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ARTICLE

Synthesis of 1*H*-Isoindoliums by Electrophile-Mediated Cascade Cyclization/Iodination of Propargylamine-based 1,6-Diynes

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Highly regio- and chemoselective synthesis of 1*H*-isoindoliums through a facile and novel cascade cyclization reaction of propargylamine-based 1,6-diynes under mild conditions has been developed. Different functional groups were compatible with the optimized reaction conditions, giving the corresponding products with up to 94% yields. Upon treatment with base, the alkyne moiety of 1*H*-isoindoliums could be further transformed to allenes in excellent yields.

Introduction

Cascade cyclization is of growing importance for synthesis of complex molecules as it reduces synthetic steps and improves cost- and time-efficiency. In particular, cascade reactions significantly increase molecular complexity via tandem reaction sequences in a one-pot reaction from simple starting materials.[1] During the past decade, transition-metal-catalyzed[2] and electrophile-promoted transformations[3] of tethered alkynes have been used as efficient methods for the construction of various synthetic intermediates and complex organic molecules with excellent atom-economy. Among these, propargylic alcohol-based 1,6-diynes are versatile synthetic building blocks in constructing functional molecules (Scheme 1). Propargylic alcohol-based 1,6-diynes have been transformed to a wide variety of structurally complicated polycyclic aromatics exhibiting interesting biological activities through transition metal catalysis and/or additions/cycloisomerizations with electrophiles, such as benzo[*b*]fluorenes,[4] halogen-containing benzo[*a*]fluorenols,[5] stannyl benzo[*a*]fluorene derivatives,[6] naphthyl ketones.[7] Although many advancements have been achieved on studies of propargylic alcohol-based 1,6-diynes, investigations on the corresponding cycloisomerizations of propargylamine-based 1,6-diynes have been rarely explored.[8]

Along with our ongoing interests in the synthesis of propargylamines,[9] as well as our efforts on development of efficient transformation of propargylamines,[10] we envisioned that propargylamine-based 1,6-diynes **1** would react with an electrophile to give nitrogen-containing heterocyclic compounds. Herein, we disclose a novel electrophile-mediated cascade cyclization of propargylamine-based 1,6-diynes **1** to build spiro 1*H*-isoindoliums **2**. Upon treatment with triethylamine, the alkyne moieties of 1*H*-isoindoliums **2** were smoothly transformed to the corresponding allenes **3**.

Results and discussion

Initial investigations were conducted by using propargylamine-based 1,6-diyne **1a** as a substrate and iodine (I_2) as an electrophile for optimization of the reaction conditions. To our delight, this iodine-mediated cascade cyclization provided 1*H*-isoindoliums product **2a** in 75% yield with high regio- and chemoselectivity (Table 1, entry 1). Then, other silver salts, including AgOTf, $AgOCOCF_3$, and $AgPF_6$ were screened (Table 1, entries 2-4). Note that $AgPF_6$ was found to give the best result affording **2a** in 88% yield. Without adding silver salts, the crude product was unstable, decomposing into black impurities during purification. Thus, the purpose of addition of Ag(I) salts was to exchange the iodide anion (I^-). It was found that the reactions could not proceed successfully to afford the product **2a** in CH_2Cl_2 and MeOH (Table 1, entries 5-6). Low product yields

Scheme 1 The Transformations of 1,6-Diynes

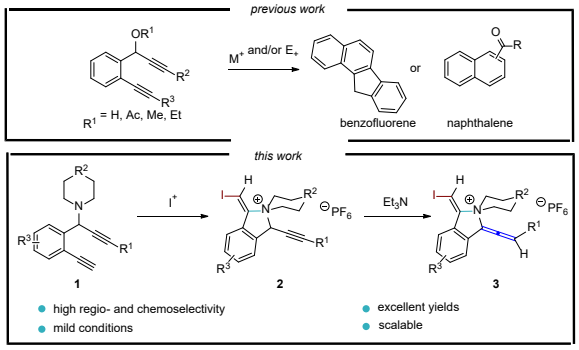

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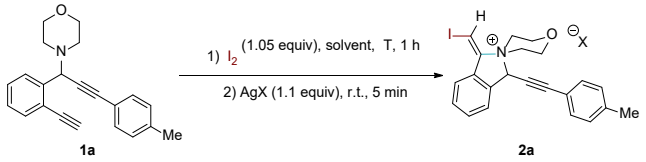
Table 1 Optimization of Reaction Conditions.[a]



Entry	Solvent	AgX	T (°C)	Yield of **2a** (%)[b]
1	CH_3CN	$AgNO_3$	r.t.	75[c]
2	CH_3CN	AgOTf	r.t.	85[c]
3	CH_3CN	$AgOCOCF_3$	r.t.	77[c]
4	CH_3CN	$AgPF_6$	r.t.	88[c]
5	CH_2Cl_2	$AgPF_6$	r.t.	0
6	MeOH	$AgPF_6$	r.t.	0
7	THF	$AgPF_6$	r.t.	9
8	DCE	$AgPF_6$	r.t.	2
9	1,4-dioxane	$AgPF_6$	r.t.	31
10	DMF	$AgPF_6$	r.t.	27
11	CH_3CN	$AgPF_6$	40	26
12	CH_3CN	$AgPF_6$	60	9
13	CH_3CN	$AgPF_6$	80	0

[a] Reactions were performed with **1a** (0.3 mmol), I_2 (0.315 mmol, 1.05 equiv), and AgX (0.33 mmol, 1.1 equiv) in solvent (3 mL). [b] Determined by ^1H NMR using CH_2Br_2 as the internal reference. [c] Isolated yield. THF = tetrahydrofuran. DCE = dichloroethane. DMF = dimethyl formamide. r.t. = room temperature (25 °C).

(2-31%) were obtained in THF, DCE, dioxane, and DMF (Table 1, entries 7-10). Increasing the temperature from room temperature to 80 °C reduced the yield to 0%, possibly the high temperature caused the decomposition of **2a**. Overall, the reaction conditions of treating 1.0 equivalent of **1** and 1.05 equivalent of iodine in CH_3CN at room temperature followed by addition of 1.1 equivalent of $AgPF_6$ were used for the subsequent studies.

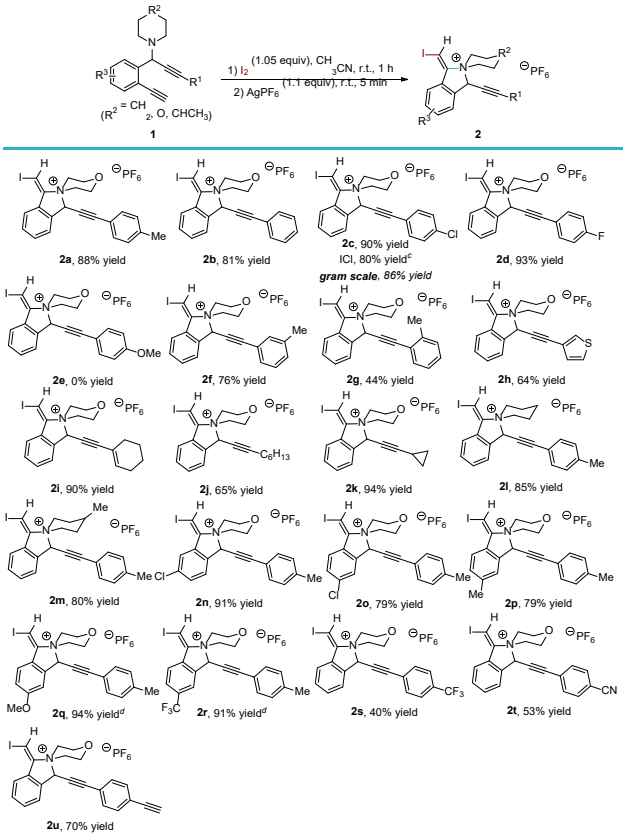
With the optimized reaction conditions, we prepared various propargylamine-based 1,6-diynes **1** to examine the generality and the scope of this cyclization. The results summarized in Table 2 showed that the optimal conditions found in Table 1 could be employed for a variety of substrates. Investigations of the scope of R^1 group demonstrated that a wide range of *para*-substituted phenyls, such as methyl, halogen, were found to give the desired products in good to excellent yields (Table 2, **2a**-**2d**, **2s**-**2u**, up to 93% yield). However, the product **2e** containing electron-rich methoxyl group could not be obtained. To our pleasure, the efficiency of the reaction was not impeded by *meta*- and *ortho*-methyl groups on the aryl ring, revealing that steric constraints could be tolerated (Table 2, **2f** and **2g**, 76% and 44% yield respectively). In addition, a 3-thienyl-containing substrate could be employed to afford the corresponding product **2h** in 64% yield. Notably, cyclohexenyl, alkyl and cyclopropyl groups were also compatible under these mild reaction conditions (Table 2, **2i**-**2k,** up to 94% yield).

Propargylamine-based 1,6-diynes **1** with different amine components at R^2 position (piperidine, 4-methylpiperidine) were smoothly reacted to give the corresponding products with good isolated yields (Table 2, **2l**-**2m**, 80-85% yield). For propargylamine-based 1,6-diyne with acyclic tertiary amine, substrate **1v** bearing *N,N*-dibenzylamine has been employed for the reaction (see Scheme S1 of ESI). Analysis of the ^1H NMR of the reaction mixture indicated the disappearance of the 1,6-diyne together with complicated ^1H NMR signals, and the desired product was not found (see Figure S2 of ESI).

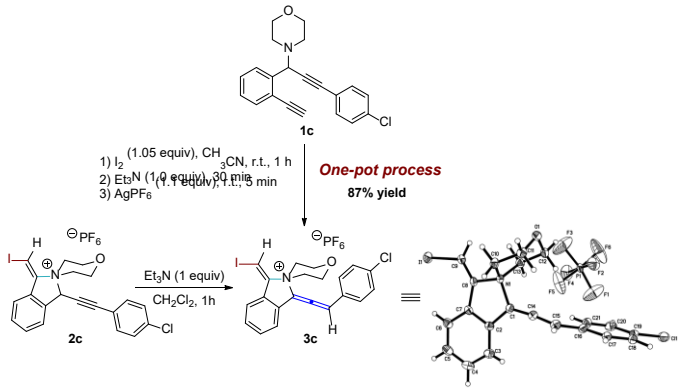
We next turned our attention to the scope of R^3 group. Methyl- and halogen-substituted propargylamines could be transformed to the corresponding 1*H*-isoindoliums in moderate to good yields (Table 2, **2n**-**2p**). Moreover, electron-donating methoxyl group and electron-withdrawing trifluoromethyl group were also tolerated to give excellent yields (Table 2, **2q**-**2r**).

We also explored the use of internal alkyne substrate for this newly developed iodine-mediated cascade cyclization by treatment of 1-(3-phenyl-1-(2-(phenylethynyl)phenyl)prop-2-yn-1-yl)piperidine **1w** with I_2 under the optimized reaction conditions (see Scheme S2 of ESI). As indicated by the ^1H NMR spectrum of the crude reaction mixture, the starting material was consumed with formation of complex reaction mixture (see Figure S4 of ESI).

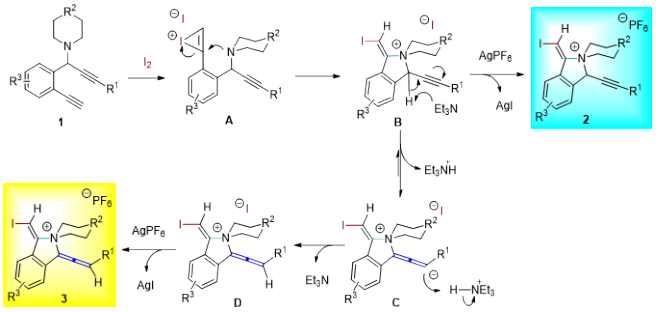
Table 2 Reaction Scope. [a,b]



[a] Reactions were performed with **1** (1 mmol), I_2 (1.05 mmol, 1.05 equiv), and $AgPF_6$ (1.1 mmol, 1.1 equiv) in CH_3CN (5 mL). [b] Isolated yield. [c] The reaction was carried out with ICl (1.05 mmol, 1.05 equiv). [d] Reactions were performed with **1** (0.3 mmol), I_2 (0.315 mmol, 1.05 equiv), and $AgPF_6$ (0.33 mmol, 1.1 equiv) in CH_3CN (3 mL).



Scheme 2 The Synthesis of Allene **3c**.



Scheme 3 Proposed Reaction Mechanism.

In addition, we found that ICl worked well as an electrophile affording the corresponding product **2c** in 80% yield (Table 2, **2c**). This method was practical and easily scalable. When 1.01 g of **1c** was used, the corresponding (**2c**) was obtained in 1.55 g (86% yield).

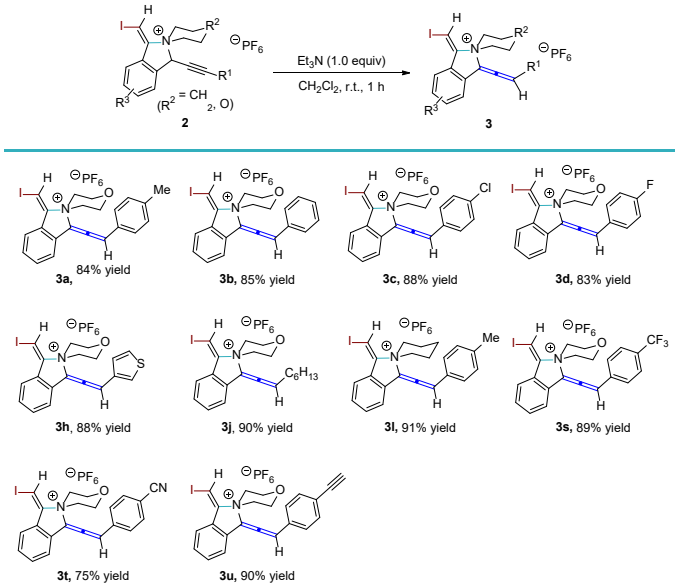
Interestingly, **2** is very sensitive to base. Upon treatment with Et_3N, **2c** with an alkyne moiety was easily isomerized to allene **3c**. Note that **3c** could be also obtained from **1c** with 87% yield under basic conditions in one pot reaction. ^1H NMR and ^{13}C NMR spectra of **2c** and **3c** indicated that the compounds did not consist of *E*/*Z* isomers. We further confirmed the structure of product **3c** by X-ray diffraction study (Scheme 2). [11]

Allenes have long been recognized as a very important class of compounds with unique structural features and reactivity. They have been utilized in the synthesis of numerous biologically active compounds and pharmaceuticals over the past decades.[12,13] Thus, much attention has been focused on deve-loping novel approaches to synthesize different types of allenes from various starting materials.[14] To the best of our knowledge, the synthesis of this class of electron-deficient allenes **3** has not been reported.

To show the scope of this isomerization of alkynes **2**, other ten allenes **3** were successfully obtained from the corresponding alkynes **2** in good to excellent yields (Table 3, up to 91% yield).

We proposed a reaction mechanism for this novel iodine-mediated cascade cyclization (Scheme 3). Electrophilic addition of iodine to the terminal alkyne of **1** gives iodonium salt **A**. Then, the nitrogen atom of **A** attacks the iodonium moiety to afford quaternary ammonium salt **B**. Subsequent anion exchange with $AgPF_6$ gives alkyne **2**. Under basic conditions, isomerization of alkyne **B** to allene **C** followed by anion exchange with $AgPF_6$ provides allene **3**.

Table 3 Reaction Scope of Isomerization of Alkynes **2**.[a,b]



[a] Reactions were performed with **2** (0.2 mmol), Et_3N (0.2 mmol, 1.0 equiv) in CH_2Cl_2 (2 mL). [b] Isolated yield.

Conclusions

In summary, we have first developed a novel electrophile-mediated cascade cyclization of propargylamine-based 1,6-diyne **1**. A new class of spiro 1*H*-isoindoliums **2** bearing vinyl iodide and alkyne moieties has been synthesized. Upon treatment with base, the alkyne moieties of 1*H*-isoindoliums **2** were transformed to allene functionalities to give the corresponding allene products **3**.

Experimental

General Methods. Chemicals purchased from commercial sources were used without further purification. Flash column chromatography was performed using silica gel 60 (230-400 mesh ASTM). ^1H NMR, ^{13}C NMR and ^{19}F NMR spectra were recorded on Bruker DPX-400, AV400 and Ascend™-600 spectrometers. Chemical shifts (ppm) were referenced to TMS and coupling constants are given in Hz. Data for ^1H NMR were recorded as follows: chemical shift (δ, ppm), multiplicity (s, singlet; brs, broad singlet; d, doublet; dd, double doublet; t, triplet; td, triple doublet; tt, triple triplet; q, quartet; qd, quadruple doublet, m, multiplet), coupling constant (Hz), integration. Data for ^{13}C NMR are reported in terms of chemical shift (δ, ppm). Data for ^{19}F NMR are reported in terms of chemical shift (δ, ppm). High resolution mass spectra (HRMS) were measured on Agilent 6540 UHD Accurate-Mass Q-TOF LC/MS, Waters Synapt G2 Q-TOF MS and Thermo Scientific Q Executive.

General procedure for the synthesis of 1*H*-isoindoliums 2

To a solution of **1** (1.0 mmol) in CH_3CN (5 mL) was added electrophile (1.05 mmol, 1.05 equiv) at room temperature. The mixture was stirred at room temperature for 1 h, and then $AgPF_6$ (1.1 mmol, 1.1 equiv) was added to the reaction mixture and stirred for 5 min. The resulted precipitate (AgI) was separated by suction filtration and washed by CH_2Cl_2. The filtrate was concentrated under vacuum and the residue was purified by flash column chromatography (CH_2Cl_2/MeOH) to give the product **2**.

(E)-1-(iodomethylene)-3-(p-tolylethynyl)-1,3-dihydro-spiro[2H-isoindole-2,4'-morpholinium] hexafluorophosphate 2a: Pale yellow solid, 88% yield. ^{1}H NMR (400 MHz, d_6-DMSO) δ 8.58 (d, *J* = 7.5 Hz, 1H), 8.22 (s, 1H), 7.80 – 7.67 (m, 3H), 7.40 (d, *J* = 8.1 Hz, 2H), 7.22 (d, *J* = 8.0 Hz, 2H), 6.95 (s, 1H), 4.43 – 4.25 (m, 3H), 4.20 – 4.09 (m, 1H), 4.03 (t, *J* = 13.1 Hz, 2H), 3.81 (dd, *J* = 16.7, 7.2 Hz, 1H), 3.62 (d, *J* = 12.0 Hz, 1H), 2.30 (s, 3H). ^{13}C NMR (100 MHz, d_6-DMSO) δ 146.68, 140.70, 136.59, 132.71, 132.06, 130.26, 129.57, 129.14, 126.01, 124.87, 116.56, 94.48, 78.98, 78.80, 65.99, 62.85, 62.00, 61.80, 56.42, 21.22. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. for $[C_{22}H_{21}INO]^+$ 442.0662, found 442.0667.

(E)-1-(iodomethylene)-3-(phenylethynyl)-1,3-dihydro-spiro[2H-isoindole-2,4'-morpholinium] hexafluorophosphate 2b: Grey solid, 81% yield. ^{1}H NMR (600 MHz, d_6-DMSO) δ 8.60 (d, *J* = 8.5 Hz, 1H), 8.25 (s, 1H), 7.80 – 7.68 (m, 3H), 7.50 (dd, *J* = 25.8, 6.9 Hz, 3H), 7.42 (t, *J* = 7.5 Hz, 2H), 6.99 (s, 1H), 4.40 (t, *J* = 11.6 Hz, 1H), 4.32 (t, *J* = 14.0 Hz, 2H), 4.19 – 4.11 (m, 1H), 4.07 (d, *J* = 12.9 Hz, 1H), 4.01 (d, *J* = 13.5 Hz, 1H), 3.81 (t, *J* = 11.5 Hz, 1H), 3.65 (d, *J* = 12.9 Hz, 1H). ^{13}C NMR (150 MHz, d_6-DMSO) δ 146.57, 136.40, 132.57, 132.01, 130.44, 130.17, 129.05, 128.84, 125.86, 124.76, 119.50, 94.01, 79.31, 79.02, 65.79, 62.83, 61.92, 61.69, 56.39. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. for $[C_{21}H_{19}INO]^+$ 428.0506, found 428.0505.

(E)-1-(iodomethylene)-3-((4-chlorophenyl)ethynyl))-1,3-dihydro-spiro[2H-isoindole-2,4'-morpholinium] hexafluorophosphate 2c: Grey solid, 90% yield. ^{1}H NMR (400 MHz, d_6-DMSO) δ 8.60 (d, *J* = 7.7 Hz, 1H), 8.26 (s, 1H), 7.84 – 7.68 (m, 3H), 7.59 – 7.53 (m, 2H), 7.50 – 7.44 (m, 2H), 6.99 (s, 1H), 4.42 (td, *J* = 10.4, 2.8 Hz, 1H), 4.32 (td, *J* = 14.2, 2.4 Hz, 2H), 4.20 – 3.99 (m, 3H), 3.87 – 3.77 (m, 1H), 3.66 (d, *J* = 12.1 Hz, 1H). ^{13}C NMR (100 MHz, d_6-DMSO) δ 146.60, 136.25, 135.29, 133.80, 132.60, 130.21, 129.08, 129.00, 125.90, 124.82, 118.45, 92.86, 80.29, 79.03, 65.67, 62.94, 61.96, 61.72, 56.44. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. for $[C_{21}H_{18}ClINO]^+$ 462.0116, found 462.0114; $[PF_6]^-$ Calcd. for $[M\text{-}C_{21}H_{18}ClINO]^-$ 144.9647, found 144.9650.

(E)-1-(iodomethylene)-3-((4-fluorophenyl)ethynyl))-1,3-dihydro-spiro[2H-isoindole-2,4'-morpholinium] hexafluorophosphate 2d: Brown solid, 93% yield [a]. ^{1}H NMR (600 MHz, CD_3CN) δ 8.64 (d, *J* = 7.8 Hz, 1H), 7.78 (s, 1H), 7.75 (t, *J* = 7.5 Hz, 1H), 7.72 – 7.67 (m, 2H), 7.55 – 7.49 (m, 2H), 7.15 (t, *J* = 8.8 Hz, 2H), 6.43 (s, 1H), 4.26 (d, *J* = 13.8 Hz, 1H), 4.24 – 4.15 (m, 2H), 4.14 – 4.02 (m, 3H), 3.75 (ddd, *J* = 14.3, 10.7, 3.9 Hz, 1H), 3.58 (dd, *J* = 13.3, 2.1 Hz, 1H). ^{13}C NMR (150 MHz, CD_3CN) δ 164.24 (d, *J* = 250.5 Hz), 147.64, 136.67, 135.26 (d, *J* = 8.8 Hz), 133.45, 130.93, 129.83, 127.33, 125.42, 116.82 (d, *J* = 3.5 Hz), 116.68 (d, *J* = 22.7 Hz), 94.90, 78.31, 75.85, 67.58, 63.24, 62.72, 62.60, 57.15. ^{19}F NMR (565 MHz, CD_3CN) δ -72.12, -73.37, -109.10. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. for $[C_{21}H_{18}FINO]^+$ 446.0412, found 446.0410.

(E)-1-(iodomethylene)-3-(m-tolylethynyl)-1,3-dihydro-spiro[2H-isoindole-2,4'-morpholinium] hexafluorophosphate 2f: Grey solid, 76% yield. ^{1}H NMR (400 MHz, d_6-DMSO) δ 8.60 (d, *J* = 7.7 Hz, 1H), 8.24 (s, 1H), 7.81 – 7.65 (m, 3H), 7.33 (s, 1H), 7.32 – 7.24 (m, 3H), 6.97 (s, 1H), 4.46 – 4.26 (m, 3H), 4.15 (t, *J* = 12.0 Hz, 1H), 4.04 (t, *J* = 15.1 Hz, 2H), 3.82 (t, *J* = 10.5 Hz, 1H), 3.64 (d, *J* = 12.8 Hz, 1H), 2.27 (s, 3H). ^{13}C NMR (100 MHz, d_6-DMSO) δ 146.58, 138.34, 136.46, 132.56, 132.30, 131.14, 130.13, 129.07, 129.04, 128.70, 125.88, 124.75, 119.36, 94.27, 78.95, 65.80, 62.80, 61.92, 61.70, 56.36, 20.54. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. for $[C_{22}H_{21}INO]^+$ 442.0662, found 442.0658.

(E)-1-(iodomethylene)-3-(o-tolylethynyl)-1,3-dihydro-spiro[2H-isoindole-2,4'-morpholinium] hexafluorophosphate 2g: White solid, 44% yield. ^{1}H NMR (400 MHz, d_6-DMSO) δ 8.59 (d, *J* = 7.6 Hz, 1H), 8.24 (s, 1H), 7.84 – 7.67 (m, 3H), 7.44 (d, *J* = 7.4 Hz, 1H), 7.36 (t, *J* = 7.4 Hz, 1H), 7.29 (d, *J* = 7.4 Hz, 1H), 7.21 (t, *J* = 7.5 Hz, 1H), 7.02 (s, 1H), 4.50 – 4.27 (m, 3H), 4.24 – 4.12 (m, 1H), 4.05 (dd, *J* = 22.5, 13.2 Hz, 2H), 3.83 (td, J_1 = 13.2, 3.6 Hz, 1H), 3.65 (d, *J* = 12.1 Hz, 1H), 2.26 (s, 3H). ^{13}C NMR (100 MHz, d_6-DMSO) δ 146.54, 140.59, 136.75, 132.54, 132.25, 130.38, 130.12, 129.81, 129.03, 126.05, 125.95, 124.65, 119.42, 93.15, 83.15, 78.94, 65.84, 62.60, 61.84, 61.67, 56.26, 20.04. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. for $[C_{22}H_{21}INO]^+$ 442.0662, found 442.0657.

(E)-1-(iodomethylene)-3-(thiophenylethynyl)-1,3-dihydro-spiro[2H-isoindole-2,4'-morpholinium] hexafluorophosphate 2h: Brown solid, 64% yield. ^{1}H NMR (400 MHz, d_6-DMSO) δ 8.59 (d, *J* = 7.5 Hz, 1H), 8.24 (s, 1H), 8.01 (dd, *J* = 2.9, 1.1 Hz, 1H), 7.81 – 7.68 (m, 3H), 7.64 (dd, *J* = 5.0, 2.9 Hz, 1H), 7.23 (dd, *J* = 5.0, 1.2 Hz, 1H), 6.97 (s, 1H), 4.46 – 4.24 (m, 3H), 4.16 – 4.08 (m, 1H), 4.07 – 3.96 (m, 2H), 3.86 – 3.74 (m, 1H), 3.63 (d, *J* = 11.6 Hz, 1H). ^{13}C NMR (100 MHz, d_6-DMSO) δ 146.49, 136.28, 133.10, 132.44, 130.04, 129.61, 128.96, 127.35, 125.78, 124.64, 118.29, 89.74, 78.74, 78.67, 66.02, 62.67, 61.83, 61.61, 56.24. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. for $[C_{19}H_{17}INOS]^+$ 434.0070, found 434.0094.

(E)-1-(iodomethylene)-3-(cyclohex-1-en-1-ylethynyl)-1,3-dihydro-spiro[2H-isoindole-2,4'-morpholinium] hexafluorophosphate 2i: White solid, 90% yield. ^{1}H NMR (400 MHz, d_6-DMSO) δ 8.56 (d, *J* = 7.7 Hz, 1H), 8.20 (s, 1H), 7.83 – 7.58 (m, 3H), 6.83 (s, 1H), 6.24 (s, 1H), 4.43 – 4.19 (m, 3H), 4.09 – 3.95 (m, 2H), 3.90 (d, *J* = 12.4 Hz, 1H), 3.78 (t, *J* = 10.3 Hz, 1H), 3.57 (d, *J* = 12.7 Hz, 1H), 2.11 – 1.91 (m, 4H), 1.64 – 1.37 (m, 4H). ^{13}C NMR (100 MHz, d_6-DMSO) δ 146.53, 139.46, 136.71, 132.48, 129.98, 128.93, 125.85, 124.59, 118.11, 96.13, 78.71, 76.75, 66.00, 62.52, 61.82, 61.65, 56.08, 27.87, 25.16, 21.42, 20.63. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. for $[C_{21}H_{23}INO]^+$ 432.0819, found 432.0813.

(E)-1-(iodomethylene)-3-(oct-1-yn-1-yl)-1,3-dihydro-spiro[2H-isoindole-2,4'-morpholinium] hexafluorophosphate 2j: White solid, 65% yield. ^{1}H NMR (400 MHz, d_6-DMSO) δ 8.54 (d, *J* = 7.9 Hz, 1H), 8.17 (s, 1H), 7.76 – 7.65 (m, 2H), 7.62 (d, *J* = 7.1 Hz, 1H), 6.67 (s, 1H), 4.40 – 4.17 (m, 3H), 4.08 – 3.87 (m, 3H), 3.75 (td, *J* = 12.8, 3.6 Hz, 1H), 3.52 (d, *J* = 12.9 Hz, 1H), 2.30 (td, *J* = 6.8, 1.7 Hz, 2H), 1.48 – 1.29 (m, 2H), 1.28 – 1.12 (m, 6H), 0.82 (t, *J* = 6.9 Hz, 3H). ^{13}C NMR (100 MHz, d_6-DMSO) δ 146.56, 137.17, 132.39, 129.91, 128.88, 125.84, 124.49, 97.26, 78.65, 70.98, 65.50, 62.37, 61.73, 61.59, 55.81, 30.51, 27.70, 27.12, 21.96, 18.04, 13.87. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. for $[C_{21}H_{27}INO]^+$ 436.1132, found 436.1127.

(E)-1-(iodomethylene)-3-(cyclopropylethynyl)-1,3-dihydro-spiro[2H-isoindole-2,4'-morpholinium] hexafluorophosphate 2k: Pale yellow solid, 94% yield. ^{1}H NMR (400 MHz, d_6-DMSO) δ 8.54 (d, *J* = 7.8 Hz, 1H), 8.17 (s, 1H), 7.82 – 7.57 (m, 3H), 6.63 (s, 1H), 4.26 (dd,

J = 25.6, 12.7 Hz, 3H), 4.10 – 3.83 (m, 3H), 3.73 (t, *J* = 11.0 Hz, 1H), 3.52 (d, *J* = 13.1 Hz, 1H), 1.45 (s, 1H), 0.92 – 0.81 (m, 2H), 0.75 – 0.64 (m, 2H). ^{13}C NMR (100 MHz, d_6-DMSO) δ 146.51, 136.93, 132.42, 129.93, 128.90, 125.78, 124.57, 100.06, 78.78, 65.95, 65.67, 62.35, 61.77, 61.62, 55.91, 8.66, 8.62, -0.90. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. for $[C_{18}H_{19}INO]^+$ 392.0506, found 392.0493.

(E)-1-(iodomethylene)-3-(p-tolylethynyl)-1,3-dihydro-spiro[isoindole-2,1'-piperidinium] hexafluorophosphate 2l: White solid, 85% yield. ^{1}H NMR (600 MHz, d_6-DMSO) δ 8.59 (d, *J* = 7.8 Hz, 1H), 8.09 (s, 1H), 7.81 – 7.62 (m, 3H), 7.37 (d, *J* = 7.9 Hz, 2H), 7.21 (d, *J* = 7.8 Hz, 2H), 6.76 (s, 1H), 4.20 (t, *J* = 13.3 Hz, 1H), 4.00 (d, *J* = 11.9 Hz, 1H), 3.63 (t, *J* = 12.0 Hz, 1H), 3.55 (d, *J* = 12.0 Hz, 1H), 2.35 – 2.20 (m, 4H), 2.13 (s, 2H), 1.83 (d, *J* = 12.7 Hz, 2H), 1.68 – 1.57 (m, 1H). ^{13}C NMR (150 MHz, d_6-DMSO) δ 147.57, 140.38, 136.93, 132.44, 131.80, 129.98, 129.46, 129.30, 125.73, 124.71, 116.64, 93.03, 79.40, 77.80, 64.88, 64.54, 57.56, 21.56, 21.34, 21.07, 20.18. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. for $[C_{23}H_{23}IN]^+$ 440.0870, found 440.0837.

(E)-1-(iodomethylene)-3-(p-tolylethynyl)-4'-methyl-1,3-dihydro-spiro[isoindole-2,1'-piperidinium] hexafluorophosphate 2m: Yellow solid, 80% yield. ^{1}H NMR (400 MHz, d_6-DMSO) δ 8.50 (dd, *J* = 6.1, 3.4 Hz, 1H), 8.16 (s, 1H), 7.76 – 7.66 (m, 3H), 7.45 (d, *J* = 8.1 Hz, 2H), 7.25 (d, *J* = 8.0 Hz, 2H), 6.77 (s, 1H), 4.02 – 3.90 (m, 1H), 3.90 – 3.76 (m, 2H), 3.61 (dd, *J* = 12.5, 6.3 Hz, 1H), 2.37 – 2.23 (m, 4H), 2.21 – 2.11 (m, 1H), 2.02 (d, *J* = 5.3 Hz, 1H), 1.84 – 1.66 (m, 2H), 1.12 (d, *J* = 6.9 Hz, 3H). ^{13}C NMR (100 MHz, d_6-DMSO) δ 146.00, 140.47, 136.24, 132.25, 131.98, 129.94, 129.87, 129.45, 126.05, 124.45, 116.60, 93.65, 79.54, 78.37, 67.78, 59.54, 54.21, 27.84, 27.42, 24.46, 21.10, 18.21. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. for $[C_{24}H_{25}INO]^+$ 454.1026, found 454.1020.

(E)-1-(iodomethylene)-6-chloro-3-(p-tolylethynyl)-1,3-dihydro-spiro[2H-isoindole-2,4'-morpholinium] hexafluorophosphate 2n: Brown solid, 91% yield [a]. ^{1}H NMR (600 MHz, CD_3CN) δ 8.60 (d, *J* = 1.8 Hz, 1H), 7.88 (s, 1H), 7.74 (dd, *J* = 8.3, 1.8 Hz, 1H), 7.68 (d, *J* = 8.3 Hz, 1H), 7.38 (d, *J* = 8.1 Hz, 2H), 7.22 (d, *J* = 8.0 Hz, 2H), 6.40 (s, 1H), 4.27 – 4.22 (m, 1H), 4.20 – 4.14 (m, 2H), 4.11 – 4.01 (m, 3H), 3.74 (ddd, *J* = 14.2, 10.5, 3.9 Hz, 1H), 3.63 – 3.55 (m, 1H), 2.35 (s, 3H). ^{13}C NMR (150 MHz, CD_3CN) δ 146.41, 142.06, 136.18, 135.57, 133.35, 132.75, 131.84, 130.11, 127.08, 126.86, 117.27, 96.68, 78.36, 77.45, 67.59, 63.21, 62.68, 62.58, 57.26, 21.30. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. for $[C_{22}H_{20}ClINO]^+$ 476.0273, found 476.0273.

(E)-1-(iodomethylene)-5-chloro-3-(p-tolylethynyl)-1,3-dihydro-spiro[2H-isoindole-2,4'-morpholinium] hexafluorophosphate 2o: Pale yellow solid, 79% yield. ^{1}H NMR (400 MHz, d_6-DMSO) δ 8.57 (d, *J* = 7.7 Hz, 1H), 8.29 (s, 1H), 7.82 (s, 2H), 7.44 (d, *J* = 6.2 Hz, 2H), 7.24 (d, *J* = 6.7 Hz, 2H), 6.92 (s, 1H), 4.39 (t, *J* = 13.1 Hz, 1H), 4.27 (t, *J* = 11.7 Hz, 2H), 4.13 (d, *J* = 11.8 Hz, 1H), 4.01 (dd, *J* = 26.1, 13.5 Hz, 2H), 3.79 (t, *J* = 11.3 Hz, 1H), 3.70 (d, *J* = 12.3 Hz, 1H), 2.32 (s, 3H). ^{13}C NMR (100 MHz, d_6-DMSO) δ 145.62, 140.66, 138.41, 136.71, 132.04, 130.44, 129.41, 128.09, 127.41, 124.80, 116.35, 94.70, 80.24, 78.11, 65.35, 62.79, 61.85, 61.64, 56.39, 21.10. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. for $[C_{22}H_{20}ClINO]^+$ 476.0273, found 476.0271.

(E)-1-(iodomethylene)-5-methyl-3-(p-tolylethynyl)-1,3-dihydro-spiro[2H-isoindole-2,4'-morpholinium] hexafluorophosphate 2p: White solid, 79% yield. ^{1}H NMR (400 MHz, d_6-DMSO) δ 8.46 (d, *J* = 7.9 Hz, 1H), 8.14 (s, 1H), 7.57 – 7.47 (m, 2H), 7.42 (d, *J* = 7.5 Hz, 2H), 7.22 (d, *J* = 7.5 Hz, 2H), 6.92 (s, 1H), 4.48 – 4.25 (m, 3H), 4.17 (t, *J* = 11.8 Hz, 1H), 4.03 (t, *J* = 13.0 Hz, 2H), 3.81 (t, *J* = 10.5 Hz, 1H), 3.63 (d, *J* = 12.5 Hz, 1H), 2.45 (s, 3H), 2.17 (s, 3H). ^{13}C NMR (100 MHz, d_6-DMSO) δ 146.71, 143.18, 140.51, 136.72, 131.95, 130.88, 129.41, 126.44, 125.72, 124.83, 116.50, 94.25, 78.76, 77.31, 65.79, 62.79, 61.89, 61.69, 56.24, 21.25, 21.08. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. for $[C_{23}H_{23}INO]^+$ 456.0819, found 456.0866.

(E)-1-(iodomethylene)-5-methoxy-3-(p-tolylethynyl)-1,3-dihydro-spiro[2H-isoindole-2,4'-morpholinium] hexafluorophosphate 2q: Brown solid, 94% yield [a]. ^{1}H NMR (600 MHz, CD_3CN) δ 8.54 (d, J = 9.5 Hz, 1H), 7.52 (s, 1H), 7.38 (d, J = 7.9 Hz, 2H), 7.21 (t, J = 7.8 Hz, 4H), 6.36 (s, 1H), 4.31 – 4.14 (m, 3H), 4.14 – 3.99 (m, 3H), 3.91 (s, 3H), 3.74 (td, J = 13.8, 4.2 Hz, 1H), 3.57 (d, J = 13.1 Hz, 1H), 2.34 (s, 3H). ^{13}C NMR (150 MHz, CD_3CN) δ 163.78, 147.60, 141.87, 139.10, 132.65, 130.02, 128.87, 121.85, 117.34, 117.17, 110.13, 96.15, 77.80, 71.72, 67.40, 63.39, 62.72, 62.59, 57.07, 56.56, 21.23. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. for $[C_{23}H_{23}INO_2]^+$ 472.0768, found 472.0768.

(E)-1-(iodomethylene)-5-trifluoromethyl-3-(p-tolylethynyl)-1,3-dihydro-spiro[2H-isoindole-2,4'-morpholinium] hexafluorophosphate 2r: Brown solid, 91% yield [a]. ^{1}H NMR (600 MHz, CD_3CN) δ 8.82 (d, J = 8.3 Hz, 1H), 8.02 (s, 2H), 7.98 (d, J = 8.4 Hz, 1H), 7.39 (d, J = 8.1 Hz, 2H), 7.23 (d, J = 8.0 Hz, 2H), 6.49 (s, 1H), 4.32 – 4.01 (m, 6H), 3.80 – 3.73 (m, 1H), 3.60 (dd, J = 13.3, 2.1 Hz, 1H), 2.35 (s, 3H). ^{13}C NMR (150 MHz, CD_3CN) δ 146.46, 142.06, 137.70, 133.84 (q, J = 33.0 Hz), 133.63, 133.51, 132.75, 130.05, 128.15, 127.91 (q, J = 3.5 Hz), 125.23 (q, J = 3.5 Hz), 122.72 (q, J = 270.5 Hz), 117.18, 96.94, 79.86, 77.12, 67.54, 63.17, 62.63, 62.47, 57.26, 21.27. ^{19}F NMR (565 MHz, CD_3CN) δ -63.35, -72.08, -73.33. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. for $[C_{23}H_{20}F_3INO]^+$ 510.0536, found 510.0535.

(E)-1-(iodomethylene)-3-((4-(trifluoromethyl)phenyl)ethynyl)spiro[isoindoline-2,4'-morpholinium] hexafluorophosphate 2s: White solid, 40% yield. ^{1}H NMR (400 MHz, d_6-DMSO) δ 8.60 (d, *J* = 7.4 Hz, 1H), 8.27 (s, 1H), 7.82 – 7.73 (m, 7H), 7.03 (s, 1H), 4.48 – 4.38 (m, 1H), 4.36 – 4.25 (m, 2H), 4.14 (t, *J* = 12.2 Hz, 2H), 4.02 (d, *J* = 13.6 Hz, 1H), 3.86 – 3.73 (m, 1H), 3.67 (d, *J* = 12.7 Hz, 1H). ^{13}C NMR (100 MHz, d_6-DMSO) δ 146.56, 136.05, 132.87, 132.59, 130.28, 130.25, 129.08, 125.85, 125.65 (q, J = 3.7 Hz), 124.82, 123.87, 122.36, 92.26, 81.62, 79.16, 65.45, 63.07, 61.96, 61.68, 56.54. ^{19}F NMR (376 MHz, d_6-DMSO) δ -62.55, -70.21, -72.10. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. for $[C_{22}H_{18}F_3INO]^+$ 496.0380, found 496.0388.

(E)-1-((4-cyanophenyl)ethynyl)-3-(iodomethylene)spiro[isoindoline-2,4'-morpholinium] 2t: White solid, 53% yield. ^{1}H NMR (400 MHz, d_6-DMSO) δ 8.60 (d, *J* = 8.7 Hz, 1H), 8.27 (s, 1H), 7.91 (d, *J* = 8.3 Hz, 2H), 7.75 (t, *J* = 10.1 Hz, 5H), 7.03 (s, 1H), 4.42 (t, *J* = 10.8 Hz, 1H), 4.35 – 4.25 (m, 2H), 4.13 (t, *J* = 10.1 Hz, 2H), 4.01 (d, *J* = 13.4 Hz, 1H), 3.80 (t, *J* = 11.7 Hz, 1H), 3.66 (d, *J* = 12.2 Hz, 1H). ^{13}C NMR (100 MHz, d_6-DMSO) δ 146.54, 135.93, 132.76, 132.57, 130.27, 129.07, 125.83, 124.82, 124.33, 118.06, 112.55, 92.16, 82.81, 79.13, 65.42, 63.10, 61.95, 61.67, 56.55. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. for $[C_{22}H_{18}IN_2O]^+$ 453.0458, found 453.0461.

(E)-1-((4-ethynylphenyl)ethynyl)-3-(iodomethylene)spiro[isoindoline-2,4'-morpholinium] hexafluorophosphate 2u: White solid, 70% yield. ^{1}H NMR (400 MHz, d_6-DMSO) δ 8.62 – 8.57 (m, 1H), 8.25 (s, 1H), 7.80 – 7.70 (m, 3H), 7.57 – 7.48 (m, 4H), 6.99 (s, 1H), 4.40 – 4.36 (m, 2H), 4.35 – 4.25 (m, 2H), 4.17 – 4.06 (m, 2H), 4.01 (d, *J* = 14.3 Hz, 1H), 3.80 (td, *J* = 11.7, 3.9 Hz, 1H), 3.65 (d, *J* = 10.9 Hz, 1H). ^{13}C NMR (100 MHz, d_6-DMSO) δ 146.52, 136.20, 132.53, 132.22, 131.97, 130.17, 129.03, 125.81, 124.75,

123.50, 119.87, 93.19, 83.66, 82.59, 81.06, 79.04, 65.68, 62.90, 61.91, 61.66, 56.43. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. for $[C_{23}H_{19}INO]^+$ 452.0506, found 452.0510.

[a] The resulted precipitate (AgI) was separated by suction filtration and washed by CH_2Cl_2. The product **2** was obtained directly by concentration under vacuum at room temperature without flash column chromatography.

General procedure for the synthesis of 3

To a solution of **2** (0.5 mmol) in CH_2Cl_2 (5 mL) was added Et_3N (0.5 mmol, 1.0 equiv) at room temperature. The mixture was stirred at room temperature for 1 h. The product was separated by suction filtration and washed by CH_2Cl_2 to give the product **3**.

(E)-1-(iodomethylene)-3-(1-tolyl-1-ylidene)-1,3-dihydro-spiro[2H-isoindole-2,4'-morpholinium] hexafluorophosphate 3a: White solid, 84% yield. ^{1}H NMR (600 MHz, d_6-DMSO) δ 8.84 – 8.72 (m, 1H), 8.42 (s, 1H), 7.98 (s, 1H), 7.72 (p, *J* = 6.5 Hz, 2H), 7.54 (d, *J* = 7.8 Hz, 2H), 7.43 – 7.35 (m, 1H), 7.30 (d, *J* = 7.8 Hz, 2H), 4.51 (t, *J* = 12.6 Hz, 1H), 4.33 (d, *J* = 12.5 Hz, 1H), 4.26 – 4.04 (m, 6H), 2.36 (s, 3H). ^{13}C NMR (150 MHz, d_6-DMSO) δ 194.91, 148.60, 140.51, 132.89, 130.82, 130.76, 130.07, 128.98, 128.92, 127.20, 124.76, 122.14, 121.05, 113.63, 77.97, 64.00, 63.26, 60.80, 60.65, 21.01. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. for $[C_{22}H_{21}INO]^+$ 442.0662, found 442.0662.

(E)-1-(iodomethylene)-3-(1-phenyl-1-ylidene)-1,3-dihydro-spiro[2H-isoindole-2,4'-morpholinium] hexafluorophosphate 3b: White solid, 85% yield. ^{1}H NMR (600 MHz, d_6-DMSO) δ 8.88 – 8.65 (m, 1H), 8.45 (s, 1H), 8.02 (s, 1H), 7.77 – 7.70 (m, 2H), 7.66 (dd, *J* = 4.3, 3.1 Hz, 2H), 7.53 – 7.42 (m, 4H), 4.53 (t, *J* = 12.4 Hz, 1H), 4.36 (d, *J* = 12.1 Hz, 1H), 4.30 – 4.04 (m, 6H). ^{13}C NMR (150 MHz, d_6-DMSO) δ 195.22, 148.66, 132.95, 130.87, 130.75, 130.49, 130.16, 129.51, 129.07, 128.95, 124.83, 122.24, 121.23, 113.80, 78.01, 64.11, 63.32, 60.87, 60.73. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. for $[C_{21}H_{19}INO]^+$ 428.0506, found 428.0500.

(E)-1-(iodomethylene)-3-(1-(4-chlorophenyl)-1-ylidene)-1,3-dihydro-spiro[2H-isoindole-2,4'-morpholinium] hexafluorophosphate 3c: White solid, 88% yield. ^{1}H NMR (400 MHz, d_6-DMSO) δ 8.79 (dd, *J* = 6.8, 1.9 Hz, 1H), 8.44 (s, 1H), 8.03 (s, 1H), 7.78 – 7.71 (m, 2H), 7.71 – 7.65 (m, 2H), 7.55 (d, *J* = 8.4 Hz, 2H), 7.48 – 7.42 (m, 1H), 4.49 (t, *J* = 11.6 Hz, 1H), 4.35 (d, *J* = 12.5 Hz, 1H), 4.28 – 4.06 (m, 6H). ^{13}C NMR (100 MHz, d_6-DMSO) δ 195.44, 148.62, 135.10, 132.96, 130.97, 130.76, 130.63, 129.52, 129.20, 129.01, 124.82, 122.30, 121.35, 112.79, 78.09, 64.18, 63.20, 60.86, 60.76. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. For $[C_{21}H_{18}ClINO]^+$ 462.0116, found 462.0153; $[PF_6]^-$ Calcd. for $[M\text{-}C_{21}H_{18}ClINO]^-$ 144.9647, found 144.9648.

(E)-1-(iodomethylene)-3-(1-(4-fluorophenyl)-1-ylidene)-1,3-dihydro-spiro[2H-isoindole-2,4'-morpholinium] hexafluorophosphate 3d: White solid, 83% yield. ^{1}H NMR (600 MHz, d_6-DMSO) δ 8.80 (s, 1H), 8.44 (s, 1H), 8.03 (s, 1H), 7.73 (s, 4H), 7.45 (s, 1H), 7.33 (s, 2H), 4.50 (t, J = 12.2 Hz, 1H), 4.35 (d, J = 12.4 Hz, 1H), 4.29 – 4.02 (m, 6H). ^{13}C NMR (150 MHz, d_6-DMSO) δ 194.92, 163.24 (d, J = 248.5 Hz), 148.60, 132.91, 131.39, 131.33, 130.79 (d, J = 23.1 Hz), 128.96, 126.69, 124.79, 122.24, 121.26, 116.54 (d, J = 21.9 Hz), 112.78, 77.94, 64.12, 63.15, 60.83, 60.73. ^{19}F NMR (565 MHz, d_6-DMSO) δ -69.46, -70.42, -109.78. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. For $[C_{21}H_{18}FINO]^+$ 446.0412, found 446.0370.

(E)-1-(iodomethylene)-3-(1-thiophenyl-1-ylidene)-1,3-dihydro-spiro[2H-isoindole-2,4'-morpholinium] hexafluorophosphate 3h: White solid, 88% yield. ^{1}H NMR (400 MHz, d_6-DMSO) δ 8.84 – 8.68 (m, 1H), 8.41 (s, 1H), 8.04 (s, 1H), 8.00 (s, 1H), 7.77 – 7.64 (m, 3H), 7.45– 7.36 (m, 2H), 4.49 (t, *J* = 12.1 Hz, 1H), 4.34 – 4.04 (m, 7H). ^{13}C NMR (100MHz, d_6-DMSO) δ 195.23, 148.53, 132.84, 131.20, 130.81, 130.66, 128.97, 128.82, 128.46, 126.71, 124.68, 122.22, 120.12, 108.01, 77.71, 63.87, 63.21, 60.76, 60.62. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. for $[C_{19}H_{17}INOS]^+$ 434.0070, found 434.0065.

(E)-1-(iodomethylene)-3-(oct-1-en-1-ylidene)-1,3-dihydro-spiro[2H-isoindole-2,4'-morpholinium] hexafluorophosphate 3j: White solid, 90% yield. ^{1}H NMR (400 MHz, d_6-DMSO) δ 8.74 (d, *J* = 7.9 Hz, 1H), 8.36 (s, 1H), 7.71 (dt, *J* = 23.6, 7.5 Hz, 2H), 7.39 (d, *J* = 7.6 Hz, 1H), 6.99 (t, *J* = 7.0 Hz, 1H), 4.48 (t, *J* = 12.1 Hz, 1H), 4.35 (t, *J* = 12.1 Hz, 1H), 4.22 – 3.96 (m, 6H), 2.44 (q *J* = 7.2 Hz, 2H), 1.61 – 1.48 (m, 2H), 1.42 – 1.23 (m, 6H), 0.85 (t, *J* = 6.4 Hz, 3H). ^{13}C NMR (100 MHz, d_6-DMSO) δ 192.79, 148.51, 132.75, 131.42, 130.28, 128.15, 124.67, 121.73, 118.92, 114.13, 77.38, 64.01, 63.22, 60.80, 60.73, 30.82, 29.20, 28.28, 27.38, 21.93, 13.77. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. for $[C_{21}H_{27}INO]^+$ 436.1132, found 436.1126.

(E)-1-(iodomethylene)-3-(1-tolyl-1-ylidene)-1,3-dihydro-spiro[isoindole-2,1'-piperidinium] hexafluorophosphate 3l: White solid, 91% yield. ^{1}H NMR (400 MHz, d_6-DMSO) δ 8.82 – 8.75 (m, 1H), 8.33 (s, 1H), 7.91 (s, 1H), 7.75 – 7.66 (m, 2H), 7.51 (d, *J* = 8.3 Hz, 2H), 7.43 – 7.36 (m, 1H), 7.29 (d, *J* = 8.3 Hz, 2H), 4.25 (dd, *J* = 12.3, 4.0 Hz, 1H), 4.07 – 3.99 (m, 3H), 2.49 – 2.39 (m, 1H), 2.35 (s, 3H), 2.20 – 2.04 (m, 1H), 1.88 (dt, *J* = 14.8, 3.1 Hz, 2H), 1.80 – 1.66 (m, 2H). ^{13}C NMR (100 MHz, d_6-DMSO) δ 195.64, 149.45, 140.31, 132.91, 131.02, 130.69, 130.08, 128.92, 128.83, 127.45, 124.67, 122.08, 120.68, 112.42, 77.17, 66.27, 65.06, 21.01, 20.46, 20.26, 19.03. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. for $[C_{23}H_{23}IN]^+$ 440.0870, found 440.0862.

(E)-1-(iodomethylene)-3-(1-(4-trifluoromethylphenyl)-1-ylidene)-1,3-dihydro-spiro[2H-isoindole-2,4'-morpholinium] hexafluorophosphate 3s: Grey solid, 89% yield. ^{1}H NMR (400 MHz, d_6-DMSO) δ 8.86 – 8.79 (m, 1H), 8.48 (s, 1H), 8.14 (s, 1H), 7.90 (d, *J* = 8.4 Hz, 2H), 7.83 (d, *J* = 8.5 Hz, 2H), 7.81 – 7.71 (m, 2H), 7.52 – 7.45 (m, 1H), 4.51 (ddd, *J* = 13.8, 11.1, 2.6 Hz, 1H), 4.42 – 4.20 (m, 3H), 4.20 – 4.07 (m, 4H). ^{13}C NMR (100 MHz, d_6-DMSO) δ 196.30, 148.57, 134.55, 132.93, 131.05, 130.44, 130.12 (q, J = 31.8 Hz), 129.71, 129.04, 126.18 (q, J = 3.6 Hz), 124.81, 123.95 (q, J = 270.6 Hz), 122.32, 121.46, 112.64, 78.20, 64.28, 63.17, 60.79, 54.89. ^{19}F NMR (376 MHz, d_6-DMSO) δ -62.26, -70.21, -72.10. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. for $[C_{22}H_{18}F_3INO]^+$ 496.0380, found 496.0376.

(E)-1-(iodomethylene)-3-(1-(4-cyanophenyl)-1-ylidene)-1,3-dihydro-spiro[2H-isoindoline-2,4'-morpholinium] hexafluorophosphate 3t: White solid, 75% yield. ^{1}H NMR (400 MHz, d_6-DMSO) δ 8.79 (d, *J* = 7.9 Hz, 1H), 8.44 (s, 1H), 8.11 (s, 1H), 7.95 (d, *J* = 8.2 Hz, 2H), 7.85 (d, *J* = 8.2 Hz, 2H), 7.74 (p, *J* = 7.3 Hz, 2H), 7.46 (d, *J* = 7.9 Hz, 1H), 4.49 – 4.33 (m, 2H), 4.30 – 4.06 (m, 6H). ^{13}C NMR (100 MHz, d_6-DMSO) δ 196.69, 148.55, 135.07, 133.19, 132.92, 131.08, 130.36, 129.69, 129.05, 124.81, 122.34, 121.56, 118.41, 112.70, 112.40, 78.16, 64.30, 63.09, 60.86, 60.80. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. For $[C_{22}H_{18}IN_2O]^+$ 453.0458, found 453.0462.

(E)-1-(iodomethylene)-3-(1-(4-ethynylphenyl)-1-ylidene)-1,3-dihydro-spiro[2H-isoindoline-2,4'-morpholinium] hexafluorophosphate 3u: White solid, 90% yield. ^{1}H NMR (400 MHz, d_6-DMSO) δ 8.81 – 8.76 (m, 1H), 8.43 (s, 1H), 8.04 (s, 1H), 7.77 – 7.69 (m, 2H), 7.66 (d, *J* = 8.3 Hz, 2H), 7.57 (d, *J* = 8.2 Hz, 2H), 7.49 – 7.41 (m, 1H), 4.53 – 4.43 (m, 1H), 4.41 – 4.30 (m, 2H), 4.29 – 4.15 (m, 2H), 4.14 – 4.08 (m, 4H). ^{13}C NMR (100 MHz, d_6-DMSO) δ 195.80, 148.56, 132.89, 132.59, 130.90, 130.66, 130.57, 129.20, 128.97, 124.76, 123.46, 122.24, 121.31, 113.13, 82.96, 78.00, 64.14, 63.15, 60.81, 60.71. HRMS (ESI): $[M\text{-}PF_6]^+$ Calcd. For $[C_{23}H_{19}INO]^+$ 452.0506, found 452.0510.

Conflicts of interest

There are no conflicts to declare.

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