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Synthesis of Azonia Aromatic Heterocycles Bearing 6−6−6−5−6 Pentacyclic Core via Intramolecular [4 + 2]-Cycloaddition and Oxidative Aromatization Reaction Sequence in One Pot

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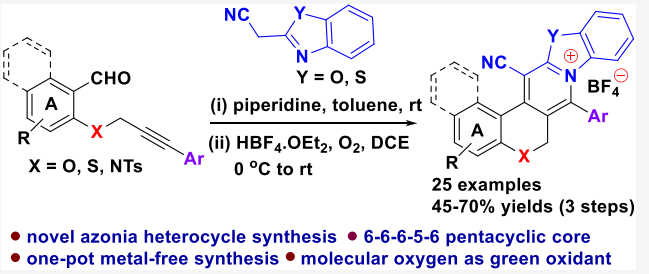
ABSTRACT: Cationic aza-heterocycle-fused compounds have gained wide applications in materials science, biological applications, and synthetic organic chemistry. In this report, synthesis of benzothiazolochromenopyridinium tetrafluoroborates, a novel molecular scaffold, bearing 6−6−6−5−6 pentacyclic core is described that proceeds via (i) piperidine-catalyzed Knoevenagel condensation between 2-propargyloxyarylaldehydes bearing internal alkynes and 2-benzothiazoleacetonitrile, (ii) intramolecular formal [4 + 2]-cycloaddition, and (iii) crucial molecular oxygen-mediated oxidative aromatization reaction sequence in one pot. These quaternary pyridinium salts are obtained at ambient temperature in good to high yields.



INTRODUCTION

Azonia aromatic heterocycles occur in many natural alkaloids and bioactive compounds[1] [Figure 1]. They appear as key intermediates in several natural products and pharmaceuticals syntheses.[2] Many cationic heterocycles are used as photocatalysts,[3] fluorescent dyes[4] for various biological studies (DNA binding properties,[4] nucleic acid imaging,[4] DNA intercalator,[4] etc.), and in spectroscopic[4] and microscopic methods.[4] They are also considered as potential candidates for organic light-emitting diodes (OLEDs).[5]

Owing to these wide range of applications, the development of new methods for the synthesis of cationic *N*-heterocycles has gained significant traction in recent years. Notable methods for the synthesis of *N*-heterocycle-fused cationic organic compounds are ring-closing metathesis (Scheme 1a),[6] Rh-catalyzed C−H activation (Scheme 1b),[7] Pd-catalyzed C−H activation (Scheme 1c),[8] Au-catalyzed cyclization (Scheme 1d),[9] Cu-mediated C−H activation−cyclization (Scheme 1e),[10] intramolecular radical arylation,[11] and oxidative photocyclization,[12] among others.[13] Many of these methods, in particular C−H activation methods which have witnessed meteoric growth, require stoichiometric or catalytic amount of precious metal salts/complexes and rigorous conditions. Therefore, a metal-free cost-effective synthesis of *N*-heterocycle-fused cationic organic compounds is highly warranted. Despite tremendous research activities, to the best of our knowledge, synthesis of quaternary pyridinium salt bearing a biologically important chromene ring has not been reported in the literature.

On the other hand, 2-propargyloxyarylaldehydes are readily obtained from commercially available starting materials and have been extensively used for various important transformations.[14] Upon adequate synthetic modifications, 2-propargyloxyarylaldehydes undergo formal cycloaddition reactions to generate chromene-fused polycyclic compounds.[15] For instance, Balci et al. reported a concise synthesis of chromenopyridines from 2-propargyloxyarylaldehydes and propargylamine via a cycloaddition reaction.[16] Recently, Balaile et al.[17] demonstrated a Cu(I)-catalyzed intramolecular cycloaddition reaction of azomethine ylide with internal alkyne to generate novel diazabicyclic piperizinochromenes. Inspired by these literature reports, we envisioned of utilizing 2-propargyloxyarylaldehydes for the synthesis of quaternary pyridinium salts. Our working hypothesis is outlined in Scheme 2. Knoevenagel adduct **3**, derived via a base-catalyzed condensation of 2-propargyloxyarylaldehyde **1** with 2-benzothiazoleacetonitrile **2a**, would undergo a formal [4 + 2]-cycloaddition reaction to generate dihydropyridine-type intermediate **4**.[18] In the presence of a suitable oxidant and a Bronsted acid, intermediate **4** would undergo oxidative aromatization giving rise to a novel class of chromenopyridinium salt **5**. However, finding an oxidant that is compatible with the reaction conditions appears to be the key challenge associated with this one-pot multistep synthesis.

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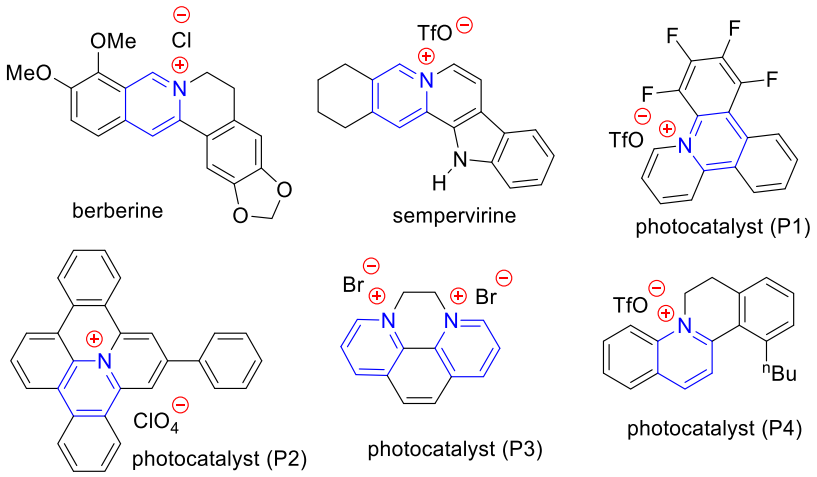

Figure 1. Selected pyridinium containing functional molecules.

RESULTS AND DISCUSSION

Our Investigation toward the synthesis of pyridinium salt **5a** commenced with 2-propargyloxyarylaldehyde **1a**. Knoevenagel condensation of **1a** with commercially available 2-benzothiazoleacetonitrile **2a** using 10 mol % piperidine in toluene at ambient temperature (20 °C) provided Knoevenagel adduct **3a**. The reaction profile was clean, and therefore, we decided to carry forward the crude product **3a** to the next step. After evaporation of toluene and other volatiles, crude **3a** was dissolved in 1,2-dichloroethane, cooled to 0 °C and treated with $HBF_4.OEt_2$ (1.5 equiv). After, stirring overnight at room temperature, TLC analysis indicated formation of a polar compound visible under long UV (354 nm). Silica gel column chromatographic separation of the crude reaction mixture provided **5a** in 28% yield (entry a, Table 1). Interestingly, compound **3a′**, the reduced form of Knoevenagel adduct **3a**, was also obtained along with other unidentified products. Reduction of **3a** to **3a′** took place, possibly due to an intermolecular hydride transfer reaction (see the mechanism below). Hence, conversion of Knoevenagel adduct **3a** to the quaternary pyridinium salt **5a** was carried out in the presence of various oxidants (3.0 equiv) to avoid the formation of **3a′**. Oxidants such as DDQ, IBX, PIDA, DMP, oxone, and $K_2S_2O_8$, which are known to undergo reactions via the single-electron-transfer (SET) mechanism, were found to provide variable results for the desired oxidation of the intermediate **4a** (see the mechanism below). Among these, DMP was found to be a better oxidant to give **5a** in 54% yield (entry e, Table 1). However, to our delight, when the solution of crude **3a** was saturated with oxygen gas before adding $HBF_4{\cdot}OEt_2$, the desired compound **5a** was obtained in 64% isolated yield (entry h, Table 1). Interestingly, formation of reduced product **3a′** was not observed by TLC analysis under these conditions. Next, the domino cycloaddition−oxidation reaction was carried out in various solvents (DCM, $CHCl_3$, CH_3CN, EtOH, THF, 1,4-dioxane) in the presence of oxygen. DCM and $CHCl_3$ as the solvent provided good yield of the desired product **5a** (entries i and j, Table 1). However, CH_3CN, EtOH, THF, and 1,4-dioxane as the solvent provided lower yield of the desired product, possibly due to the low solubility of **3a** in these solvents (entries k−n, Table 1). It is noteworthy that 2.5 equiv of $HBF_4{\cdot}OEt_2$ also provided similar yield of desired product **5a** when compared to the reaction using 1.5 equiv of $HBF_4{\cdot}OEt_2$. (entry o, Table 1).

Seeking to evaluate the scope of this domino reaction, a series of 2-propargyloxyarylaldehydes bearing electron-donating and electron-withdrawing substituents in the aryl ring A as well as (hetero)aryl substituents in the terminal position of the alkyne were tested under the optimized reaction conditions. The summary of the results is presented in Table 2. Mono- and dihalogenated (Cl, Br) aryl ring A containing quaternary pyridinium salts (**5b**−**5e**) were obtained in good yields (60−67%). Pyridinium salt **5f** bearing 3,5-diphenyl substituents in the A ring was obtained in 62% yield. Similarly, tetrafluoroborate salt **5g** having 3,5-di-*tert*-butyl groups in the A ring was also obtained in good yield (55%). Other strong Bronsted acids (TfOH, $HNTf_2$) were found to be equally effective for the domino reaction. For example, while tetrafluoroborate salt **5h** having naphthyl as the A ring was obtained in 63% yield, corresponding triflate salt **5i** and *N*-bistriflamide salts **5j** were obtained in 65 and 64% yields, respectively. Likewise, triflate salt **5k** having 1,4-benzodioxan as the A ring was obtained in 58% yield. Tetrafluoroborate salt **5l** possessing a diethylamino group at the 4-position of the A ring was isolated in 70% yield. Interestingly, an ethyl group at the propargylic position was tolerated to give triflate salt **5m** in 58% yields. Next, substrates scope varying (hetero)aryl substituents on the terminal position of the alkyne was evaluated. 2-Bromophenyl, 3-(trifluoromethy)phenyl, and 3-chloro-4-fluorophenyl as alkyne substituents provided pyridinium salts **5n**, **5o**, and **5p** in 56, 52, and 54% yields, respectively. Interestingly, 2,3-dihydrobenzo-[*b*][1,4]-dioxine as alkyne substituent furnished pyridinium salt **5q** in 62% yield. A 2-thiophene group as the alkyne substituent provided higher yield of tetrafluoroborate salt **5t** compared to that containing a 2-furan group (**5s**). Gratifyingly, thiochromenopyridinium salt **5u** was also obtained in good yield under the aerobic oxidation reaction conditions. Similarly, aza-analogues, *N*-tosyl containing pyridinium salt **5w** along with tosyl deprotected and fully aromatized salt **5w′** were obtained as an inseparable mixture in 61% yield. Using ethyl 2-benzothiazoleacetate as the counterpart in the Knoevenagel condensation worked well. However, the subsequent domino reaction was less-efficient, and pyridinium salt **5v** was obtained in 42% yield. On the other hand, the domino reaction was efficient in the case of the Knoevenagel adduct derived from 2-benzoxazoleacetonitrile, giving access to the desired tetrafluoroborate salt **5x** in 52% yield. The Knoevenagel adduct derived from 2-pyridylacetonitrile failed

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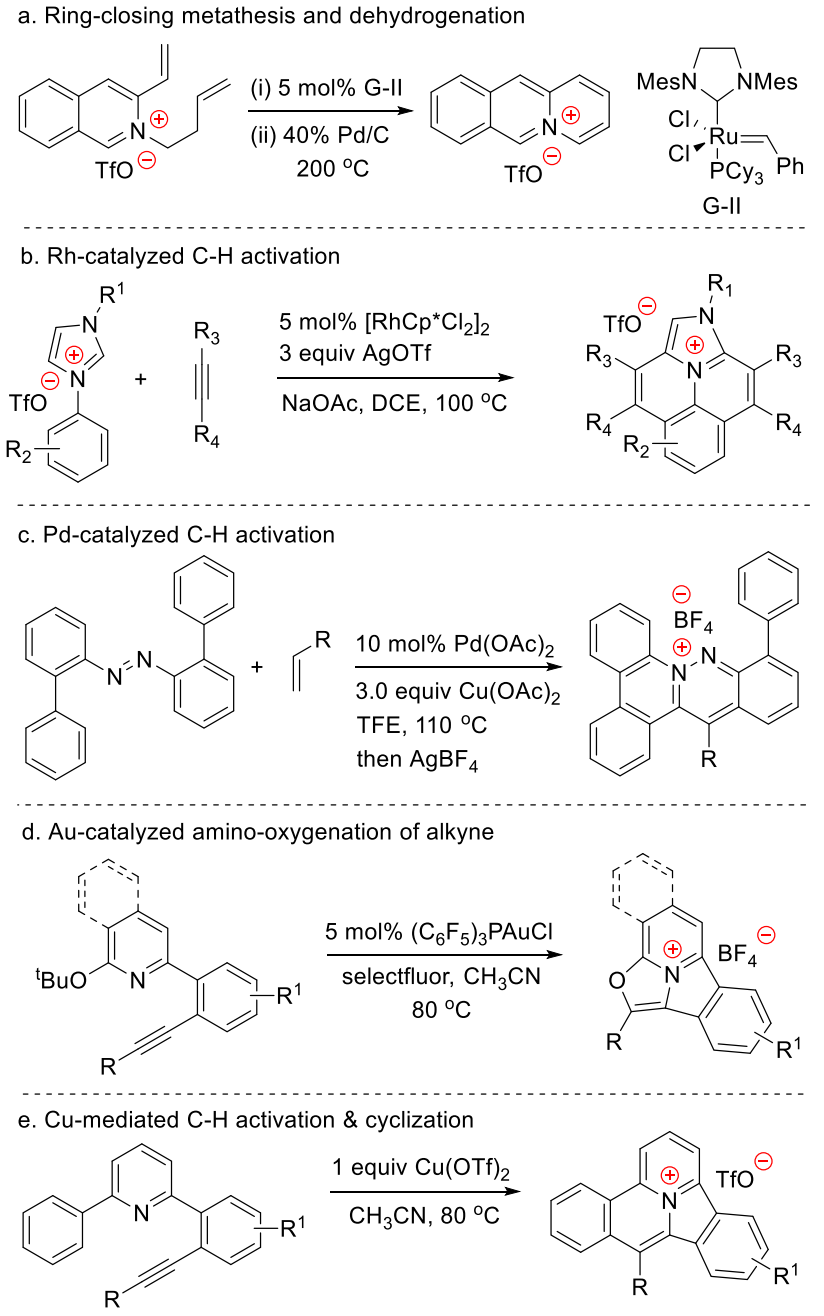
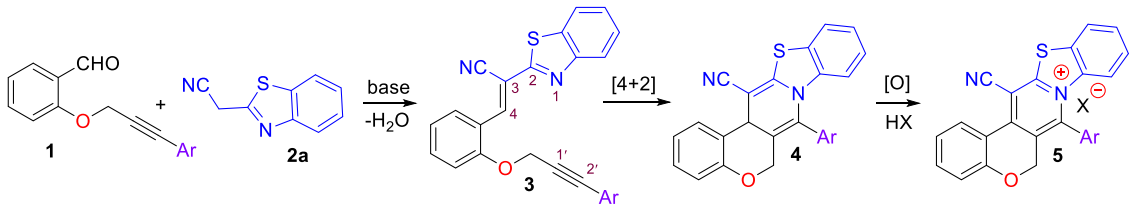
Scheme 1. Transition-Metal-Promoted Synthesis of Aza-Fused Heterocycles (a) Ring-Closing Metathesis and Dehydrogenation (b) Rh-Catalyzed C−H Activation (c) Pd-Catalyzed C−H Activation (d) Au-Catalyzed Amino-Oxygenation of Alkyne (d) Cu-Mediated C−H Activation & Cyclization



Scheme 2. Working Hypothesis for the Synthesis of Chromenopyridinium Salt



to generate the desired product **5y** even after heating the reaction mixture at 80 °C for 4 h, possibly due to the electron-withdrawing effect of the protonated pyridine ring in acidic medium. These result indicates that the electron-rich benzothiazole and benzoxazole ring facilitates the [4 + 2]-hetero Diels−Alder reaction by increasing the electron density of heterodienes. We tested 2-benzothiazoleacetonitriles having an electron-withdrawing group (Cl-atom at the 5-position) and

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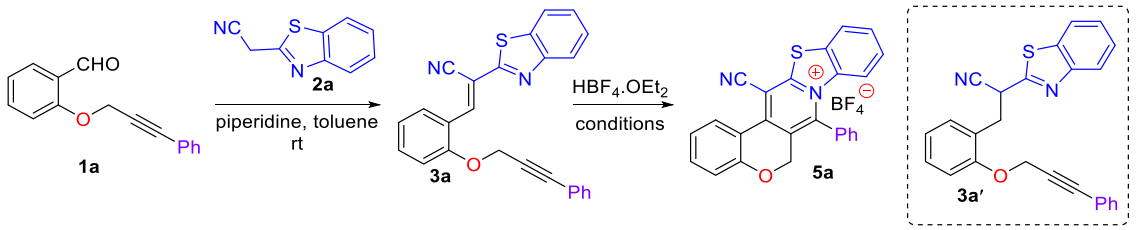
Table 1. Optimization of Reaction Conditions[a]



entry	conditions for conversion of 3a → 5a	yield (%)[b] 3a′	5a
a	$HBF_4{\cdot}OEt_2$, DCE, 0 °C to rt, 14 h	22	28
b	$HBF_4{\cdot}OEt_2$, DDQ, DCE, 0 °C to rt, 14 h	18	30
c	$HBF_4{\cdot}OEt_2$, IBX, DCE, 0 °C to rt, 14 h	12	45
d	$HBF_4{\cdot}OEt_2$, PIDA, DCE, 0 °C to rt, 14 h	10	38
e	$HBF_4{\cdot}OEt_2$, DMP, DCE, 0 °C to rt, 14 h	11	54
f	$HBF_4{\cdot}OEt_2$, oxone, DCE, 0 °C to rt, 14 h	trace	46
g	$HBF_4{\cdot}OEt_2$, $K_2S_2O_8$, DCE, 0 °C to rt, 14 h	trace	44
h	$HBF_4{\cdot}OEt_2$, O_2, DCE, 0 °C to rt, 14 h		64
i	$HBF_4{\cdot}OEt_2$, O_2, DCM, 0 °C to rt, 14 h		62
j	$HBF_4{\cdot}OEt_2$, O_2, $CHCl_3$, 0 °C to rt, 14 h		61
k	$HBF_4{\cdot}OEt_2$, O_2, CH_3CN, 0 °C to rt, 14 h		52
l	$HBF_4{\cdot}OEt_2$, O_2, EtOH, 0 °C to rt, 14 h		46
m	$HBF_4{\cdot}OEt_2$, O_2, THF, 0 °C to rt, 14 h		56
n	$HBF_4{\cdot}OEt_2$, O_2, 1,4-dioxane, 0 °C to rt, 14 h		52
o	$HBF_4{\cdot}OEt_2$, O_2, DCE, 0 °C to rt, 14 h		62[c]

[a]All reactions were carried out using 0.20 mmol scale using 1.0 equiv of **1a** and 1.0 equiv of **2a.** [b]Isolated yield over three steps. [c]2.5 Equiv of $HBF_4{\cdot}OEt_2$ was used.

an electron-donating group (methyl group at the 6-position) for the reaction. While chromenopyridinium salt **5z** was obtained in 58% yield, formation of only trace amount of compound **5za** was observed. These results suggest that substituents on the benzene ring of the 2-benzothiazoleacetonitriles moiety play a crucial role in the success of the reactions. Our method failed to give compound **5zb**. This indicates that this method is limited to propargyloxyarylaldehydes bearing aryl-substituted internal alkynes.

The mechanism of the reaction is depicted in Scheme 3. Knoevenagel adduct **3a**, obtained via piperidine-catalyzed condensation, undergoes formal [4 + 2]-cycloaddition in the presence of Bronsted acid to generate cyclic intermediate **4a** (Scheme 3a). Under anaerobic conditions, **4a** undergoes oxidation to pyridinium salt **5a** with concomitant reduction of **3a** to **3a′** via $HBF_4{\cdot}OEt_2$-promoted intermolecular hydride transfer (Scheme 3b). Under aerobic conditions, single-electron transfer from **4a** gives rise to radical cation intermediate **A** and radical anion **B**. Protonation of **B** leads to radical intermediate **C** (Scheme 3c).[19] Abstraction of single electron and single proton from **A** by **C** produces quaternary pyridinium salt **5a**. When the reaction is carried out in the presence of Ph_3P as an additive, formation of Ph_3PO was observed as confirmed by HRMS analysis of the crude reaction mixture (Scheme 3d). This indirectly indicates evolution of hydrogen peroxide during aerobic oxidation and supports the proposed mechanism. Gratifyingly, DIAD can also be utilized as an oxidizing agent leading to the formation of reduced DIAD **6** (Scheme 3e).[20] The radical cation **A** can be trapped with TEMPO to generate TEMPO-adduct **7** which was confirmed by HRMS analysis (Scheme 3f). Sterically congested TEMPO-adduct presumably gives rise to **5a** releasing reduced-TEMPO **8**.

CONCLUSIONS

In summary, synthesis of quaternary pyridinium tetrafluoroborates bearing 6−6−6−5−6 pentacyclic core has been achieved in good yields for the first time via a novel one-pot multistep protocol using molecular oxygen as a green oxidant at ambient temperature. The method can also be utilized for the synthesis of thia- and aza-analogues in good yields. These chromenopyridinium salts are likely to find wide applications in materials and biological sciences. We will explore these in near future.

EXPERIMENTAL SECTION

Unless otherwise mentioned, all chemicals received from commercial sources were used without purification. All commercial grade solvents were used without any purification. Anhydrous solvents were obtained following standard procedures. Column chromatography was performed on 100−200 mesh silica gel using a gradient mixture of MeOH in DCE as an eluent. HRMS spectra were recorded on an SCIEX G2-SQ TOF (Waters) mass spectrometer. ^1H and ^{13}C NMR spectra were recorded on a Jeol JNM-ECS or Bruker spectrometer at operating frequencies of 500/126 MHz ($^1H/^{13}C$) or 600/151 MHz ($^1H/^{13}C$) as indicated in the individual spectrum using TMS as an internal standard. Thin-layer chromatography was performed on aluminum plates (silica gel 60 PF_{254}, 0.25 mm) purchased from Merck. The multiplicity in ^1H NMR spectra is presented as s for singlet, d for doublet, dd for doublet of doublet, t for triplet, dt for doublet of triplets, apt for apparently triplet, q for quartet, ABq for AB type quartet, and m for multiplet. 2-Propargyloxyarylaldehydes bearing internal alkynes with various substitutions were synthesized following reported procedures. 2-Benzothiazoleacetonitrile and 2-pyridinylacetonitrile were purchased from commercial sources. 2-Benzoxazoleacetonitrile was prepared in the laboratory following the literature procedure.

Experimental Procedure for One-Pot Synthesis of Pyridinium Salts. 2-Propargyloxyarylaldehyde **1a** (47.3 mg, 0.20 mmol)

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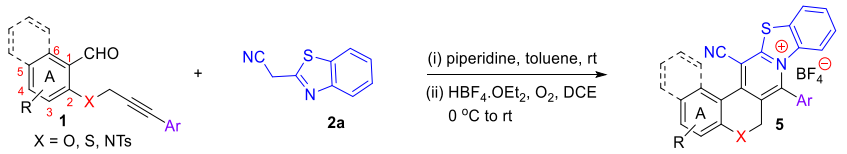
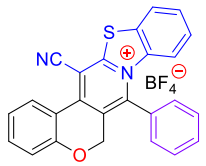
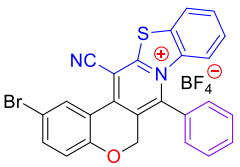
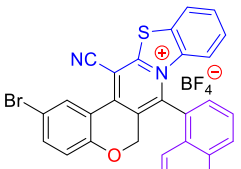
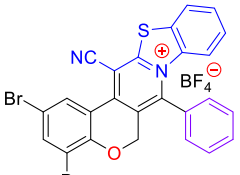
Table 2. Synthesis of Benzothiazolochromenopyridinium Tetrafluoroborates[a]

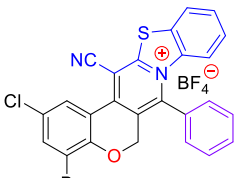


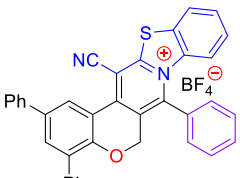

5a, 64%[b]

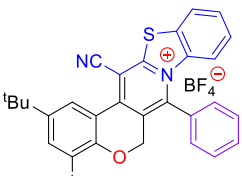

5b, 66%

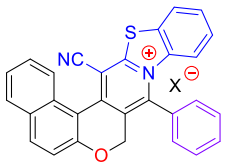

5c, 60%

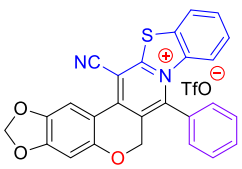

5d, 67%

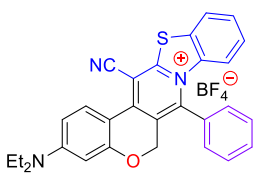

5e, 65%

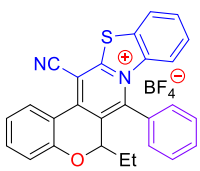

5f, 62%

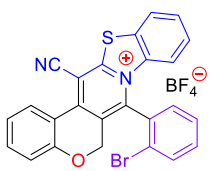

5g, 55%

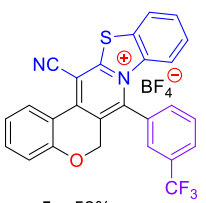

5h: X = BF_4, 63%
5i: X = TfO, 65%
5j: X = Tf_2N, 64%

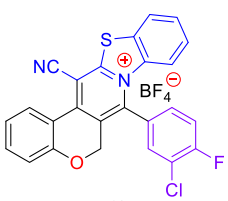

5k, 58%

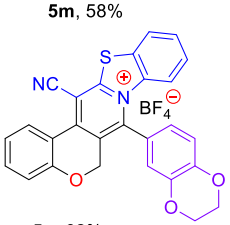

5l, 70%

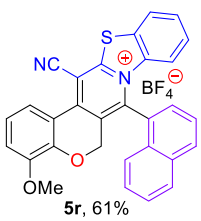

5m, 58%

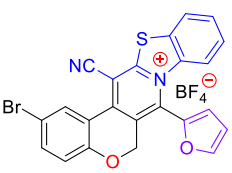

5n, 56%

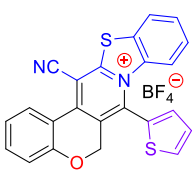

5o, 52%

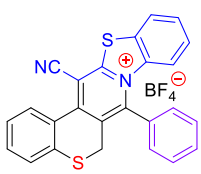

5p, 54%

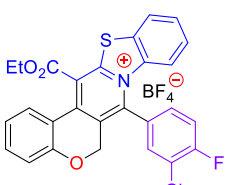

5q, 62%

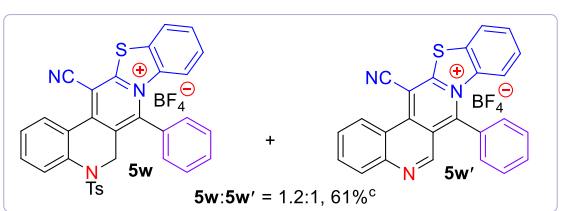

5r, 61%

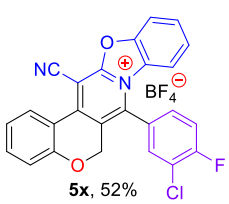

5s, 45%

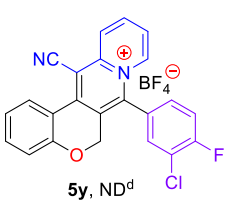

5t, 58%

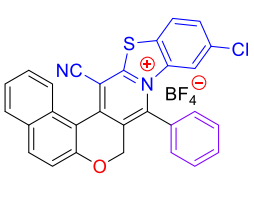

5u, 63%

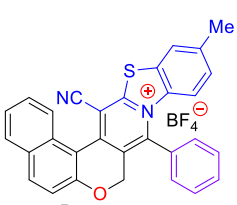

5v, 42%

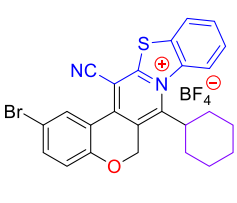

5w:**5w′** = 1.2:1, 61%[c]


5x, 52%


5y, ND[d]


5z, 58%


5za, trace


5zb, ND[d]

[a]All reactions were carried out in 0.20 mmol scale using 1.0 equiv of **1** and 1.0 equiv of **2a**. [b]Isolated yield over three steps. [c]Isolated as an inseparable mixture. [d]Yield not determined.

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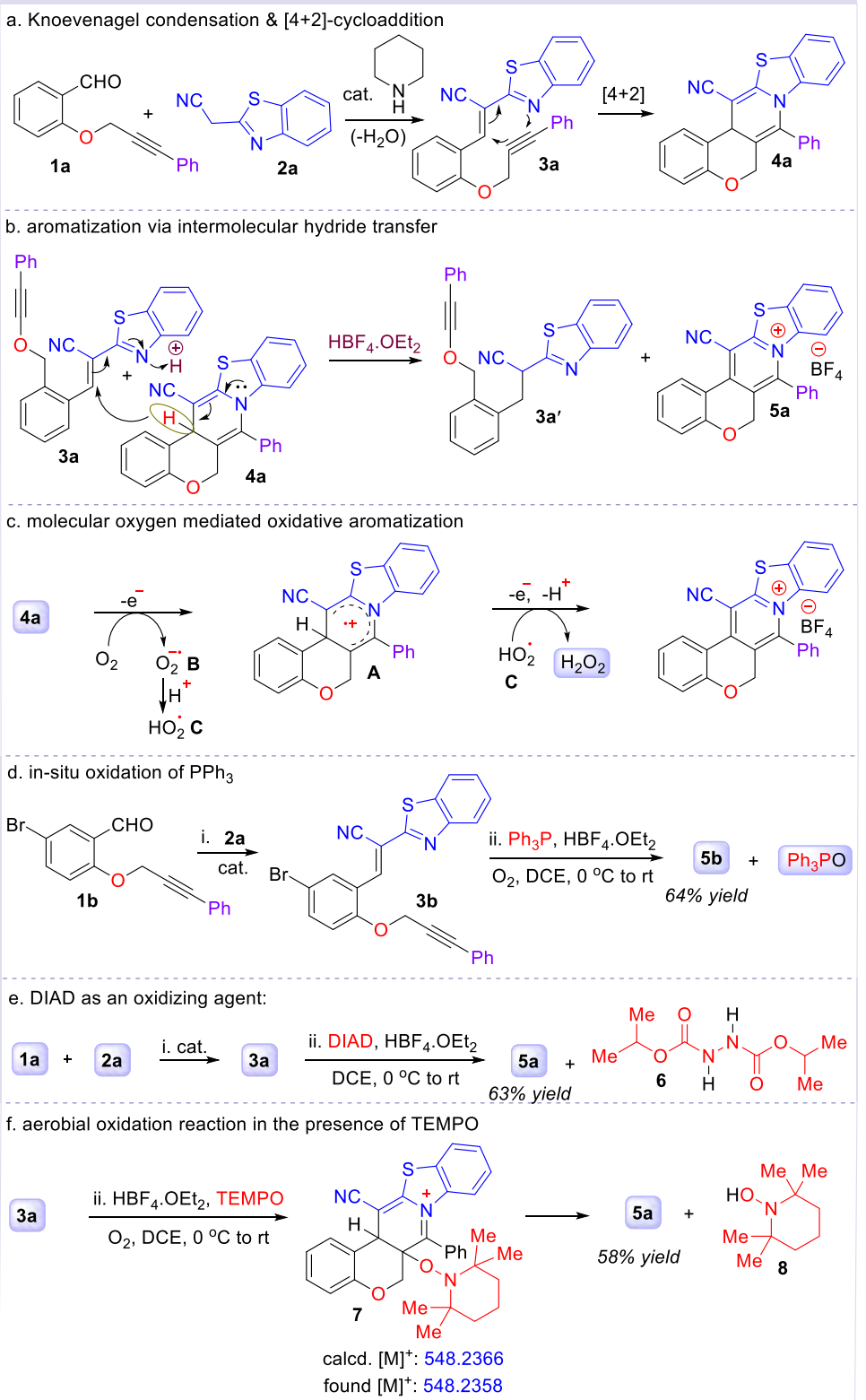
Scheme 3. Plausible Mechanism for Oxidative Aromatization (a) Knoevenagel Condensation & [4+2]-Cyclization (b) Aromatization via Intermolecular Hydride Transfer (c) Molecular Oxygen Mediated Oxidative Cyclization (d) In Situ Oxidation of PPh_3 (e) DIAD as an Oxidizing Agent (f) Aerobial Oxidation Reaction in the Presence of TEMPO



and benzothiozoleacetonitrile **2a** (34.9 mg, 0.20 mmol) were charged into an oven-dried 25 mL RBF fitted with a magnetic stir bar and nitrogen inlet. Then, toluene (0.40 mL) and piperidine (200 μL, 0.10 M solution in toluene) were added. The reaction mixture was stirred at rt for 3 h during which time TLC analysis indicated complete conversion. Then, the solvent and other volatiles were evaporated, and the residue was dissolved in DCE (10 mL), cooled to 0 °C, and purged with oxygen gas (using balloon) for 5 min. $HBF_4{\cdot}OEt_2$ (40 μL) was then added via a syringe, and the mixture was stirred at 0 °C → rt for 14 h under an oxygen atmosphere. Then, the reaction

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mixture was directly charged into a silica gel column and eluted with a gradient mixture of 0 → 5% MeOH in DCE as an eluent to obtain pyridinium tetrafluoroborate **5a** (61.3 mg, 64%) as a bright yellow solid.

Experimental Procedure for a Gram-Scale Reaction. 2-Propargyloxyarylaldehyde **1a** (1.0 g, 4.23 mmol) and benzothiozoleacetonitrile **2a** (737 mg, 4.23 mmol) were charged into an oven-dried 500 mL RBF fitted with a magnetic stir bar and nitrogen inlet. Then, toluene (12.7 mL) and piperidine (43 μL, 0.42 mmol) were added. The reaction mixture was stirred at rt for 4 h during which time TLC analysis indicated complete conversion. Then, the solvent and other volatiles were evaporated, and the residue was dissolved in DCE (210 mL), cooled to 0 °C, and purged with oxygen gas (using balloon) for 5 min. $HBF_4{\cdot}OEt_2$ (0.85 mL, 6.16 mmol) was then added via a syringe, and the mixture was stirred at 0 °C → rt for 14 h under an oxygen atmosphere. Then, the reaction mixture was directly charged into a silica gel column and eluted with a gradient mixture of 0 → 5% MeOH in DCE as an eluent to obtain pyridinium tetrafluoroborate **5a** (1.25 g, 62%) as a bright yellow solid.

Analytical Data of Synthesized Compounds. *14-Cyano-7-phenyl-6H-benzo[4,5]thiazolo[3,2-a]chromeno[4,3-d]pyridin-8-ium Tetrafluoroborate (**5a**).* Bright yellow solid, 61.3 mg (64% yield); R_f = 0.20 (9:1 DCE/MeOH); compound **5a** was purified by silica gel column chromatography using a gradient mixture of 0 → 5% MeOH in DCE as an eluent; **^{1}H NMR** (DMSO-d_6, 500 MHz) δ 8.63 (apt, J = 8.0 Hz, 2H), 7.98 (d, J = 8.0 Hz, 1H), 7.96−7.86 (m, 2H), 7.84 (apt, J = 8.0 Hz, 1H), 7.77 (d, J = 7.0 Hz, 2H), 7.62−7.46 (m, 2H), 7.34 (d, J = 8.0 Hz, 2H), 6.40 (d, J = 9.0 Hz, 1H), 5.08 (s, 2H); **^{13}C{^{1}H} NMR** (DMSO-d_6, 126 MHz) δ 160.7, 157.9, 146.9, 142.4, 138.6, 137.6, 132.8, 131.4, 130.7, 130.2, 129.0, 128.6, 128.4, 127.5, 127.4, 125.4, 124.0, 119.3, 118.7, 117.0, 114.4, 100.1, 64.4; **HRMS** (ESI-TOF) calculated for $C_{25}H_{15}N_2OS$ $[M\text{-}BF_4]^+$: 391.0900 found 391.0899.

*2-Bromo-14-cyano-7-phenyl-6H-benzo[4,5]thiazolo[3,2-a]chromeno[4,3-d]pyridin-8-ium (**5b**).* Pale yellow solid, 73.6 mg (66% yield); R_f = 0.20 (9:1 DCE/MeOH); compound **5b** was purified by silica gel column chromatography using a gradient mixture of 0 → 5% MeOH in DCE as an eluent; **^{1}H NMR** (DMSO-d_6, 500 MHz) δ 8.81 (d, J = 2.5 Hz, 1H), 8.62 (d, J = 8.0 Hz, 1H), 8.03−7.95 (m, 2H), 7.94−7.87 (m, 3H), 7.76 (d, J = 6.5 Hz, 2H), 7.57 (apt, J = 8.0 Hz, 1H), 7.33 (d, J = 9.0 Hz, 1H), 6.41 (d, J = 9.5 Hz, 1H), 5.10 (s, 2H); **^{13}C{^{1}H} NMR** (DMSO-d_6, 126 MHz) δ 160.4, 157.1, 147.2, 140.9, 139.6, 138.6, 132.9, 130.8, 130.4, 129.7, 128.9, 128.7, 128.6, 127.2, 125.5, 121.1, 119.5, 118.9, 115.0, 114.3, 100.9, 64.6; **^{19}F NMR** ($CDCl_3$, 470 MHz) δ −148.20, −148.26; **HRMS** (ESI-TOF) calculated for $C_{25}H_{14}BrN_2OS$ $[M\text{-}BF_4]^+$: 469.0005 found 469.0011.$C_{25}H_{15}N_2OS$ $[M\text{-}BF_4]^+$: 391.0900 found 391.0899.

*2-Bromo-14-cyano-7-(naphthalen-1-yl)-6H-benzo[4,5]thiazolo-[3,2-a]chromeno[4,3-d]pyridin-8-ium Tetrafluoroborate (**5c**).* Pale yellow solid, 72.8 mg (60% yield); R_f = 0.20 (9:1 DCE/MeOH); compound **5c** was purified by silica gel column chromatography using a gradient mixture of 0 → 5% MeOH in DCE as an eluent; **^{1}H NMR** (DMSO-d_6, 500 MHz) δ 8.84 (s, 1H), 8.61 (d, J = 8.0 Hz, 1H), 8.56 (d, J = 8.0 Hz, 1H), 8.32 (d, J = 8.0 Hz, 1H), 8.02−7.92 (m, 3H), 8.4−7.74 (m, 3H), 7.59 (apt, J = 7.0 Hz, 1H), 7.34 (apt, J = 8.0 Hz, 1H), 7.26 (d, J = 9.0 Hz, 1H), 6.16 (d, J = 9.5 Hz, 1H), 4.90 (ABq, J = 13.5, 2H); **^{13}C{^{1}H} NMR** (DMSO-d_6, 126 MHz) δ 161.4, 157.2, 145.7, 141.0, 139.6, 138.1, 133.4, 130.4, 129.6, 129.5, 129.4, 129.0, 128.9, 128.7, 128.6, 128.2, 128.1, 126.5, 125.5, 125.5, 123.8, 121.1, 118.9, 118.8, 115.0, 114.4, 101.4, 64.5; **HRMS** (ESI-TOF) calculated for $C_{29}H_{16}BrN_2OS$ $[M\text{-}BF_4]^+$: 519.0161 found 519.0165.

*2,4-Dibromo-14-cyano-7-phenyl-6H-benzo[4,5]thiazolo[3,2-a]chromeno[4,3-d]pyridin-8-ium Tetrafluoroborate (**5d**).* Bright yellow solid, 85.3 mg (67% yield); R_f = 0.20 (9:1 DCE/MeOH); compound **5d** was purified by silica gel column chromatography using a gradient mixture of 0 → 5% MeOH in DCE as an eluent; **^{1}H NMR** (DMSO-d_6, 600 MHz) δ 8.77 (d, J = 2.4 Hz, 1H), 8.60 (d, J = 8.4 Hz, 1H), 8.35 (d, J = 2.4 Hz, 1H), 7.94 (apt, J = 7.8 Hz, 1H), 7.88 (apt, J = 7.8 Hz, 3H), 7.74 (d, J = 7.2 Hz, 2H), 7.55 (apt, J = 7.2 Hz, 1H), 6.43 (d, J = 9.0 Hz, 1H), 5.18 (s, 2H); **^{13}C{^{1}H} NMR** (DMSO-d_6, 151 MHz) δ 160.3, 154.0, 147.4, 141.1, 140.4, 138.6, 132.9, 130.7, 130.5, 129.3, 128.7, 128.5, 127.1, 125.5, 119.9, 119.6, 115.0, 114.1, 113.4, 101.5, 65.3; **HRMS** (ESI-TOF) calculated for $C_{25}H_{13}Br_2N_2OS$ $[M\text{-}BF_4]^+$: 546.9110 found 546.9152.

*4-Bromo-2-chloro-14-cyano-7-phenyl-6H-benzo[4,5]thiazolo-[3,2-a]chromeno[4,3-d]pyridin-8-ium Tetrafluoroborate (**5e**).* Bright yellow solid, 76.9 mg (65% yield); R_f = 0.20 (9:1 DCE/MeOH); compound **5e** was purified by silica gel column chromatography using a gradient mixture of 0 → 5% MeOH in DCE as an eluent; **^{1}H NMR** (DMSO-d_6, 500 MHz) δ 8.71 (s, 1H), 8.65 (d, J = 8.0 Hz, 1H), 8.31 (s, 1H), 7.98 (apt, J = 6.5 Hz, 1H), 7.92 (apt, J = 6.5 Hz, 3H), 7.78 (d, J = 7.0 Hz, 2H), 7.60 (apt, J = 8.0 Hz, 1H), 6.47 (d, J = 8.0 Hz, 1H), 5.22 (s, 2H); **^{13}C{^{1}H} NMR** (DMSO-d_6, 126 MHz) δ 160.3, 153.7, 147.5, 140.5, 138.6, 132.9, 130.7, 130.5, 128.7, 128.5, 127.6, 127.2, 126.4, 125.5, 119.6, 119.3, 114.0, 113.2, 101.5, 65.3; **HRMS** (ESI-TOF) calculated for $C_{25}H_{13}BrClN_2OS$ $[M\text{-}BF_4]^+$: 502.9615 found 502.9619.

*14-Cyano-2,4,7-triphenyl-6H-benzo[4,5]thiazolo[3,2-a]-chromeno[4,3-d]pyridin-8-ium (**5f**).* Orange powdered solid, 78.2 mg (62% yield); R_f = 0.20 (9:1 DCE/MeOH); compound **5f** was purified by silica gel column chromatography using a gradient mixture of 0 → 5% MeOH in DCE as an eluent; **^{1}H NMR** (DMSO-d_6, 500 MHz) δ 8.93 (s, 1H), 8.64 (d, J = 9.0 Hz, 1H), 8.16 (s, 1H), 8.01−7.85 (m, 6H), 7.79 (d, J = 8.0 Hz, 2H), 7.72 (d, J = 6.5 Hz, 2H), 7.66−7.56 (m, 3H), 7.55−7.43 (m, 4H), 6.49 (d, J = 9.0 Hz, 1H), 5.16 (s, 2H); **^{13}C{^{1}H} NMR** (DMSO-d_6, 126 MHz) δ 160.5, 154.4, 147.0, 142.8, 138.6, 138.3, 135.9, 135.7, 135.3, 132.8, 132.2, 130.7, 130.3, 129.4, 129.3, 128.9, 128.6, 128.5, 128.3, 128.2, 128.1, 127.6, 126.7, 125.5, 124.8, 119.5, 118.2, 114.8, 100.8, 64.7; **HRMS** (ESI-TOF) calculated for $C_{37}H_{23}N_2OS$ $[M\text{-}BF_4]^+$: 543.1526 found 543.1526.

*2,4-Di-tert-butyl-14-cyano-7-phenyl-6H-benzo[4,5]thiazolo[3,2-a]chromeno[4,3-d]pyridin-8-ium Tetrafluoroborate (**5g**).* Light yellow solid, 65.1 mg (55% yield); R_f = 0.25 (9:1 DCE/MeOH); compound **5g** was purified by silica gel column chromatography using a gradient mixture of 0 → 5% MeOH in DCE as an eluent; **^{1}H NMR** (DMSO-d_6, 600 MHz) δ 8.63 (d, J = 8.4 Hz, 1H), 8.48 (s, 1H), 7.99 (apt, J = 8.4 Hz, 1H), 7.96−7.87 (m, 3H), 7.84−7.78 (m, 2H), 7.76 (s, 1H), 7.57 (apt, J = 8.4 Hz, 1H), 6.48 (d, J = 9.6 Hz, 1H), 5.08 (s, 2H), 1.46 (s, 9H), 1.42 (s, 9H); **^{13}C{^{1}H} NMR** (DMSO-d_6, 151 MHz) δ 160.6, 154.6, 146.5, 145.4, 143.7, 139.2, 138.5, 132.8, 131.4, 130.7, 130.2, 129.0, 128.7, 128.5, 128.4, 128.0, 125.4, 122.5, 119.4, 117.6, 114.7, 100.5, 64.0, 34.8, 34.7, 30.9, 29.4; **HRMS** (ESI-TOF) calculated for $C_{33}H_{31}N_2OS$ $[M\text{-}BF_4]^+$: 503.2152 found 503.2155.

*16-Cyano-9-phenyl-8H-benzo[4,5]thiazolo[3,2-a]benzo[5,6]-chromeno[4,3-d]pyridin-10-ium Tetrafluoroborate (**5h**).* Dark yellow solid, 66.6 mg (63% yield); R_f = 0.20 (9:1 DCE/MeOH); compound **5h** was purified by silica gel column chromatography using a gradient mixture of 0 → 5% MeOH in DCE as an eluent; **^{1}H NMR** (DMSO-d_6, 500 MHz) δ 8.62 (d, J = 8.0 Hz, 1H), 8.45 (d, J = 9.5 Hz, 1H), 8.29 (d, J = 9.5 Hz, 1H), 8.21 (d, J = 8.0 Hz, 1H), 8.05−7.81 (m, 6H), 7.79−7.68 (m, 2H), 7.61−7.50 (m, 2H), 6.50 (d, J = 9.5 Hz, 1H), 5.18 (ABq, J = 13.5 Hz, 2H); **^{13}C{^{1}H} NMR** (DMSO-d_6, 126 MHz) δ 161.4, 160.2, 145.8, 142.0, 139.0, 138.1, 132.8, 130.6, 130.5, 130.1, 130.0, 129.9, 129.4, 129.1, 128.7, 128.5, 128.4, 128.3, 128.2, 128.0, 126.5, 125.5, 125.3, 119.2, 117.5, 113.5, 112.6, 101.7, 65.2; **HRMS** (ESI-TOF) calculated for $C_{29}H_{17}N_2OS$ $[M\text{-}BF_4]^+$: 441.1056 found 441.1060.

*16-Cyano-9-phenyl-8H-benzo[4,5]thiazolo[3,2-a]benzo[5,6]-chromeno[4,3-d]pyridin-10-ium Trifluoromethanesulfonate (**5i**).* Dark yellow solid, 76.8 mg (65% yield); R_f = 0.25 (9:1 DCE/MeOH); compound **5i** was purified by silica gel column chromatography using a gradient mixture of 0 → 4% MeOH in DCE as an eluent; **^{1}H NMR** (DMSO-d_6, 500 MHz) δ 8.62 (d, J = 8.0 Hz, 1H), 8.45 (d, J = 9.5 Hz, 1H), 8.29 (d, J = 9.5 Hz, 1H), 8.20 (d, J = 8.0 Hz, 1H), 8.03−7.81 (m, 6H), 7.78−7.70 (m, 2H), 7.60−7.50 (m, 2H), 6.50 (d, J = 9.0 Hz, 1H), 5.17 (ABq, J = 12.0 Hz, 2H); **^{13}C{^{1}H} NMR** (DMSO-d_6, 126 MHz) δ 161.4, 160.2, 145.8, 142.0, 139.0, 138.2, 132.8, 130.6,130.5, 130.1, 130.0, 129.9, 129.4, 129.2, 128.7, 128.5, 128.4, 128.3, 128.2, 128.0, 126.5, 125.5, 125.3, 120.6 (q, J_{C-F} = 321.0 Hz), 119.3, 117.5, 113.5, 112.6, 101.7, 65.2; **HRMS**

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(ESI-TOF) calculated for $C_{29}H_{17}N_2OS$ [M-OTf]$^+$: 441.1056 found 441.1061.

*16-Cyano-9-phenyl-8H-benzo[4,5]thiazolo[3,2-a]benzo[5,6]-chromeno[4,3-d]pyridin-10-ium Bis((trifluoromethyl)sulfonyl)-amide (**5j**).* Dark yellow solid, 92.4 mg (64% yield); R_f = 0.25 (9:1 DCE/MeOH); compound **5j** was purified by silica gel column chromatography using a gradient mixture of 0 → 4% MeOH in DCE as an eluent; **^{1}H NMR** (DMSO-d_6, 500 MHz) δ 8.62 (d, J = 8.0 Hz, 1H), 8.45 (d, J = 9.5 Hz, 1H), 8.29 (d, J = 8.0 Hz, 1H), 8.21 (d, J = 8.0 Hz, 1H), 8.04−7.82 (m, 6H), 7.78−7.69 (m, 2H), 7.60−7.51 (m, 2H), 6.50 (d, J = 8.0 Hz, 1H), 5.17 (ABq, J = 13.5 Hz, 2H); **^{13}C{^{1}H} NMR** (DMSO-d_6, 126 MHz) δ 161.4, 160.2, 145.8, 142.0, 139.0, 138.1, 132.8, 130.6, 130.5, 130.1, 130.0, 129.9, 129.5, 129.1, 128.7, 128.5, 128.4, 128.3, 128.0, 126.5, 125.5, 125.3, 119.4 (q, J_{C-F} = 319.4 Hz), 119.2, 117.5, 113.5, 112.6, 101.7, 65.2; **HRMS** (ESI-TOF) calculated for $C_{29}H_{17}N_2OS$ [M-NTf$_2$]$^+$: 441.1056 found 441.1062.

*14-Cyano-7-phenyl-6H-[1,3]dioxolo[4′,5′:6,7]chromeno[4,3-d]-benzo[4,5]thiazolo[3,2-a]pyridin-8-ium Trifluoromethanesulfonate (**5k**).* Orange solid, 67.8 mg (58% yield); R_f = 0.25 (9:1 DCE/MeOH); compound **5k** was purified by silica gel column chromatography using a gradient mixture of 0 → 4% MeOH in DCE as an eluent; **^{1}H NMR** (DMSO-d_6, 500 MHz) δ 8.57 (d, J = 8.0 Hz, 1H), 8.03 (s, 1H), 8.00−7.70 (m, 6H), 7.51 (apt, J = 7.0 Hz, 1H), 7.05 (s, 1H), 6.34 (s, 2H), 6.32 (apt, J = 9.5 Hz, 1H), 5.00 (s, 2H); **^{13}C{^{1}H} NMR** (DMSO-d_6, 126 MHz) δ 160.7, 156.9, 155.8, 145.9, 144.5, 142.2, 138.6, 132.6, 130.6, 129.8, 129.1, 128.7, 128.4, 128.0, 125.6, 125.3, 120.6 (q, J_{C-F} = 319.3 Hz), 119.0, 114.8, 109.5, 104.0, 103.6, 99.7, 97.8, 64.6; **HRMS** (ESI-TOF) calculated for $C_{26}H_{15}N_2O_3S$ [M-OTf]$^+$: 435.0798 found 435.0798.

*14-Cyano-3-(diethylamino)-7-phenyl-6H-benzo[4,5]thiazolo-[3,2-a]chromeno[4,3-d]pyridin-8-ium Tetrafluoroborate (**5l**).* Crimson red solid, 76.9 mg (70% yield); R_f = 0.20 (9:1 DCE/MeOH); compound **5l** was purified by silica gel column chromatography using a gradient mixture of 0 → 5% MeOH in DCE as an eluent; **^{1}H NMR** (DMSO-d_6, 500 MHz) δ 8.47 (d, J = 8.0 Hz, 1H), 8.41 (d, J = 9.5 Hz, 1H), 7.93 (apt, J = 8.0 Hz, 1H), 7.87 (apt, J = 7.0 Hz, 2H), 7.77−7.71 (m, 3H), 7.42 (apt, J = 8.0 Hz, 1H), 6.94 (d, J = 9.5 Hz, 1H), 6.42 (s, 1H), 6.16 (d, J = 9.5 Hz, 1H), 4.90 (s, 2H), 3.58 (q, J = 7.0 Hz, 4H), 1.21 (t, J = 7.0 Hz, 6H); **^{13}C{^{1}H} NMR** ($CDCl_3$, 126 MHz) δ 160.7, 160.3, 154.8, 144.1, 141.1, 138.7, 132.3, 130.3, 129.4, 129.1, 129.0, 128.8, 128.0, 127.2, 125.0, 124.0, 118.3, 115.8, 109.7, 104.5, 97.6, 93.3, 64.2, 44.6, 12.6; **^{19}F NMR** ($CDCl_3$, 470 MHz) δ −148.17, −148.23; **HRMS** (ESI-TOF) calculated for $C_{29}H_{24}N_3OS$ [M-BF$_4$]$^+$: 462.1635 found 462.1633.

*14-Cyano-6-ethyl-7-phenyl-6H-benzo[4,5]thiazolo[3,2-a]-chromeno[4,3-d]pyridin-8-ium Tetrafluoroborate (**5m**).* Bright yellow solid; 48.7 mg (58% yield); R_f = 0.25 (9:1 DCE/MeOH); compound **5m** was purified by silica gel column chromatography using a gradient mixture of 0 → 4% MeOH in DCE as an eluent; **^{1}H NMR** (DMSO-d_6, 500 MHz) δ 8.90 (s, 1H), 8.63 (d, J = 8.0 Hz, 1H), 8.07−7.97 (m, 2H), 7.97−7.86 (m, 4H), 7.77 (d, J = 8.0 Hz, 1H), 7.57 (apt, J = 8.0 Hz, 1H), 7.36 (d, J = 8.0 Hz, 1H), 6.33 (d, J = 9.5 Hz, 1H), 4.95 (d, J = 9.5 Hz, 1H), 1.95−1.81 (m, 1H), 1.67−1.55 (m, 1H), 0.80 (t, J = 7.0 Hz, 3H); **^{13}C{^{1}H} NMR** (DMSO-d_6, 126 MHz) δ 160.2, 154.0, 147.7, 139.8, 139.5, 138.8, 132.8, 131.0, 130.5, 130.4, 129.6, 129.5, 129.4, 128.8, 128.7, 128.4, 128.0, 125.5, 121.9, 119.5, 118.7, 114.8, 114.4, 101.0, 75.1, 25.0, 9.8; **HRMS** (ESI-TOF) calculated for $C_{27}H_{18}BrN_2OS$ [M-BF$_4$]$^+$: 497.0318 found 497.0325.

*7-(2-Bromophenyl)-14-cyano-6H-benzo[4,5]thiazolo[3,2-a]-chromeno[4,3-d]pyridin-8-ium Tetrafluoroborate (**5n**).* Bright yellow solid, 62.5 mg (56% yield); R_f = 0.25 (9:1 DCE/MeOH); compound **5n** was purified by silica gel column chromatography using a gradient mixture of 0 → 4% MeOH in DCE as an eluent; **^{1}H NMR** (DMSO-d_6, 500 MHz) δ 8.68 (d, J = 8.0 Hz, 2H), 8.24 (d, J = 6.5 Hz, 1H), 8.01−7.90 (m, 3H), 7.86 (apt, J = 8.0 Hz, 1H), 7.80 (d, J = 6.5 Hz, 1H), 7.68 (apt, J = 8.0 Hz, 1H), 7.54 (apt, J = 8.0 Hz, 1H), 7.37 (d, J = 9.5 Hz, 1H), 6.51 (d, J = 9.0 Hz, 1H), 5.06 (ABq, J = 13.5 Hz, 2H); **^{13}C{^{1}H} NMR** (DMSO-d_6, 126 MHz) δ 161.1, 158.2, 144.3, 142.4, 137.9, 137.8, 135.1, 134.4, 131.2, 130.6, 130.3, 129.7, 129.5, 128.6, 127.8, 127.6, 125.8, 124.1, 122.1, 118.9, 118.0, 116.9, 114.4, 101.2, 64.2; **HRMS** (ESI-TOF) calculated for $C_{25}H_{14}BrN_2OS$ [M-BF$_4$]$^+$: 469.0005 found 469.0017.

*14-Cyano-7-(3-(trifluoromethyl)phenyl)-6H-benzo[4,5]thiazolo-[3,2-a]chromeno[4,3-d]pyridin-8-ium Tetrafluoroborate (**5o**).* Bright yellow solid, 56.8 mg (52% yield); R_f = 0.25 (9:1 DCE/MeOH); compound **5o** was purified by silica gel column chromatography using a gradient mixture of 0 → 4% MeOH in DCE as an eluent; **^{1}H NMR** (DMSO-d_6, 500 MHz) δ 8.62 (apt, J = 6.5 Hz, 2H), 8.35 (d, J = 6.5 Hz, 1H), 8.21 (s, 1H), 8.19−8.11 (m, 2H), 7.90 (apt, J = 6.5 Hz, 1H), 7.83 (apt, J = 6.5 Hz, 1H), 7.58 (apt, J = 8.0 Hz, 1H) 7.50 (apt, J = 8.0 Hz, 1H), 7.33 (d, J = 8.0 Hz, 1H), 6.36 (d, J = 9.5 Hz, 1H), 5.09 (s, 2H); **^{13}C{^{1}H} NMR** (DMSO-d_6, 126 MHz) δ 160.9, 158.1, 145.0, 142.9, 138.6, 137.9, 133.4, 132.3, 131.3 (q, J_{C-F} = 31.6 Hz), 130.5, 130.0, 129.7, 128.9, 128.7, 128.1, 127.8, 126.0, 125.7, 124.2, 123.7 (q, J_{C-F} = 271.1), 119.3, 118.9, 117.1, 114.6, 100.7, 64.4; **HRMS** (ESI-TOF) calculated for $C_{26}H_{14}F_3N_2OS$ [M-BF$_4$]$^+$: 459.0773 found 459.0766.

*7-(3-Chloro-4-fluorophenyl)-14-cyano-6H-benzo[4,5]thiazolo-[3,2-a]chromeno[4,3-d]pyridin-8-ium Tetrafluoroborate (**5p**).* Pale yellow solid, 57.4 mg (54% yield); R_f = 0.25 (9:1 DCE/MeOH); compound **5p** was purified by silica gel column chromatography using a gradient mixture of 0 → 4% MeOH in DCE as an eluent; **^{1}H NMR** (DMSO-d_6, 500 MHz) δ 8.63 (d, J = 8.0 Hz, 2H), 8.07 (d, J = 7.0 Hz, 1H), 8.02−7.90 (m, 2H), 7.84 (apt, J = 7.0 Hz, 2H), 7.69 (apt, J = 8.0 Hz, 1H), 7.51 (apt, J = 8.0 Hz, 1H), 7.35 (d, J = 8.0 Hz, 1H), 6.67 (d, J = 9.5 Hz, 1H), 5.15 (ABq, J = 14.5 Hz, 2H); **^{13}C{^{1}H} NMR** (DMSO-d_6, 126 MHz) δ 160.6, 159.7 (d, J_{C-F} = 252.7 Hz), 158.0, 144.5, 142.6, 138.5, 137.7, 131.4, 130.4, 130.3 (d, J_{C-F} = 8.2 Hz), 129.2, 128.4, 128.2, 127.7, 126.3 (d, J_{C-F} = 3.4 Hz), 125.5, 124.0, 122.4 (d, J_{C-F} = 18.4 Hz), 119.8, 119.7 (d, J_{C-F} = 18.3 Hz), 118.8, 117.0, 114.4, 100.5, 64.4; **HRMS** (ESI-TOF) calculated for $C_{25}H_{13}ClFN_2OS$ [M-BF$_4$]+: 443.0416 found 443.0413.

*14-Cyano-7-(2,3-dihydrobenzo[b][1,4]dioxin-6-yl)-6H-benzo-[4,5]thiazolo[3,2-a]chromeno[4,3-d]pyridin-8-ium Tetrafluoroborate (**5q**).* Bright yellow solid, 66.5 mg (62% yield); R_f = 0.20 (9:1 DCE/MeOH); compound **5q** was purified by silica gel column chromatography using a gradient mixture of 0 → 5% MeOH in DCE as an eluent; **^{1}H NMR** (DMSO-d_6, 500 MHz): (mixture of rotamers, 1:1) δ 8.61 (d, J = 8.0 Hz, 3H), 8.08 (d, J = 8.0 Hz, 1H), 8.01−7.88 (m, 3H), 7.87−7.77 (m, 2H), 7.74 (apt, J = 8.0 Hz, 1H), 7.67 (apt, J = 8.0 Hz, 1H), 7.51 (apt, J = 8.0 Hz, 1H), 7.47 (d, J = 8.0 Hz, 1H), 7.42−7.14 (m, 8H), 6.66 (d, J = 9.0 Hz, 1H), 5.42 (ABq, J = 14.5 Hz, 2H), 5.15 (ABq, J = 14.5 Hz, 2H), 4.60−4.34 (m, 8H); **^{13}C{^{1}H} NMR** (DMSO-d_6, 126 MHz): (mixture of rotamers, 1:1) δ 160.5, 160.4, 159.3, 157.8, 155.9, 154.9, 152.1, 151.5, 146.9, 146.7, 144.9, 144.0, 143.5, 142.3, 138.6, 137.5, 133.8, 130.2, 128.8, 128.3, 127.7, 127.5, 126.1, 125.4, 125.3, 123.9, 123.3, 122.9, 122.6, 122.1, 121.9, 121.5, 121.2, 120.9, 119.7, 119.4, 118.7, 117.4, 117.3, 117.0, 116.8, 116.6, 116.2, 116.1, 114.5, 107.6, 99.9, 64.7, 64.7, 64.5, 64.4, 64.2, 64.1, 63.9; **HRMS** (ESI-TOF) calculated for $C_{27}H_{17}N_2O_3S$ [M-BF$_4$]$^+$: 449.0954 found 449.0951.

*14-Cyano-4-methoxy-7-(naphthalen-1-yl)-6H-benzo[4,5]-thiazolo[3,2-a]chromeno[4,3-d]pyridin-8-ium Tetrafluoroborate (**5r**).* Bright yellow solid, 68.2 mg (61% yield); R_f = 0.20 (9:1 DCE/MeOH); compound **5r** was purified by silica gel column chromatography using a gradient mixture of 0 → 5% MeOH in DCE as an eluent; **^{1}H NMR** (DMSO-d_6, 500 MHz) δ 8.61 (d, J = 8.0 Hz, 1H), 8.57 (d, J = 8.0 Hz, 1H), 8.33 (d, J = 8.0 Hz, 1H), 8.24 (d, J = 8.0 Hz, 1H), 7.98 (apt, J = 8.0 Hz, 1H), 7.94 (d, J = 7.0 Hz, 1H), 7.85−7.75 (m, 3H), 7.61 (apt, J = 8.0 Hz, 1H), 7.54 (d, J = 8.0 Hz, 1H), 7.47 (apt, J = 8.0 Hz, 1H), 7.36 (apt, J = 8.0 Hz, 1H), 6.15 (d, J = 9.5 Hz, 1H), 4.87 (ABq, J = 13.0 Hz, 2H), 3.87 (s, 3H); **^{13}C{^{1}H} NMR** (DMSO-d_6, 126 MHz) δ 161.7, 149.3, 147.9, 145.4, 142.7, 138.1, 133.3, 133.2, 130.3, 129.6, 129.3, 128.9, 128.8, 128.5, 128.4, 128.1, 126.5, 125.8, 125.5, 123.9, 123.8, 119.2, 118.7, 118.2, 117.6, 114.6, 100.8, 64.3, 56.2; **HRMS** (ESI-TOF) calculated for $C_{30}H_{19}N_2O_2S$ [M-BF$_4$]$^+$: 471.1162 found 471.1143.

*2-Bromo-14-cyano-7-(furan-2-yl)-6H-benzo[4,5]thiazolo[3,2-a]-chromeno[4,3-d]pyridin-8-ium Tetrafluoroborate (**5s**).* Bright yellow solid, 49.3 mg (45% yield); R_f = 0.20 (9:1 DCE/MeOH);

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compound **5s** was purified by silica gel column chromatography using a gradient mixture of 0 → 5% MeOH in DCE as an eluent; **^{1}H NMR** (DMSO-d_6, 500 MHz) δ 8.75 (s, 1H), 8.66 (d, J = 8.0 Hz, 1H), 8.39 (s, 1H), 8.05−7.96 (m, 2H), 7.82 (apt, J = 7.0 Hz, 1H), 7.58−7.50 (m, 1H), 7.38 (d, J = 8.0 Hz, 1H), 7.20 (s, 1H), 6.24 (d, J = 9.5 Hz, 1H), 5.43 (s, 2H); **^{13}C{^{1}H} NMR** (DMSO-d_6, 126 MHz) δ 161.1, 156.9, 147.7, 141.0, 139.6, 138.0, 137.9, 134.9, 130.6, 129.6, 129.3, 129.1, 128.6, 125.4, 121.0, 120.0, 118.9, 118.2, 115.0, 114.1, 113.8, 102.1, 64.4; **HRMS** (ESI-TOF) calculated for $C_{23}H_{12}BrN_2O_2S$ [M-BF_4]$^+$: 458.9797 found 458.9761.

*14-Cyano-7-(thiophen-2-yl)-6H-benzo[4,5]thiazolo[3,2-a]-chromeno[4,3-d]pyridin-8-ium Tetrafluoroborate (**5t**).* Bright yellow solid, 56.2 mg (58% yield); R_f = 0.20 (9:1 DCE/MeOH); compound **5t** was purified by silica gel column chromatography using a gradient mixture of 0 → 5% MeOH in DCE as an eluent; **^{1}H NMR** (DMSO-d_6, 600 MHz) δ 8.64 (d, J = 8.4 Hz, 1H), 8.62 (d, J = 7.8 Hz, 1H), 8.37 (d, J = 5.4 Hz, 1H), 7.94 (apt, J = 7.84 Hz, 1H), 7.85 (apt, J = 7.8 Hz, 1H), 7.74 (d, J = 3.6 Hz, 1H), 7.69 (apt, J = 7.8 Hz, 1H), 7.63 (apt, J = 4.2 Hz, 1H), 7.52 (apt, J = 7.8 Hz, 1H), 7.36 (d, J = 7.8 Hz, 1H), 6.56 (d, J = 9.0 Hz, 1H), 5.18 (ABq, J = 14.4 Hz, 2H); **^{13}C{^{1}H} NMR** (DMSO-d_6, 151 MHz) δ 160.3, 157.9, 142.1, 141.2, 138.5, 137.6, 134.2, 133.4, 130.4, 129.6, 129.4, 128.9, 128.4, 127.6, 127.4, 125.4, 124.0, 119.2, 118.8, 116.9, 114.4, 100.5, 64.5; **HRMS** (ESI-TOF) calculated for $C_{23}H_{13}N_2OS_2$ [M-BF_4]$^+$: 397.0464 found 397.0463.

*14-Cyano-7-phenyl-6H-benzo[4,5]thiazolo[3,2-a]thiochromeno-[4,3-d]pyridin-8-ium Tetrafluoroborate (**5u**).* Bright yellow solid, 62.3 mg (63% yield); R_f = 0.20 (9:1 DCE/MeOH); compound **5u** was purified by silica gel column chromatography using a gradient mixture of 0 → 5% MeOH in DCE as an eluent; **^{1}H NMR** (DMSO-d_6, 500 MHz) δ 8.63 (d, J = 8.0 Hz, 1H), 8.57 (d, J = 6.5 Hz, 1H), 8.04−7.87 (m, 4H), 7.86−7.73 (m, 4H), 7.69 (apt, J = 7.0 Hz, 1H), 7.56 (apt, J = 8.0 Hz, 1H), 6.32 (d, J = 8.0 Hz, 1H), 3.94 (s, 2H); **^{13}C{^{1}H} NMR** (DMSO-d_6, 126 MHz) δ 159.5, 147.7, 147.1, 139.6, 138.7, 134.0, 132.6, 131.4, 130.8, 130.5, 130.3, 130.1, 129.6, 128.8, 128.7, 128.5, 128.2, 127.3, 125.4, 119.6, 114.6, 103.9, 27.9; **HRMS** (ESI-TOF) calculated for $C_{25}H_{15}N_2S_2$ [M-BF_4]$^+$: 407.0671 found 407.0667.

*7-(3-Chloro-4-fluorophenyl)-14-(ethoxycarbonyl)-6H-benzo[4,5]-thiazolo[3,2-a]chromeno[4,3-d]pyridin-8-ium Tetrafluoroborate (**5v**).* Pale yellow solid, 48.5 mg (42% yield); R_f = 0.25 (9:1 DCE/MeOH); compound **5v** was purified by silica gel column chromatography using a gradient mixture of 0 → 4% MeOH in DCE as an eluent; **^{1}H NMR** (DMSO-d_6, 500 MHz) δ 8.56 (d, J = 8.0 Hz, 1H), 8.08 (dd, J = 7.0, 2.5 Hz, 1H), 7.96 (apt, J = 9.5 Hz, 1H), 7.86 (apt, J = 8.0 Hz, 1H), 7.79−7.70 (m, 2H), 7.65−7.56 (m, 2H), 7.36 (apt, J = 8.0 Hz, 1H), 7.31 (d, J = 8.0 Hz, 1H), 6.64 (d, J = 9.0 Hz, 1H), 5.10 (ABq, J = 14.5 Hz, 2H), 4.58 (q, J = 8.0 Hz, 2H), 1.27 (t, J = 8.0 Hz, 3H); **^{13}C{^{1}H} NMR** (DMSO-d_6, 126 MHz) δ 164.7. 159.5 (d, J_{C-F} = 251.1 Hz), 157.6, 156.0, 143.3, 140.0, 137.7, 136.0, 131.4, 130.4, 129.9 (d, J_{C-F} = 6.6 Hz), 129.7, 128.8, 128.7, 128.5, 127.0 (d, J_{C-F} = 3.3 Hz), 124.9, 123.4, 122.2 (d, J = 18.3 Hz), 119.7, 119.6, 119.5 (d, J_{C-F} = 19.8 Hz), 118.5, 118.3, 64.7, 64.0, 13.4; **HRMS** (ESI-TOF) calculated for $C_{27}H_{18}ClFNO_3S$ [M-BF_4]$^+$: 490.0674 found 490.0666.

Compound **5w** was isolated along with **5w′** as an inseparable mixture (**5w**:**5w′** = 1.2:1); bright yellow solid, 75.3 mg (61% yield); R_f = 0.20 (9:1 DCE/MeOH); compounds **5w**/**5w′** was purified by silica gel column chromatography using a gradient mixture of 0 → 5% MeOH in DCE as an eluent; 14-cyano-7-phenyl-5-tosyl-5,6-dihydrobenzo[f]benzo[4,5]thiazolo[3,2-b][2,7]naphthyridin-8-ium tetrafluoroborate (**5w**): **^{1}H NMR** (DMSO-d_6, 500 MHz) δ 9.78−9.13 (m, 1H), 8.66 (d, J = 8.0 Hz, 1H), 8.39 (d, J = 8.0 Hz, 1H), 8.05 (d, J = 8.0 Hz, 2H), 7.91 (d, J = 8.0 Hz, 2H),, 7.85−7.76 (m, 2H), 7.63 (dd, J = 8.0 Hz, 3H), 7.19 (d, J = 8.0 Hz, 2H), 6.98 (d, J = 8.0 Hz, 2H), 6.54 (d, J = 9.0 Hz, 1H), 4.85 (s, 2H), 2.35 (s, 3H); **^{13}C{^{1}H} NMR** (DMSO-d_6, 126 MHz) δ 164.0, 159.0, 144.8, 142.7, 138.6, 135.5, 134.1, 133.0, 132.0, 130.3, 129.9, 129.6, 128,7, 128.5, 128.2, 127.9, 126.9, 126.6, 125.3, 124.3, 122.9, 122.1, 120.7, 119.5, 118.3, 115.0, 113.0, 101.0, 45.6, 20.6; **HRMS** (ESI-TOF) calculated for $C_{32}H_{22}N_3O_2S_2$ [M-BF_4]$^+$: 544.1148 found 544.1158.

*14-Cyano-7-phenylbenzo[f]benzo[4,5]thiazolo[3,2-b][2,7]-naphthyridine-5,8-diium Tetrafluoroborate (**5w′**).* **^{1}H NMR** (DMSO-d_6, 500 MHz) δ 9.28 (s, 1H), 8.32 (d, J = 6.5 Hz, 1H), 8.23 (d, J = 6.5 Hz, 2H), 8.01 (d, J = 6.5 Hz, 2H), 8.01−7.97 (m, 2H), 7.95 (d, J = 7.0 Hz, 2H), 7.88 (d, J = 8.0 Hz, 1H), 7.69 (apt, J = 8.0 Hz, 2H); **^{13}C{^{1}H} NMR** (DMSO-d_6, 126 MHz) δ 152.0, 151.8, 146.4, 143.4, 138.3, 135.5, 133.1, 130.6, 129.6, 128.7, 128.4, 127.0, 126.9, 126.6, 124.9, 122.9, 122.1, 122.7, 119.5, 118.3, 115.0, 113.1, 101.1; **HRMS** (ESI-TOF) calculated for $C_{27}H_{18}ClFNO_3S$ [M-BF_4]$^+$: $C_{25}H_{14}N_3S$ [M-BF_4]$^+$: 388.0903 found 388.0917.

*7-(3-Chloro-4-fluorophenyl)-14-cyano-6H-benzo[4,5]oxazolo-[3,2-a]chromeno[4,3-d]pyridin-8-ium Tetrafluoroborate (**5x**).* Bright yellow solid, 53.6 mg (52% yield); R_f = 0.25 (9:1 DCE/MeOH); compound **5x** was purified by silica gel column chromatography using a gradient mixture of 0 → 4% MeOH in DCE as an eluent; **^{1}H NMR** (DMSO-d_6, 500 MHz): (mixture of rotamers, 1:1) δ 8.52 (d, J = 8.0 Hz, 2H), 7.69 (d, J = 6.5 Hz, 1H), 7.65 (apt, J = 8.0 Hz, 2H), 7.53 (d, J = 6.5 Hz, 1H), 7.47−7.37 (m, 3H), 7.37−7.28 (m, 3H), 7.27−7.07 (m, 6H), 6.90−6.68 (m, 4H), 4.72−4.51 (m, 4H); **^{13}C{^{1}H} NMR** (DMSO-d_6, 126 MHz): (mixture of rotamers, 1:1) δ 160.1, 157.6 (d, J_{C-F} = 249.4 Hz), 157.4, 152.3, 152.2, 147.3, 147.2, 146.8, 134.8, 131.8, 130.5 (d, J_{C-F} = 8.3 Hz), 130.4, 130.3, 130.1, 130.0, 129.9, 128.9 (d, J_{C-F} = 8.3 Hz), 128.7, 127.2, 124.8, 124.7, 122.7, 119.4 (d, J_{C-F} = 16.3 Hz), 118.9, 118.8, 118.5, 118.3, 116.9, 116.8 (d, J_{C-F} = 16.6 Hz), 116.7, 116.6, 116.3, 116.1, 111.1, 95.9, 64.7; **HRMS** (ESI-TOF) calculated for $C_{25}H_{13}ClFN_2O_2$ [M-BF_4]$^+$: 427.0644 found 427.0642.

*12-Chloro-16-cyano-9-phenyl-8H-benzo[4,5]thiazolo[3,2-a]-benzo[5,6]chromeno[4,3-d]pyridin-10-ium Tetrafluoroborate (**5z**).* Bright yellow solid, 65.3 mg (58% yield); R_f = 0.20 (9:1 DCE/MeOH); compound **5z** was purified by silica gel column chromatography using a gradient mixture of 0 → 5% MeOH in DCE as an eluent; **^{1}H NMR** (DMSO-d_6, 600 MHz) δ8.63 (d, J = 8.4 Hz, 1H), 8.47 (d, J = 9.0 Hz, 1H), 8.30 (d, J = 8.4 Hz, 1H), 8.21 (d, J = 7.8 Hz, 1H), 8.05−7.98 (m, 3H), 7.96−7.88 (m, 3H), 7.75 (apt, J = 8.4 Hz, 2H), 7.54 (d, J = 9.0 Hz, 1H), 6.27 (d, J = 2.4 Hz, 1H), 5.20 (ABq, J = 13.8 Hz, 2H); **^{13}C{^{1}H} NMR** (151 MHz, DMSO-d_6) δ162.2, 160.5, 145.8, 142.4, 139.5, 138.8, 133.0, 132.8, 130.7, 130.6, 130.2, 130.1, 129.9, 129.5, 128.9, 128.8, 128.4, 128.3, 128.1, 127.4, 126.7, 125.5, 119.3, 117.6, 113.4, 112.6, 101.6, 65.2; **HRMS** (ESI-TOF) calculated for $C_{29}H_{16}ClN_2OS$ [M-BF_4]$^+$: 475.0666 found 475.0650.

■ ASSOCIATED CONTENT

Data Availability Statement

The data underlying this study are available in the published article and its Supporting Information.

Supporting Information

The Supporting Information is available free of charge at https://pubs.acs.org/doi/10.1021/acs.joc.3c01506.

Experimental procedures for all compounds and ^{1}H and ^{13}C{^{1}H} NMR spectra of all synthesized compounds (PDF)

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Notes

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