanoindole (**10a**, solid, 0.0351 g, 0.119 mmol, 39%, R_f = 0.16 (Hex / EtOAc = 9 : 1)). Compound **23**: An analytical sample was recrystallized from Hex / EtOAc. m.p. 109–110 °C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 8.16 (d, 1H, *J* = 8.0 Hz), 7.72 (d, 2H, *J* = 8.4 Hz, Ts), 7.61 (d, 1H, *J* = 6.8 Hz), 7.38 (dt, 1H, *J* = 7.3, 1.4 Hz), 7.35 (dt, 1H, *J* = 7.6, 1.5 Hz), 7.26 (d, 2H, *J* = 8.0 Hz, Ts), 6.05 (ddt, 1H, *J* = 16.9, 10.2, 6.3 Hz), 5.23 (dd, 1H, *J* = 17.0, 1.2 Hz), 5.18 (dd, 1H, *J* = 10.1, 1.2 Hz), 4.01 (dt, 2H, *J* = 6.5, 1.4 Hz), 2.38 (s, 3H, Me); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 148.3, 146.3, 135.7, 135.4, 133.1 (CH), 130.4 (CH), 127.4, 127.0 (CH), 126.2 (CH), 125.1 (CH), 119.6 (CH), 118.8 (CH_2), 115.3 (CH), 114.1, 95.2, 32.4 (CH_2), 21.9 (CH_3); MS (EI, 70 eV) *m/z* 91 (67), 155 (76), 181 (45), 272 (17), 336 (100) (M^+); HRMS (EI, sector) calcd for $C_{19}H_{16}N_2O_2S$: 336.0932. Found: 336.0933; IR (cm^{-1}) 3069, 2925, 2855, 2226, 1638, 1597, 1562, 1451.

References

1. Gottlieb, H. E.; Kotlyar, V.; Nudelman, A. *J. Org. Chem.* **1997**, *62*, 7512.
2. Still, W. C.; Kahn, M.; Mitra, A. *J. Org. Chem.* **1978**, *43*, 2923.
3. Nissen, F.; Detert, H. *Eur. J. Org. Chem.* **2011**, 2845.
4. Jung, K.-Y.; Vanommeslaeghe, K.; Lanning, M. E.; Yap, J. L.; Gordon, C.; Wilder, P. T.; MacKerell, A. D.; Fletcher, S. *Org. Lett.* **2013**, *15*, 3234.
5. Wang, H.; Liu, L.; Wang, Y.; Peng, C.; Zhang, J.; Zhu, Q. *Tetrahedron Lett.* **2009**, *50*, 6841.
6. Anbarasan, P.; Neumann, H.; Beller, M. *Angew. Chem. Int. Ed.* **2011**, *50*, 519.
7. Gimeno, A.; Medio-Simon, M.; Ramirez de Arellano, C.; Asensio, G.; Cuenca, A. B. *Org. Lett.* **2010**, *12*, 1900.
8. Pan, Z.; Pound, S. M.; Rondla, N. R.; Douglas, C. J. *Angew. Chem. Int. Ed.* **2014**, *53*, 5170.
9. (a) Huang, H.; Zhang, G.; Gong, L.; Zhang, S.; Chen, Y. *J. Am. Chem. Soc.* **2014**, *136*, 2280; (b) Varela-Fernandez, A.; Varela, J. A.; Saa, C. *Synthesis*, **2012**, *44*, 3285.
10. Lin, C.-C.; Hsieh, T.-H.; Liao, P.-Y.; Liao, Z.-Y.; Chang, C.-W.; Shih, Y.-C.; Yeh, W.-H.; Chien, T.-C. *Org. Lett.* **2014**, *16*, 892.
11. Berry, D. A.; Chien, T. C.; Townsend, L. B. *Heterocycles*, **2004**, *63*, 2475.
12. (a) Xing, Y.; Sheng, G.; Wang, J.; Lu, P.; Wang, Y. *Org. Lett.* **2014**, *16*, 1244; (b) Hirano, K.; Inaba, Y.; Takahashi, N.; Shimano, M.; Oishi, S.; Fujii, N.; Ohno, H. *J. Org. Chem.* **2011**, *76*, 1212.
13. (a) Voth, S.; Hollett, J. W.; McCubbin, J. A. *J. Org. Chem.* **2015**, *80*, 2545; (b) Green, R. A.; Hartwig, J. F. *Angew. Chem. Int. Ed.* **2015**, *54*, 3768; (c) Vo, G. D.; Hartwig, J. F. *J. Am. Chem. Soc.* **2009**, *131*, 11049; (d) Lee, B. S.; Lee, J. H.; Chi, D. Y. *J. Org. Chem.* **2002**, *67*, 7884; (e) Green, R. A.; Hartwig, J. F. *Org. Lett.* **2014**, *16*, 4388.
14. (a) Brand, J. P.; Chevalley, C.; Waser, J. *Beil. J. Org. Chem.* **2011**, *7*, 565; (b) Nair, R. N.; Lee, P. J.; Rheingold, A. L.; Grotjahn, D. B. *Chem. Eur. J.* **2010**, *16*, 7992; (c) Koradin, C.; Dohle, W.; Rodriguez, A. L.; Schmid, B.; Knochel, P. *Tetrahedron*, **2003**, *59*, 1571.
15. (a) Murarka, S.; Studer, A. *Angew. Chem. Int. Ed.* **2012**, *51*, 12362; (b) Shen, Z.; Lu, X. *Adv. Synth. Catal.* **2009**, *351*, 3107; (c) Saito, T.; Nihei, H.; Otani, T.; Suyama, T.; Furukawa, N.; Saito, M. *Chem. Commun.* **2008**, 172
16. (a) Martinez-Esperon, M. F.; Rodriguez, D.; Castedo, L.; Saa, C. *Tetrahedron*, **2006**, *62*, 3843; (b) Martinez-Esperon, M. F.; Rodriguez, D.; Castedo, L.; Saa, C. *Org. Lett.* **2005**, *7*, 2213.
17. Kamijo, S.; Jin, T.; Yamamoto, Y. *J. Org. Chem.* **2002**, *67*, 7413.
18. (a) Tsuchiya, D.; Kawagoe, Y.; Moriyama, K.; Togo, H. *Org. Lett.* **2013**, *15*, 4194; (b) Kawagoe, Y.; Moriyama, K.; Togo, H. *Eur. J. Org. Chem.* **2014**, 4115; (c) Sakamoto, T.; Ohsawa, K. *J. Chem. Soc., Perkin Trans. 1*, **1999**, 2323; (c) Ketcha, D. M.; Gribble, G. W. *J. Org. Chem.* **1985**, *50*, 5451.
19. Jiang, B.; Kan, Y.; Zhang, A. *Tetrahedron* **2001**, *57*, 1581.
20. (a) Shimojo, H.; Moriyama, K.; Togo, H. *Synthesis*, **2013**, *45*, 2155; (b) Okamoto, K.; Watanabe, M.; Murai, M.; Hatano, R.; Ohe, K. *Chem. Commun.* **2012**, *48*, 3127; (c) Singh, M. K.; Lakshman, M. K. *J. Org. Chem.* **2009**, *74*, 3079; (d) Iida, S.; Ohmura, R.; Togo, H. *Tetrahedron*, **2009**, *65*, 6257; (e) Iida, S.; Togo, H. *Tetrahedron*, **2007**, *63*, 8274.