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N-Selenocyanato-Dibenzenesulfonimide: A New Electrophilic Selenocyanation Reagent

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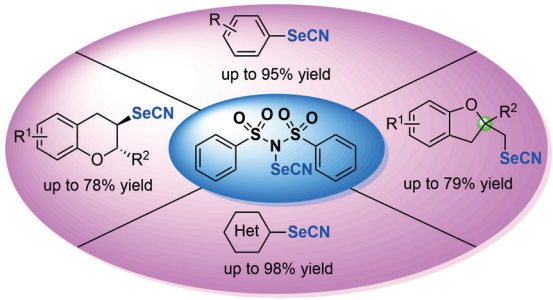

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Abstract A new electrophilic selenocyanation reagent *N*-selenocyanato-dibenzenesulfonimide was readily prepared in two steps from commercially available dibenzenesulfonimide for the first time. A variety of electrophilic selenocyanato reactions of nucleophiles have been achieved using it as selenocyanato source under mild and simple conditions. Numerous SeCN-containing compounds were obtained in moderate to excellent yields. Meanwhile, a Lewis acid mediated tandem selenocyanation/cyclization reaction of alkenes with phenols, which provided simple methods for the formation of various SeCN-containing chromanes and dihydrobenzofurans in moderate to good yields, has also been developed.

Key words *N*-selenocyanato-dibenzenesulfonimide, electrophilic selenocyanation, chromane, dihydrobenzofuran, organoselenium compound

Due to the introduction of selenium, the physical and chemical properties of the compounds will be greatly affected,[1] therefore organoselenium compounds[2] are widely found in biologically active natural products, functional materials, and drug molecules. Among them, SeCN-containing compounds can act as excellent functional molecules[3] not only like anticancer drugs towards colorectal cancer (CRC) cells,[4] but also important synthetic precursors for a series of valuable organic selenides,[5] such as selenides and diselenides through specific transformations. Therefore, in recent years, the introduction of selenocyanato group into compounds has attracted more and more attention.[6]

Electrophilic selenocyanation reaction is one of the direct and efficient methods for the construction of SeCN-containing compounds. Although the development of this type reaction was once limited to the lack of electrophilic selenocyanation reagent, some different electrophilic selenocyanation reagents have successively been developed and successfully applied to electrophilic selenocyanation reaction recently (Figure 1).[7] In 2019, Xiao and co-workers developed the benziodoxolone-based electrophilic selenocyanated hypervalent iodine reagent BI-SeCN (**1a**), which was the first electrophilic selenocyanation reagent.[7b] A variety of racemic α-selenocyanated ketones and β-keto esters were obtained under solvent-free condition in good to excellent yield with this reagent. In 2020, Chen's group reported *N*-selenocyanatosaccharin **1b**, achieving the first catalytic asymmetric selenocyanation reaction.[7c] Later, Xiao and co-workers developed another new reagent *N*-selenocyanatophthalimide (**1c**) and realized the synthesis of 3-selenocyanato-substituted chromones and quinolinone through grinding reaction without solvent.[7d] Our group has been committed to the efficient and convenient preparation of sulfur- and selenium-containing compounds, particularly catalytic asymmetric manner, with the development and application of new reagents.[8] For example, in 2019, we first reported the synthesis and application of *N*-thiocyanato-dibenzenesulfonimide, which showed high reactivity.[9a] Afterwards, Chen's group also reported this reagent and demonstrated the anticipated enhanced reactivity.[9b] Inspired by previous work and combined with our research interest, we report herein a new electrophilic selenocyanation reagent, *N*-selenocyanato-dibenzenesulfonimide (**1d**), and its reactivity (Figure 1).

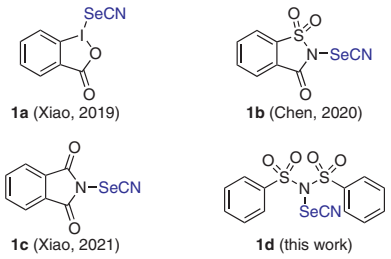

Figure 1 Electrophilic selenocyanation reagents

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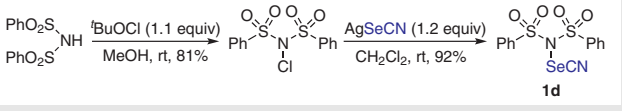
We envisioned that the preparation of *N*-selenocyanato-dibenzenesulfonimide may be achieved according to our previous synthetic strategy of *N*-thiocyanato-dibenzenesulfonimide.[9a] To our delight, *N*-selenocyanato-dibenzenesulfonimide (**1d**) was easily synthesized in two steps in 74% overall yield. *N*-Chloro-dibenzenesulfonimide, which was prepared first, reacted with AgSeCN (1.2 equiv) in CH_2Cl_2 to produce **1d** as a faint yellow solid in 92% yield (Scheme 1). Although it is not very sensitive to air and temperature, we suggest to store it under argon atmosphere and at low temperature. The configuration of **1d** was determined by X-ray crystallography (Figure 2).[10]



Scheme 1 Synthesis of *N*-selenocyanato-dibenzenesulfonimide

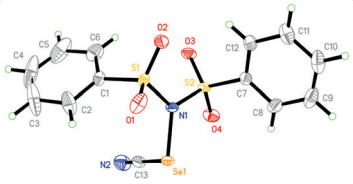


Figure 2 The configuration of **1d** determined by X-ray crystallography

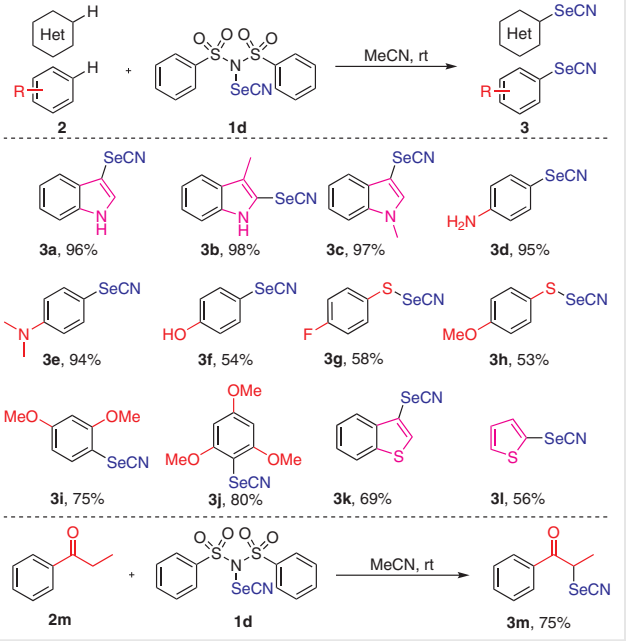
Using **1d** developed above, we first explored its reactivity with a variety of nucleophiles (Scheme 2). To our delight, without adding any catalyst or additive, the corresponding selenocyanated products of indole, aniline, phenol, thiophenol, and anisole derivatives were readily obtained in moderate to excellent yields under mild conditions, which showed the high reactivity of **1d**. The reaction of indole type compounds **3a–c** occurs in excellent yields, while the selenocyanation of aniline derivatives exclusively occurs at the *para*-position to the amino group in excellent yields (→ **3d**, **e**). Similarly, selenocyanated phenol **3f** was obtained in moderate yield with the *para*-substitution of hydroxyl group. It was worth noting that the *S*-substitution reaction took place at the sulfhydryl group in the case of thiophenols (→ **3g**, **h**). Moreover, anisole derivatives were exclusively mono-selenocyanated to **3i**, **j** in good yields, and the reaction of 1,3-dimethoxybenzene gave only 2,4-dimethoxy-1-selenocyanatobenzene (**3i**). In addition, we found that some of the substrates could not react with **1d** smoothly without any catalyst, so TfOH was chosen as the catalyst. Thus, benzothiophene (**2k**) and thiophene (**2l**) could produce the corresponding products **3k** and **3l** in 69% and 56% yield, respectively, in the presence of TfOH. Notably, the reaction of propiophenone produced the α-selenocyanated product **3m** in 75% yield.

Biographical Sketches

Deng Zhu (right) was born in 1997 in Zhejiang Province (P. R. of China). He received his bachelor's degree in Collaboration Innovation Center of Yangtze Delta Green Pharmaceuticals at Zhejiang University of Technology in 2019. Currently, he is carrying out his master's studies under the direction of associate Prof. Zhi-Min Chen at Shanghai Jiao Tong University.

Ai-Hui Ye (center) was born in Zhejiang Province (P. R. of China). She obtained her B.Sc. degree in chemistry from Guangxi Normal University in 2018. Now, she has started her Ph.D. in organic chemistry at the Shanghai Jiao Tong University under the guidance of associate Prof. Zhi-Min Chen. Her current interests focus on synthesis and applications of new electrophilic sulfur and selenium reagents.

Zhi-Min Chen (left) received his B.S. from Fuzhou University (P. R. of China) in 2009. He obtained his Ph.D. in organic chemistry in 2014 from Lanzhou University under the supervision of Prof. Yong-Qiang Tu. After spending three years (2014–2017) as a postdoctoral fellow at Shanghai Jiao Tong University (Mentor: Prof. Yong-Qiang Tu) and University of Utah (USA; 2015–2017, Mentor: Prof. Matthew S. Sigman), he was appointed as associate professor at Shanghai Jiao Tong University in 2017. His research focuses mainly on asymmetric sulfur/selenium chemistry and synthesis of natural products.

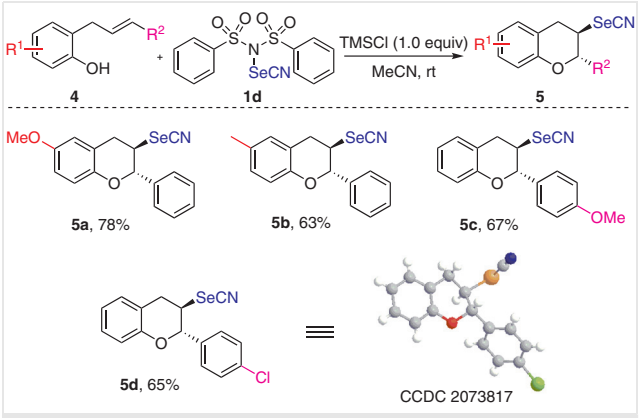


Scheme 2 Substrate scope of different kinds of nucleophiles. *Reagents and conditions*: Nucleophile **2** (0.1 mmol) and **1d** (0.13 mmol) in MeCN (1 mL) were stirred at rt for 20–30 min under argon. Isolated yields are shown. **3k**,**l**,**m**: TfOH (0.01 mmol) was added as the catalyst. **3l**: From thiophene (**2l**; 0.15 mmol) and **1d** (0.1 mmol).

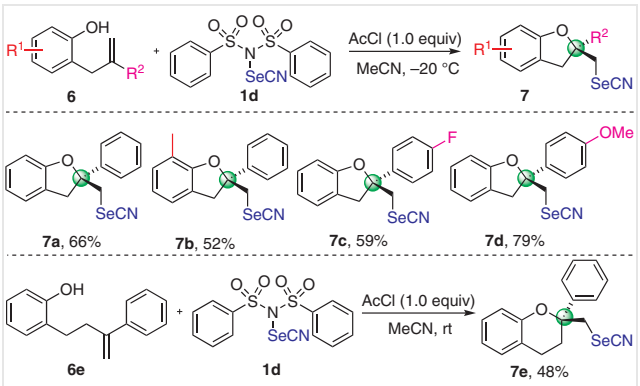
After preliminarily investigating the reactivity between **1d** and various nucleophiles, we wondered whether difunctionalization of olefins including selenocyanation could occur with reagent **1d**. Considering that compounds with chromane and dihydrobenzofuran frameworks are widely present in biologically active molecules, and combined with our previous research,[8e] we envisioned that the intramolecular tandem selenocyanation/cyclization reaction between 2-allylphenols and **1d** may be achieved.

To examine our hypothesis, γ-substituted 2-allylphenol **4a** as the model substrate was reacted first with **1d** in the presence of trimethylchlorosilane as the acid activator in acetonitrile at room temperature. To our delight, the desired product **5a** was readily obtained in 78% yield. Although some other reaction conditions were investigated, no better result was obtained. With the above conditions in hand, three other γ-substituted 2-allylphenols were also investigated. In general, the desired selenocyanated chroman skeleton compounds were obtained in moderate to good yields (Scheme 3). In some cases **5b**,**d**, acetyl chloride was used as the acid activator. Meanwhile, we found that the substrate with electron-rich substituent at phenyl group could give a higher yield (**5a** vs **5b**). The relative configuration of **5d** was determined by X-ray crystallography.[11]

Subsequently, in order to further broaden the application range of **1d**, several β-substituted 2-allylphenols were also chosen as the substrates, which could facilely synthesize diverse SeCN-containing dihydrobenzofurans and construct oxa-quaternary stereocenters. After screening some reaction conditions, we found that the desired product **7a** was delivered in 66% yield using acetyl chloride as the acid promotor when β-substituted 2-allylphenol **6a** was used as the model substrate. Similarly, some different β-substituted 2-allylphenols were tested for the examination of the applicability of this reaction. Generally, the desired products were obtained in moderate to good yields (Scheme 4). It was found that the *ortho*-substituted phenol **7b** and the alkene with the electron-deficient phenyl group **7c** decreased the yield. Compared with **6a**, substrate **6d** with electron-rich alkene gave a higher yield (79%) using trimethylchlorosilane instead of acetyl chloride as the acid



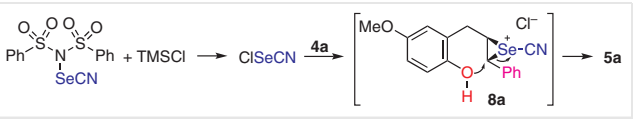
Scheme 3 Substrate scope of γ-substituted 2-allylphenols. *Reagents and conditions*: γ-substituted 2-allylphenol **4** (0.1 mmol), **1d** (0.13 mmol), and TMSCl (0.1 mmol) in MeCN (1 mL) were stirred at rt for 2–12 h under argon. Isolated yields are shown. **5b**,**d**: AcCl was used instead of TMSCl.



Scheme 4 Substrate scope of β-substituted 2-allylphenols and γ-substituted 2-homoallylphenol. *Reagents and conditions*: β-substituted 2-allylphenol (γ-substituted 2-homoallylphenol) **6** (0.1 mmol), **1d** (0.13 mmol), and AcCl (0.1 mmol) in MeCN (1 mL) were stirred at –20 °C for 2–12 h under argon. Isolated yields are shown. **7d**: TMSCl was used instead of AcCl.

promotor. Finally, γ-substituted 2-homoallylphenol **6e** was also subjected to this reaction and the corresponding chroman product **7e** was obtained, albeit in only 48% yield.

Based on our previous work[8e] and the above results, a possible mechanism for intramolecular selenocyanation of 2-allylphenol is proposed in Scheme 5. TMSCl may directly activate **1d** to form the more active ClSeCN, which then undergoes the electrophilic addition to alkene, forming CN-containing selenonium ion intermediate **8a**. This is subsequently attacked by phenolic hydroxyl group and the product **5a** would be obtained after deprotonation, accompanied by the formation of dibenzenesulfonimide. The excellent diastereoselectivity of this reaction could result from the collaborative process. For 1,1-disubstituted alkene substrates, the regioselectivity may be attributed to distinct electronic bias for selenonium ion opening.



Scheme 5 Proposed mechanism

In summary, we have developed a convenient and efficient method for the synthesis of a new electrophilic selenocyanation reagent, *N*-selenocyanato-dibenzenesulfonimide (**1d**), which showed good reactivity with various nucleophiles. Furthermore, a Lewis acid mediated tandem selenocyanation/cyclization reaction of alkenes with phenols was explored for the first time. Various SeCN-containing chromanes and dihydrobenzofurans were readily synthesized in moderate to good yields. Further exploration of the applications of reagent **1d** are underway in our lab.

Unless otherwise noted, all reactions were carried out under an atmosphere of argon. All chemicals were purchased from commercial suppliers and used without further purification. In addition to commercially available extra anhydrous solvents, all solvents were purified by standard operating method. TLC was performed with EMD silica gel 60 F_{254} plates eluting with solvents indicated; visualized by a 254 nm UV lamp and stained with phosphomolybdic acid (PMA). ^{1}H NMR, ^{13}C NMR, and ^{19}F NMR spectra were obtained on a Bruker AM-400 spectrometer. Chemical shifts (δ) were quoted in ppm relative to deuterated solvent as internal standard ($CDCl_3$: 7.26 ppm for ^{1}H NMR; $CDCl_3$: 77.16 ppm for ^{13}C NMR), multiplicities are indicated by standard abbreviations. High-resolution mass spectral analysis (HRMS) data were measured on a Bruker impact II(Q-TOF) mass spectrometer by means of the ESI technique and a Fourier Transform Ion Cyclotron (SolariX 7.0T). Crystallographic data was obtained from a Bruker D8 VENTURE diffractometer. Melting points were measured on a melting point apparatus and are uncorrected. Substrates **2** were purchased from commercial suppliers while substrates **4** and **6** were prepared according to previously reported procedures.[8e]

N-Selenocyanato-Benzenesulfonamide (1d)

Under dark, water-free, and oxygen-free conditions, to a stirred solution of *N*-chloro-dibenzenesulfonimide (500 mg, 1.5 mmol) in CH_2Cl_2 (15 mL) was added silver selenocyanate (383 mg, 1.8 mmol, 1.2 equiv) under an argon atmosphere. The flask was covered with thin foil and stirred at rt for 3.5 h. After completion of the reaction, the undissolved solids were filtered off and the residue was concentrated under vacuum to give **1d** as a faint yellow solid; yield: 553 mg (1.38 mmol, 92%); mp 150–153 °C.

^{1}H NMR (CD_2Cl_2, 400 MHz): δ = 7.99 (d, *J* = 7.5 Hz, 4 H), 7.74 (t, *J* = 7.4 Hz, 2 H), 7.61 (t, *J* = 7.9 Hz, 4 H).

^{13}C NMR (CD_2Cl_2, 101 MHz): δ = 135.2, 129.8, 128.9, 102.4.

HRMS (APCI): *m*/*z* [M + H]$^+$ calcd for $C_{13}H_{11}N_2O_4S_2Se$: 402.9325; found: 402.9319.

Selenocyanation; General Procedure

At rt, **2** (0.10 mmol) and **1d** (52.1 mg, 0.13 mmol) were added to an over-dried 10 mL flask equipped with a stir bar. The flask was then sealed with a septum. Anhyd MeCN (1 mL) was added via a syringe, and the solution was stirred for about 20 min. After the completion of the reaction (monitored by TLC), the solvent was removed under reduced pressure, and the crude product was purified by silica gel flash column chromatography.

3-Selenocyanato-1*H*-indole (3a)

Orange solid; R_f = 0.20 (silica gel, PE:EtOAc 5:1, v/v); yield: 21.2 mg (0.096 mmol, 96%); mp 80–82 °C.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 8.74 (s, 1 H), 7.76–7.74 (m, 1 H), 7.48–7.40 (m, 2 H), 7.33–7.29 (m, 2 H).

^{13}C NMR ($CDCl_3$, 101 MHz): δ = 136.1, 132.0, 128.8, 123.9, 121.9, 119.6, 112.0, 102.2, 89.5.

HRMS (ESI): *m*/*z* [M + Na]$^+$ calcd for $C_9H_6N_2SeNa$: 244.9588; found: 244.9589.

3-Methyl-2-selenocyanato-1*H*-indole (3b)

Orange solid; R_f = 0.35 (silica gel, PE:EtOAc 8:1, v/v); yield: 23.0 mg (0.098 mmol, 98%); mp 87–88 °C.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 8.31 (s, 1 H), 7.59 (d, *J* = 8.0 Hz, 1 H), 7.35 (d, *J* = 8.2 Hz, 1 H), 7.30 (t, *J* = 7.6 Hz, 1 H), 7.18 (t, *J* = 7.5 Hz, 1 H), 2.46 (s, 3 H).

^{13}C NMR ($CDCl_3$, 101 MHz): δ = 138.2, 127.7, 124.9, 122.5, 120.4, 119.9, 111.3, 107.8, 100.1, 10.5.

HRMS (ESI): *m*/*z* [M + Na]$^+$ calcd for $C_{10}H_8N_2SeNa$: 258.9745; found: 258.9744.

1-Methyl-3-selenocyanato-1*H*-indole (3c)

Yellow solid; R_f = 0.40 (silica gel, PE:EtOAc 5:1, v/v); yield: 22.7 mg (0.097 mmol, 97%); mp 80–82 °C.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.75 (d, *J* = 7.3 Hz, 1 H), 7.39–7.29 (m, 4 H), 3.81 (s, 3 H).

^{13}C NMR ($CDCl_3$, 101 MHz): δ = 137.3, 136.0, 129.6, 123.4, 121.6, 119.9, 110.1, 101.9, 87.3, 33.4.

HRMS (ESI): *m*/*z* [M + Na]$^+$ calcd for $C_{10}H_8N_2SeNa$: 258.9745; found: 258.9745.

4-Selenocyanatoaniline (3d)

Yellow solid; R_f = 0.30 (silica gel, PE:EtOAc 2:1, v/v); yield: 18.8 mg (0.095 mmol, 95%); mp 73–74 °C.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.44 (d, *J* = 8.4 Hz, 2 H), 6.64 (d, *J* = 8.4 Hz, 2 H), 3.95 (s, 2 H).

^{13}C NMR ($CDCl_3$, 101 MHz): δ = 148.9, 136.6, 116.4, 107.3, 102.8.

HRMS (ESI): *m*/*z* [M + Na]$^+$ calcd for $C_7H_6N_2SNae$: 220.9588; found: 220.9589.

***N*,*N*-Dimethyl-4-selenocyanatoaniline (3e)**

Yellow solid; R_f = 0.30 (silica gel, PE:EtOAc 8:1, v/v); yield: 21.3 mg (0.094 mmol, 94%); mp 97–98 °C.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.51 (d, *J* = 8.9 Hz, 2 H), 6.65 (d, *J* = 9.0 Hz, 2 H), 2.99 (s, 6 H).

^{13}C NMR ($CDCl_3$, 101 MHz): δ = 151.8, 136.5, 113.4, 104.5, 102.9, 40.2.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_9H_{11}N_2Se$: 227.0082; found: 227.0079.

4-Selenocyanatophenol (3f)

Yellow solid; R_f = 0.35 (silica gel, PE:EtOAc 2:1, v/v); yield: 10.7 mg (0.054 mmol, 54%); mp 75–77 °C.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.55 (d, *J* = 8.7 Hz, 2 H), 6.86 (d, *J* = 8.7 Hz, 2 H), 5.67 (s, 1 H).

^{13}C NMR ($CDCl_3$, 101 MHz): δ = 158.0, 136.5, 117.7, 111.0, 102.6.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for C_7H_6NOSe: 199.9609; found: 199.9611.

***SeS*-(4-Fluorophenyl) (Selenothioperoxocyanate) (3g)**

Yellow oil; R_f = 0.50 (silica gel, pure PE); yield: 13.3 mg (0.058 mmol, 58%).

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.57–7.47 (m, 2 H), 7.05–6.91 (m, 2 H).

^{13}C NMR ($CDCl_3$, 101 MHz): δ = 163.3 (d, $J_{C,F}$ = 249.6 Hz), 134.5, 134.4 (d, $J_{C,F}$ = 8.4 Hz), 132.1 (d, $J_{C,F}$ = 3.4 Hz), 116.4 (d, $J_{C,F}$ = 22.0 Hz).

^{19}F NMR ($CDCl_3$, 376 MHz): δ = –112.26 (s, 1 F).

HRMS (MALDI): *m*/*z* [M]$^+$ calcd for C_7H_4FNSSe: 232.9214; found: 232.9208.

***SeS*-(4-Methoxyphenyl) (Selenothioperoxocyanate) (3h)**

Yellow solid; R_f = 0.50 (silica gel, PE:EtOAc 10:1, v/v); yield: 12.8 mg (0.053 mmol, 53%); mp 64–65 °C.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.40 (d, *J* = 8.7 Hz, 2 H), 6.83 (d, *J* = 8.7 Hz, 2 H), 3.80 (s, 3 H).

^{13}C NMR ($CDCl_3$, 101 MHz): δ = 160.1, 134.6, 132.8, 128.6, 114.8, 55.5.

HRMS (APCI): *m*/*z* [M + H]$^+$ calcd for C_8H_8NOSSe: 245.9492; found: 245.9486.

2,4-Dimethoxy-1-selenocyanatobenzene (3i)

Colorless oil; R_f = 0.35 (silica gel, PE:EtOAc 10:1, v/v); yield: 17.9 mg (0.075 mmol, 75%).

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.52 (d, *J* = 8.6 Hz, 1 H), 6.55 (dd, *J* = 8.7, 2.5 Hz, 1 H), 6.49 (d, *J* = 2.5 Hz, 1 H), 3.88 (s, 3 H), 3.82 (s, 3 H).

^{13}C NMR ($CDCl_3$, 101 MHz): δ = 162.6, 158.0, 133.1, 106.9, 101.9, 101.9, 99.5, 56.3, 55.8.

HRMS (ESI): *m*/*z* [M + Na]$^+$ calcd for $C_9H_9NO_2SeNa$: 265.9691; found: 265.9694.

1,3,5-Trimethoxy-2-selenocyanatobenzene (3j)

White solid; R_f = 0.30 (silica gel, PE:EtOAc 5:1, v/v); yield: 21.3 mg (0.080 mmol, 80%); mp 97–99 °C.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 6.17 (s, 2 H), 3.90 (s, 6 H), 3.84 (s, 3 H).

^{13}C NMR ($CDCl_3$, 101 MHz): δ = 164.3, 160.9, 102.1, 91.5, 89.9, 56.5, 55.7.

HRMS (ESI): *m*/*z* [M + Na]$^+$ calcd for $C_{10}H_{11}NO_3SeNa$: 295.9796; found: 295.9796.

3-Selenocyanatobenzo[*b*]thiophene (3k)

White solid; R_f = 0.45 (silica gel, PE:EtOAc 10:1, v/v); yield: 16.4 mg (0.069 mmol, 69%); mp 120–122 °C.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.98 (d, *J* = 8.0 Hz, 1 H), 7.92 (d, *J* = 6.5 Hz, 2 H), 7.56 (t, *J* = 7.5 Hz, 1 H), 7.48 (t, *J* = 7.6 Hz, 1 H).

^{13}C NMR ($CDCl_3$, 101 MHz): δ = 139.6, 138.6, 135.3, 125.8, 125.8, 123.4, 123.1, 109.2, 100.1.

HRMS (APCI): *m*/*z* [M]$^+$ calcd for C_9H_5NSSe: 238.9308; found: 238.9302.

2-Selenocyanatothiophene (3l)

Colorless oil; R_f = 0.50 (silica gel, PE:EtOAc 5:1, v/v); yield: 10.3 mg (0.056 mmol, 56%).

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.60 (dd, *J* = 5.4, 1.2 Hz, 1 H), 7.47 (dd, *J* = 3.7, 1.2 Hz, 1 H), 7.09 (dd, *J* = 5.4, 3.7 Hz, 1 H).

^{13}C NMR ($CDCl_3$, 101 MHz): δ = 139.1, 134.6, 128.8, 112.6, 101.0.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for C_5H_4NSSe: 189.9224; found: 189.9225.

1-Phenyl-2-selenocyanatopropan-1-one (3m)

White solid; R_f = 0.50 (silica gel, PE:EtOAc 6:1, v/v); yield: 17.6 mg (0.075 mmol, 75%); mp 74–76 °C.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.92 (d, *J* = 7.4 Hz, 2 H), 7.67 (t, *J* = 7.5 Hz, 1 H), 7.53 (t, *J* = 7.7 Hz, 2 H), 5.40 (q, *J* = 7.3 Hz, 1 H), 2.05 (d, *J* = 7.3 Hz, 3 H).

^{13}C NMR ($CDCl_3$, 101 MHz): δ = 197.2, 134.8, 132.9, 129.3, 129.1, 102.8, 49.2, 21.5.

HRMS (ESI): *m*/*z* [M + Na]$^+$ calcd for $C_{10}H_9NOSeNa$: 261.9742; found: 261.9743.

3-Selenocyanatochromanes 5; General Procedure

At rt, **4** (0.10 mmol), **1d** (52.1 mg, 0.13 mmol), and Me_3SiCl (13.0 μL, 0.10 mmol) were added to an over-dried 10 mL flask equipped with a stir bar. The flask was then sealed with a septum. Anhyd MeCN (1 mL) was added via a syringe, and the solution was stirred for 2 h to 12 h. After completion of the reaction (monitored by TLC), the solvent was removed under reduced pressure, and the crude product was purified by silica gel flash column chromatography.

6-Methoxy-2-phenyl-3-selenocyanatochromane (5a)

Colorless oil; R_f = 0.50 (silica gel, PE:EtOAc 5:1, v/v); yield: 26.6 mg (0.078 mmol, 78%).

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.46–7.36 (m, 5 H), 6.87 (d, *J* = 8.9 Hz, 1 H), 6.78 (dd, *J* = 8.9, 3.0 Hz, 1 H), 6.62 (d, *J* = 2.9 Hz, 1 H), 5.13 (d, *J* = 8.2 Hz, 1 H), 4.13 (td, *J* = 8.3, 6.5 Hz, 1 H), 3.77 (s, 3 H), 3.37 (d, *J* = 7.0 Hz, 2 H).

^{13}C NMR ($CDCl_3$, 101 MHz): δ = 154.4, 147.7, 138.0, 129.5, 129.2, 126.8, 120.2, 117.9, 114.9, 113.4, 100.5, 80.3, 55.8, 44.7, 33.5.

HRMS (ESI): *m*/*z* [M + Na]$^+$ calcd for $C_{17}H_{15}NO_2SeNa$: 368.0160; found: 368.0157.

6-Methyl-2-phenyl-3-selenocyanatochromane (5b)

Yellow oil; R_f = 0.60 (silica gel, PE:EtOAc 10:1, v/v); yield: 20.6 mg (0.063 mmol, 63%).

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.43–7.38 (m, 5 H), 7.08 (d, *J* = 7.2 Hz, 1 H), 6.94 (d, *J* = 7.5 Hz, 1 H), 6.87 (t, *J* = 7.4 Hz, 1 H), 5.24 (d, *J* = 7.9 Hz, 1 H), 4.12 (td, *J* = 8.0, 5.9 Hz, 1 H), 3.47–3.19 (m, 2 H), 2.22 (s, 3 H).

^{13}C NMR ($CDCl_3$, 101 MHz): δ = 151.8, 138.4, 129.8, 129.4, 129.1, 126.9, 126.6, 126.4, 121.2, 119.0, 100.6, 80.3, 45.0, 33.1, 16.1.

HRMS (ESI): *m*/*z* [M + Na]$^+$ calcd for $C_{17}H_{15}NOSeNa$: 352.0211; found: 352.0206.

2-(4-Methoxyphenyl)-3-selenocyanatochromane (5c)

Colorless oil; R_f = 0.65 (silica gel, PE:EtOAc 5:1, v/v); yield: 22.6 mg (0.067 mmol, 67%).

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.34 (d, *J* = 8.4 Hz, 2 H), 7.19 (t, *J* = 7.8 Hz, 1 H), 7.11 (d, *J* = 7.6 Hz, 1 H), 6.99–6.90 (m, 4 H), 5.09 (d, *J* = 8.8 Hz, 1 H), 4.11 (td, *J* = 8.8, 6.4 Hz, 1 H), 3.83 (s, 3 H), 3.47–3.40 (m, 2 H).

^{13}C NMR ($CDCl_3$, 101 MHz): δ = 160.6, 154.0, 129.8, 129.3, 128.5, 128.3, 121.7, 119.85, 117.1, 114.5, 100.4, 80.2, 55.5, 44.7, 33.8.

HRMS (ESI): *m*/*z* [M + Na]$^+$ calcd for $C_{17}H_{15}NO_2SeNa$: 368.0160; found: 368.0161.

2-(4-Chlorophenyl)-3-selenocyanatochromane (5d)

White solid; R_f = 0.55 (silica gel, PE:EtOAc 5:1, v/v); yield: 22.4 mg (0.065 mmol, 65%); mp 143–145 °C.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.40 (d, *J* = 8.5 Hz, 2 H), 7.35 (d, *J* = 8.4 Hz, 2 H), 7.25–7.16 (m, 1 H), 7.10 (d, *J* = 7.6 Hz, 1 H), 6.98 (t, *J* = 7.5 Hz, 1 H), 6.92 (d, *J* = 8.3 Hz, 1 H), 5.17 (d, *J* = 8.3 Hz, 1 H), 4.02 (td, *J* = 8.2, 6.5 Hz, 1 H), 3.39 (d, *J* = 7.3 Hz, 2 H).

^{13}C NMR ($CDCl_3$, 101 MHz): δ = 153.6, 136.5, 135.4, 129.4, 129.3, 128.7, 128.3, 122.0, 119.6, 117.1, 100.0, 79.9, 44.4, 33.1.

HRMS (ESI): *m*/*z* [M + Na]$^+$ calcd for $C_{16}H_{12}ClNOSeNa$: 371.9665; found: 371.9662.

2,3-Dihydrobenzofurans 7; General Procedure

At –20 °C, **6** (0.10 mmol), **1d** (52.1 mg, 0.13 mmol), and AcCl (4.0 μL, 0.10 mmol) were added to an over-dried 10 mL flask equipped with a stir bar. The flask was the sealed with a septum. Anhyd MeCN (1 mL) was added via a syringe, and the solution was stirred for 2 h to 12 h. After completion of the reaction (monitored by TLC), the solvent was removed under reduced pressure, and the crude product was purified by silica gel flash column chromatography.

2-Phenyl-2-(selenocyanatomethyl)-2,3-dihydrobenzofuran (7a)

Colorless oil; R_f = 0.45 (silica gel, PE:EtOAc 5:1, v/v); yield: 20.6 mg (0.066 mmol, 66%).

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.48–7.46 (m, 2 H), 7.41 (t, *J* = 7.5 Hz, 2 H), 7.36–7.32 (m, 1 H), 7.23–7.14 (m, 2 H), 6.97–6.89 (m, 2 H), 3.76–3.68 (m, 3 H), 3.58 (d, *J* = 15.8 Hz, 1 H).

^{13}C NMR ($CDCl_3$, 101 MHz): δ = 158.0, 142.6, 129.0, 128.8, 128.4, 125.4, 125.2, 125.0, 121.7, 110.1, 102.0, 89.2, 43.0, 41.3.

HRMS (ESI): *m*/*z* [M + Na]$^+$ calcd for $C_{16}H_{13}NOSeNa$: 338.0055; found: 338.0050.

7-Methyl-2-phenyl-2-(selenocyanatomethyl)-2,3-dihydrobenzofuran (7b)

Colorless oil; R_f =0.50 (silica gel, PE:EtOAc 5:1, v/v); yield: 16.8 mg (0.052 mmol, 52%).

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.47 (d, *J* = 7.7 Hz, 2 H), 7.41 (t, *J* = 7.5 Hz, 2 H), 7.34 (t, *J* = 7.2 Hz, 1 H), 7.04–6.96 (m, 2 H), 6.82 (t, *J* = 7.4 Hz, 1 H), 3.78–3.66 (m, 3 H), 3.58 (d, *J* = 15.7 Hz, 1 H), 2.35 (s, 3 H).

^{13}C NMR ($CDCl_3$, 101 MHz): δ = 156.4, 142.9, 130.0, 128.9, 128.4, 125.0, 124.6, 122.4, 121.6, 120.4, 102.1, 88.7, 43.4, 41.5, 15.4.

HRMS (ESI): *m*/*z* [M + Na]$^+$ calcd for $C_{17}H_{15}NOSeNa$: 352.0211; found: 352.0209.

2-(4-Fluorophenyl)-2-(selenocyanatomethyl)-2,3-dihydrobenzofuran (7c)

Colorless oil; R_f = 0.45 (silica gel, PE:EtOAc 5:1, v/v); yield: 19.2 mg (0.059 mmol, 59%).

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.45 (dd, *J* = 8.7, 5.2 Hz, 2 H), 7.23–7.14 (m, 2 H), 7.09 (t, *J* = 8.6 Hz, 2 H), 6.97–6.88 (m, 2 H), 3.76–3.63 (m, 3 H), 3.55 (d, *J* = 15.8 Hz, 1 H).

^{13}C NMR ($CDCl_3$, 101 MHz): δ = 162.6 (d, $J_{C,F}$ = 247.8 Hz), 157.9, 138.4 (d, $J_{C,F}$ = 3.2 Hz), 128.9, 127.0 (d, $J_{C,F}$ = 8.3 Hz), 125.2, 125.1, 121.9, 115.9 (d, $J_{C,F}$ = 21.8 Hz), 110.1, 101.8, 88.9, 43.1, 41.3.

^{19}F NMR ($CDCl_3$, 376 MHz): δ = –113.55 (s, 1 F).

HRMS (ESI): *m*/*z* [M + Na]$^+$ calcd for $C_{16}H_{12}FNOSeNa$: 355.9960; found: 355.9955.

2-(4-Methoxyphenyl)-2-(selenocyanatomethyl)-2,3-dihydrobenzofuran (7d)

Colorless oil; R_f = 0.45 (silica gel, PE:EtOAc 5:1, v/v); yield: 26.8 mg (0.079 mmol, 79%).

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.41–7.34 (m, 2 H), 7.21–7.11 (m, 2 H), 6.94–6.89 (m, 4 H), 3.81 (s, 3 H), 3.75–3.65 (m, 3 H), 3.55 (d, *J* = 15.7 Hz, 1 H).

^{13}C NMR ($CDCl_3$, 101 MHz): δ = 159.6, 158.0, 134.5, 128.8, 126.3, 125.5, 125.2, 121.6, 114.3, 110.0, 102.2, 89.1, 55.4, 42.9, 41.5.

HRMS (ESI): *m*/*z* [M + Na]$^+$ calcd for $C_{17}H_{15}NO_2SeNa$: 368.0160; found: 368.0162.

2-Phenyl-2-(selenocyanatomethyl)chromane (7e)

Colorless oil; R_f = 0.50 (silica gel, PE:EtOAc 5:1, v/v); yield: 15.8 mg (0.048 mmol, 48%).

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.35–7.26 (m, 5 H), 7.16 (ddd, *J* = 8.8, 7.2, 1.8 Hz, 1 H), 7.01 (dd, *J* = 8.3, 1.2 Hz, 1 H), 6.95 (dd, *J* = 7.6, 1.7 Hz, 1 H), 6.85 (td, *J* = 7.4, 1.2 Hz, 1 H), 3.63 (d, *J* = 1.7 Hz, 2 H), 2.73–2.65 (m, 1 H), 2.51–2.39 (m, 3 H).

^{13}C NMR ($CDCl_3$, 101 MHz): δ = 153.0, 140.9, 129.5, 129.1, 128.3, 127.9, 125.5, 121.3, 121.2, 117.0, 102.6, 79.2, 42.4, 30.4, 22.3.

HRMS (ESI): *m*/*z* [M + Na]$^+$ calcd for $C_{17}H_{15}NOSeNa$: 352.0211; found: 352.0213.

Conflict of Interest

The authors declare no conflict of interest.

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Supporting Information

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(11) CCDC 2073817 (**5d**) contains the supplementary crystallographic data for this paper. The data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/structures