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Transition-Metal-Free HFIP-Mediated Organo Chalcogenylation of Arenes/Indoles with Thio-/Selenocyanates

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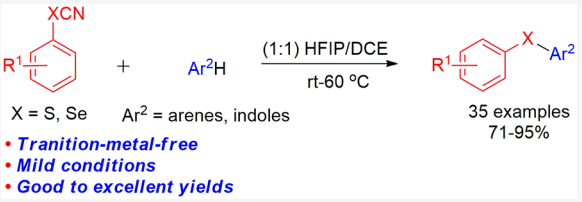
ABSTRACT: We have developed a protocol for the synthesis of diaryl thio-/selenoethers by the reaction of aryl chalcogenocyanates with electron rich arenes/hetero arenes *via* HFIP promoted C−H activation. The reaction produces chalcogenides in good to excellent yields under mild conditions without the need of a transition metal as a catalyst. The HFIP-mediated reactions tolerated a wide range of functional groups and set the stage for the synthesis of diversely decorated chalcogenides. A mechanism involving activation of the C−H bond through hydrogen bonding is proposed.



INTRODUCTION

Aryl(heteroaryl) chalcogenides have drawn tremendous attention due to their numerous applications in natural products, pharmaceuticals, and bioactive molecules.[1] Such classes of compounds and their analogues have been mainly utilized as pharmaceutical ingredients for antioxidant, anti-inflammatory, anti-infection, and analgesic activities.[2] Unlike organosulfur compounds, initially, selenium compounds were considered to be toxic; however, the importance of such compounds was later recognized after finding the selenium proteins and enzymes such as glutathione peroxidases (GPx) and thioredoxin reductases (TR).[2b] Moreover, C3 selenoether-linked indoles display unique biological properties as shown in Figure 1.[2c] As chalcogen substituted organic compounds are potential intermediates for many pharmacologically important substances, the establishment of an efficient synthesis of these compounds appears to be of great importance. In this context, it is important to mention that, among many known protocols for the construction of carbon−X (X = O, S, Se) bonds, the metal-free carbon−hydrogen bond functionalization is the most desirable approach.[3]

The conventional preparation of diaryl sulfides involves a coupling reaction of various sulfenylating agents such as sulfonium salts,[4] sulfonyl hydrazides,[5] disulfides,[6] *N*-thiophthalimides,[7] sulfenyl halides,[8] thiols,[9] and arylsulfonyl chlorides[10] with phenols/indoles. Analogously, the diaryl selenides can be obtained by the use of selenolate anions,[11] selenite,[12] phenyl tributylstannyl selenide,[13] or selenium[14] as one of the coupling partners. At the same time, transition-metal-catalyzed cross-coupling is one of the traditional strategies for the synthesis of chalcogenides.[15] However, the aforementioned transition-metal-catalyzed synthetic protocols suffer from several drawbacks, such as the reactions require expensive and sometimes toxic transition metals, raising issues of metal contamination and formation of disulfides as a byproduct due to strong coordination of the lone pair of electrons on sulfur with the transition metal. In this context, we would like to highlight our previous publications where arylpyridinyl chalcogenides were constructed *via* the ruthenium(II)-catalyzed [2+2+2] cycloaddition reaction of 1,6-diynes with (hetero)aryl chalcogenated cyanates under mild reaction conditions (Scheme 1 (a)).[16]

In order to combat the problem associated with metal-mediated reactions, metal-free C−H functionalization strategies are gaining attention. Particularly, carbon−chalcogen bond formations through metal-free strategies emerged as attractive alternative strategies to the traditional transition-metal-catalyzed cross-coupling reactions.[17] In this connection, Townsend's group[18] and Braga's group[19] independently documented the metal-free methodologies to access diaryl chalcogenides. Townsend *et al.* established an umpolung approach to achieve aryl selenides in which aryl selenocyanates were treated with electrophiles in the presence of $NaBH_4$ (Scheme 1 (b)),[18] while Braga *et al.* used KIO_3[19a,b] and iodine[19c] as catalysts to react the dichalcogenides with various nucleophiles. Miyake *et al.* developed visible-light-promoted cross-coupling reaction between thiols and aryl halides for the construction of C−S bonds in the absence of metal (Scheme 1 (c)).[20] In 2019, Radosevich *et al.* delineated the organophosphorus-catalyzed deoxygenative protocol for sulfenylation of indoles from arylsulfonyl chlorides (Scheme 1 (d)).[3a] In the same year, Kumar and group developed a visible-light-induced strategy for the organo chalcogenylation (S, Se, Te) of indoles

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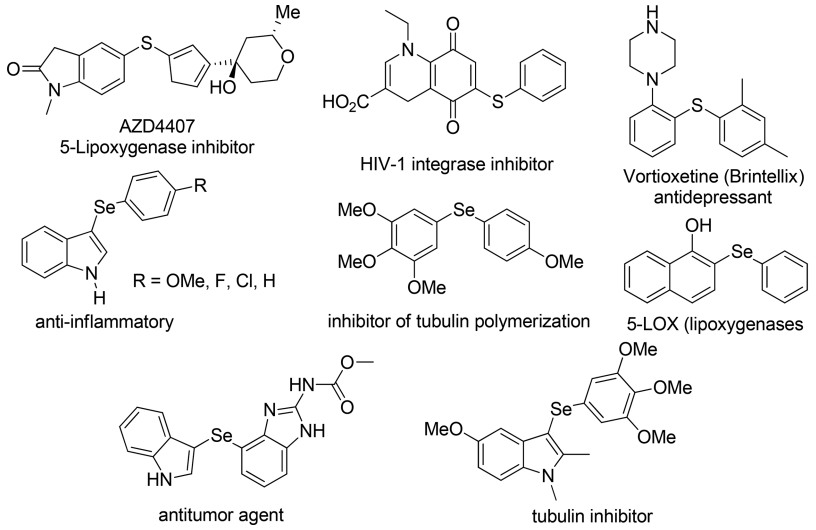
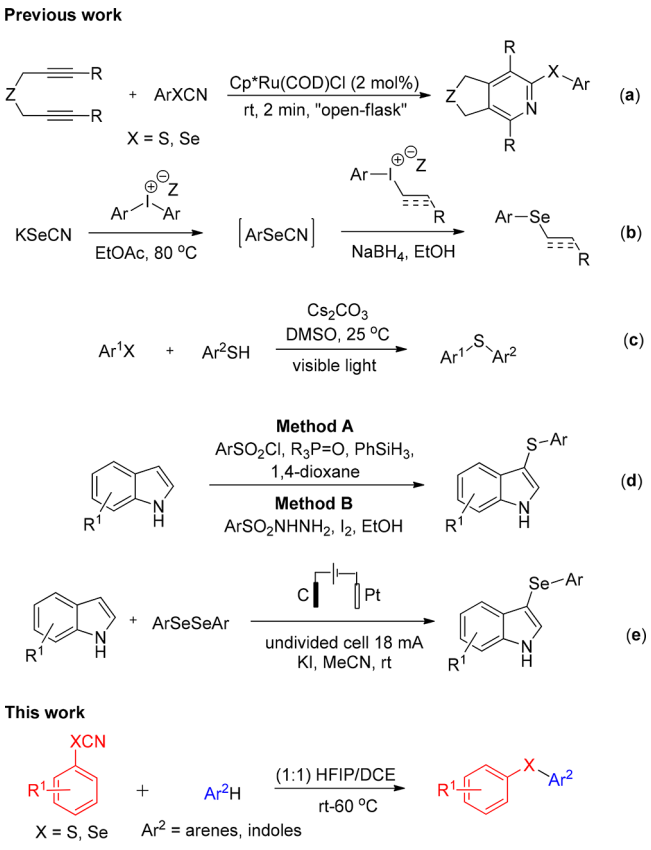


Figure 1. Examples of natural and bioactive (hetero)arenes thio-/selenoethers.

Scheme 1. Chalcogenylation of (Hetero)arenes



with diaryl dichalcogenides under an oxygen atmosphere.[3b] In 2013, Tian and group disclosed an iodine-catalyzed sulfenylation reaction of indoles with sulfonyl hydrazides (Scheme 1 (d)).[5] The direct C−H selenation of indole and imidazopyridine derivatives under aerobic electrolytic conditions employing an iodide salt as a catalyst has been documented by the group of Jiang and Sun in 2018 (Scheme 1 (e)).[21]

It is noteworthy that direct C−H bond functionalization reactions are restricted owing to two fundamental challenges: (i) the inert nature of most of the carbon−hydrogen bonds and (ii) the requirement to control site selectivity in molecules that possess various C−H groups. To achieve more efficient C−H activation, we focused on highly acidic hexafluoroisopropanol (HFIP), which is almost exclusively involved as a solvent or an additive in the stabilization of cationic intermediates due to its high polarity and low nucleophilicity.[22] Despite the remarkable developments associated with the HFIP-assisted reactions,[23] the construction of C−X bonds in the presence of HFIP is rare. In the course of our ongoing studies on aryl chalcogeno-cyanates,[16] we would like to report an operationally simple, yet powerful, protocol for the metal-free chalcogenations of arenes and indoles with chalcogenated cyanates by exploiting the hydrogen bonding ability of HFIP.

RESULT AND DISCUSSION

HFIP is known to mediate C−C and C−heteroatom bond forming reactions due to its highly polar, strong hydrogen bond donor (HBD) character and less nucleophilicity. For the initial screening and optimization of the chalcogenation reaction conditions, we have chosen HFIP, one of the strongest HBD solvents to investigate the reaction of phenyl cyanate **1a** with 1,3,5-trimethoxybenzene **4a**. Unfortunately, reaction did not deliver any product at both room temperature and refluxing conditions (Table 1, entries 1 and 2). We hypothesized that the stronger HBD capability of HFIP might not be sufficient to cleave the strongest O−CN bond to generate an electrophilic aryloxy moiety, which may eventually introduce the aryloxy group on the arene ring *via* C−H activation. With this conclusion, phenyl thiocyanate **2a**, having a relatively weaker S−CN bond was attempted with **4a** at 60 °C in DCE using a catalytic amount of HFIP. The reaction delivered the compound **6aa** in 15% yield (Table 1, entry 4). The same reaction was further conducted in different ratios of HFIP with other organic solvents to determine the role of HFIP in promoting the thioarylation (Table 1, entries 5−8). A significant change in the yield was noticed when HFIP and DCE were used as a solvent mixture with 1:1 ratio (Table 1, entry 9). At this point, it is important to mention that, when HFIP is applied as the only solvent, the above said reaction can furnish arylthioether **6aa** in 80% yield (Table 1, entry 10). Keeping the aforesaid observation in mind, the reaction of selenocyanate **3a** with arene **4a** was performed. To our delight, unsymmetrical selenoether **7aa** was obtained in 89% yield at

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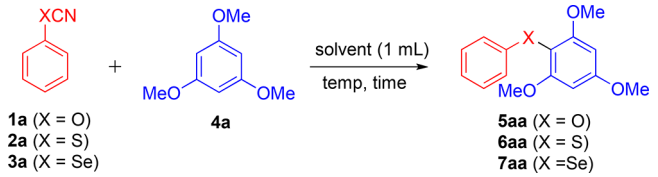
J. Org. Chem. 2021, 86, 9317−9327

Table 1. Optimization of the Reaction Conditions[a]



1a (X = O)
2a (X = S)
3a (X = Se)

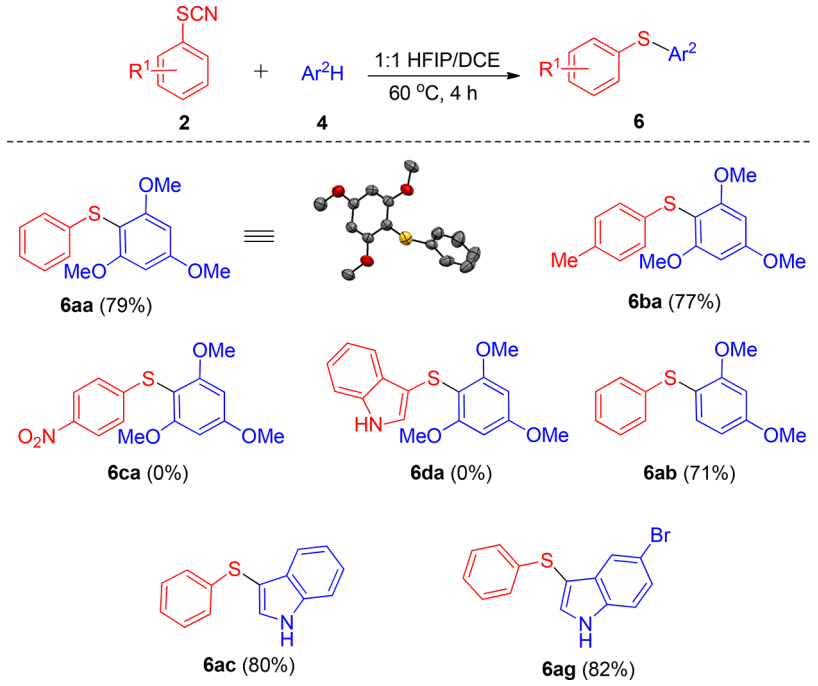
4a

5aa (X = O)
6aa (X = S)
7aa (X =Se)

entry	PhXCN	solvent	solvent ratio	temp (°C)	time (h)	yield (%)[b]
1	**1a**	HFIP		rt	24	nr
2	**1a**	HFIP		reflux	24	nr
3	**2a**	DCE		rt/reflux	24	nr
4	**2a**	HFIP:DCE	1:9	60	24	15
5	**2a**	HFIP:MeOH	1:2	60	24	nr
6	**2a**	HFIP:THF	1:2	60	24	nr
7	**2a**	HFIP:DCE	1:4	60	5	48
8	**2a**	HFIP:DCE	1:2	60	5	65
9	**2a**	**HFIP:DCE**	1:1	**60**	**4**	**79**
10	**2a**	HFIP		60	4	80
11	**2a**	HFIP:DCE	1:1	rt	15	75
12	**3a**	**HFIP:DCE**	1:1	**rt**	**10**	**89**
13	**3a**	HFIP:DCE	1:1	60	1.5	90
14	**3a**	HFIP		60	1.5	90
15	**3a**	*tert*-BuOH		70	15	nr
16	**3a**	2,2,2-trifluoroethanol		rt	1.5	52
17	**3a**	2,2,2-trifluoroethanol		75	1.5	73

[a]Optimized reaction conditions: For X = S, **2a** (67.5 mg, 0.5 mmol), **4a** (100.9 mg, 0.6 mmol), HFIP/DCE (1 mL, 1:1), inert conditions, 60 °C (oil bath temperature), 4 h. For X = Se, **3a** (91.4 mg, 0.5 mmol), **4a** (100.9 mg, 0.6 mmol), HFIP/DCE (1 mL, 1:1), inert conditions, rt, 10 h. [b]Isolated yield.

Scheme 2. Transition-Metal-Free Reaction of Aryl Thiocyanates 2 with (Hetero)arenes 4 for the Synthesis of Unsymmetrical Thioethers 6[a]



[a]Reaction conditions: **2** (0.5 mmol), **4** (0.6 mmol), HFIP/DCE (1 mL, 1:1), inert conditions, 60 °C (oil bath temperature), 4 h.

room temperature for 5 h under inert conditions (Table 1, entry 12). In the process to enhance the yield of **7aa**, the reaction was further heated at 60 °C under the same conditions, and the product was obtained within 1.5 h without significance enhancement of the yield (Table 1, entry 13). The reaction was further performed by changing the solvent to *tert*-BuOH, and TFE (Table 1, entries 15−17). The result implies that the strongest H-bonding capability of HFIP with the nitrogen atom of the nitrile group caused the cleavage of the

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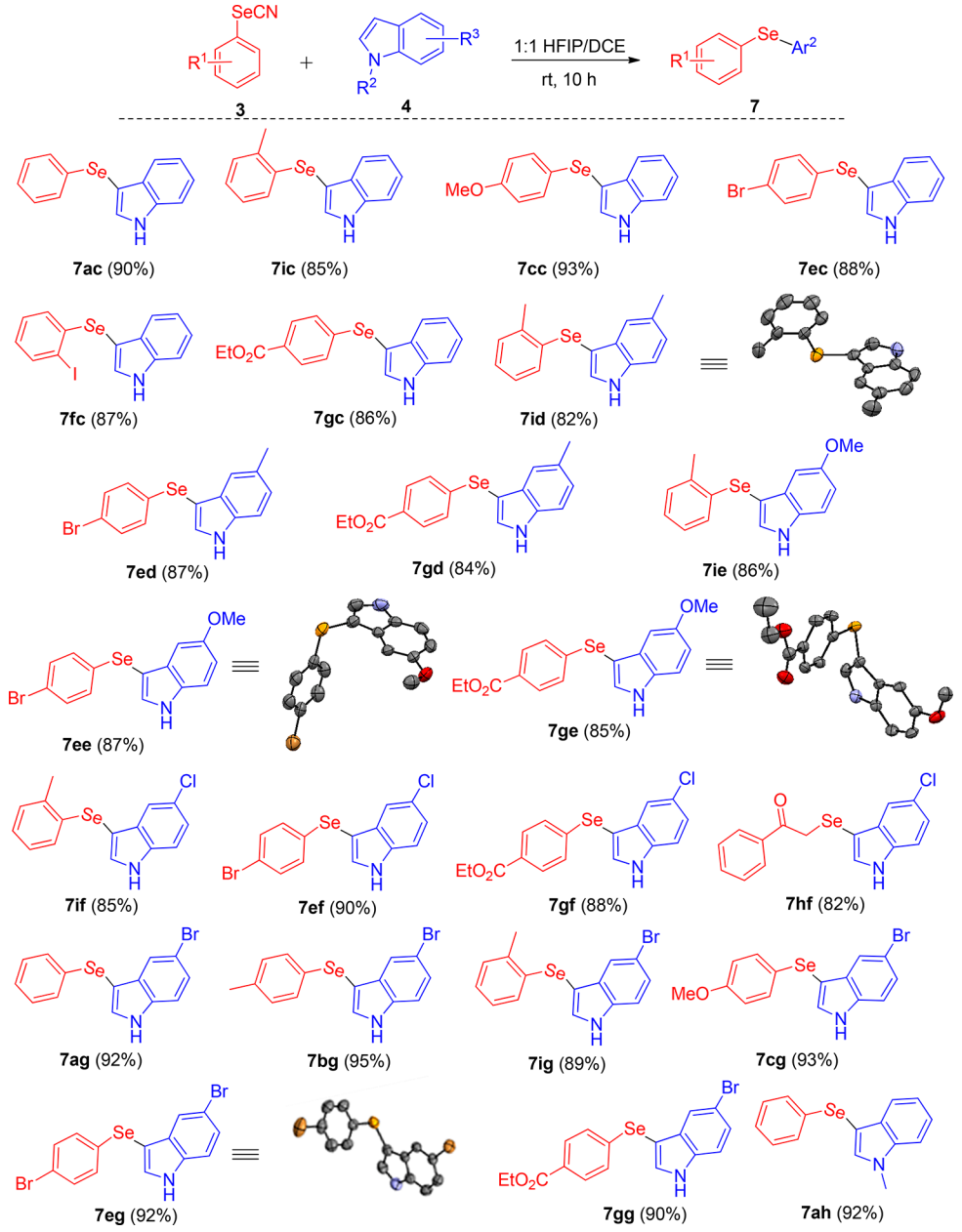
J. Org. Chem. 2021, 86, 9317−9327

Scheme 3. Transition-Metal-Free Reactions of Aryl Selenocyanates with Heteroarenes for the Synthesis of Unsymmetrical Selenoethers (7)[a]



[a]Reaction conditions: **3** (0.5 mmol), **4** (0.6 mmol), HFIP/DCE (1 mL, 1:1), inert conditions, rt, 10 h.

weaker Se−CN bond to form the selenoether **7aa** in excellent yield.

With the optimized reaction conditions in hand, we extended our exploration to various aryl thiocyanates **2** with (hetero)arenes **4** to figure out the substrate scope of the reaction leading to the unsymmetrical thioethers **6**. Employing this methodology, electron rich arenes and indoles delivered the diaryl sulfide derivatives **6** in very good yields; however, the nitro-substituted arylthiocyanate **2c** and 3-indole thiocyanate **2d** failed to give the desire products under this reaction conditions. The compound **6aa** was isolated as a pure single crystal, and the structure was unequivocally confirmed by single crystal X-ray[24] analysis (Scheme 2).

Next, we moved to examine the substrate scope for the synthesis of diarylselenoethers **7** from the reaction of aryl selenocyantes **3** with indoles mediated by HFIP, and the results are summarized in Scheme 3. A wide range of aryl selenocyanates (**3a−3i**) were reacted with commercially available heteroarenes (**4c−4h**) to achieve the desired unsymmetrical diarylselenoether.

To our delight, electron-donating (**3a−3c**, **3i**) and electron-withdrawing (**3e−3g**) substituents were well tolerated and the corresponding diaryl selenides were obtained in excellent yields. Analogously, it was observed that steric variation on the aryl selenocyanate counterpart was slightly sensitive to the reaction efficiency. The hindered *ortho*-methyl substituted selenocyanate underwent the reaction and delivered the corresponding products (**7ic**, **7id**, **7ie**, and **7if**), albeit with relatively lower yield. In the course of in-depth studies, next we devote our attention to investigate the substrate scope with

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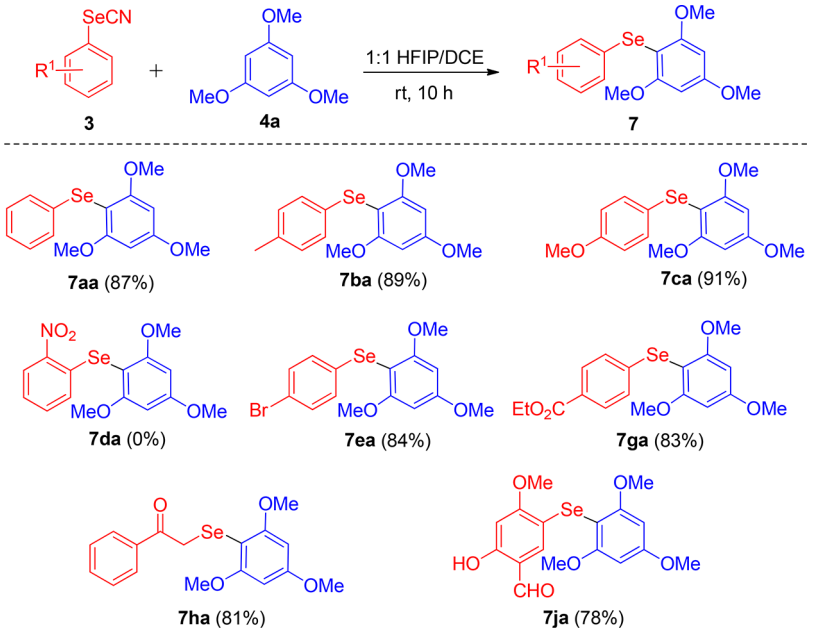
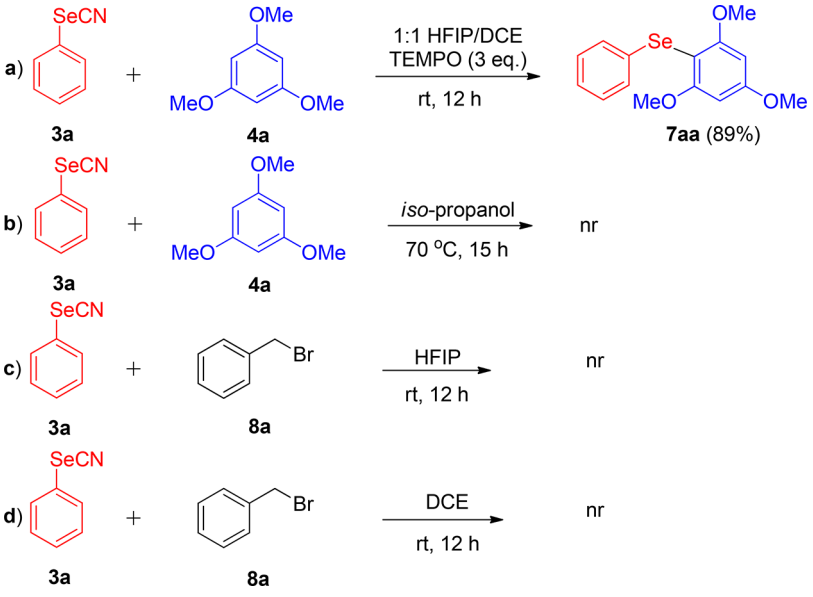
J. Org. Chem. 2021, 86, 9317−9327

Scheme 4. Transition-Metal-Free Reactions of Aryl Selenocyanates with 1,3,5-Trimethoxybenzene for the Synthesis of Unsymmetrical Selenoethers (7)[a]



[a]Reaction conditions: **3** (0.5 mmol), **4a** (0.6 mmol), HFIP/DCE (1 mL, 1:1), inert conditions, rt, 10 h.

Scheme 5. Preliminary Mechanism Investigation



regard to the indole compounds **4** and found that the metal-free C−H selenoarylation can lead to the corresponding selenides **7** using a number of electron rich as well as electron-withdrawing substituted indoles. The compounds **7id**, **7ee**, **7ge**, and **7eg** were isolated as pure single crystals, and their structures were unequivocally confirmed by single crystal X-ray[24] analysis (Scheme 3).

Besides heteroaromatics, trimethoxybenzene participated well in this protocol to afford aryl selenides (**7aa**−**7ha**) in high to excellent yields. Electron-donating (**3a**−**3c**) and electron-withdrawing (**3e**, **3g**) substituents were amenable to the protocol. Unfortunately, compound **7da** was not obtained as aryl selenocyanate **3d** remained elusive for arene **4a**. Preferential interaction of HFIP with the nitro group over the SCN moiety might be the reason for the inertness of nitro-substituted selenocyanate **3d**. The reaction of aliphatic selenocyanate **3h** with 1,3,5-trimethoxybenzene **4a** successfully led to the formation of unsymmetrical selenoether **7ha** in 81% yield. A selenocyanate containing −OH, −OMe, and −CHO groups (**4j**) was seen to be compatible with trimethoxybenzene (Scheme 4). It is noteworthy to mention that selenocyanates outperform the thiocyanates in terms of substrate scope as well as the efficiency of the reaction. We surmised that it might be because the bigger size of selenium allows the facile removal of the nitrile group by strong H-bonding with HFIP. The HFIP triggered electrophilic aryl selenocyanates activate the nucleophilic indole to attack at Se, resulting in the formation of selenoethers with higher yields.

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To gain more insight into the reaction mechanism, a few control experiments have been carried out. The model reaction was performed in the presence of radical inhibitor 2,2,6,6-tetramethyl-1-piperidinyloxy (TEMPO), and results suggested that the reaction pathway does not follow the radical pathway (Scheme 5 (a)). When the solvent was changed to *iso*-propanol, the transformation was stopped; this result clearly indicated the essential presence of HFIP to accomplish the reaction (Scheme 5 (b)). To illustrate the nature of phenyl selenocyanate, two reactions were conducted with benzyl bromide as an electrophile in the presence and absence of HFIP. Both the experiments ended up with the recovery of starting materials. The results show the evidence of the electrophilic nature of phenyl selenocyanate (Scheme 5 (c) and (d)).

To get the evidence of H-bonding of the nitrile group with HFIP, IR data have been taken. The position of the OH bond of HFIP and the C≡N group in selenocyanate **3h** is observed at $\tilde{\nu}$ = 3435 cm^{-1} and $\tilde{\nu}^{bond(CN)}$ = 2149 cm^{-1}, respectively. During the reaction of selenocyanate **3h** with trimethoxybenzene **4a** in HFIP, a new broad band appeared at frequency ($\tilde{\nu}^{bond(CN\cdots H)}$ = 3370 cm^{-1}). and $\tilde{\nu}^{bond(CN)}$ = 2161 cm^{-1} (Figure 2). The shift in frequencies might be due to H-bonding.[26]

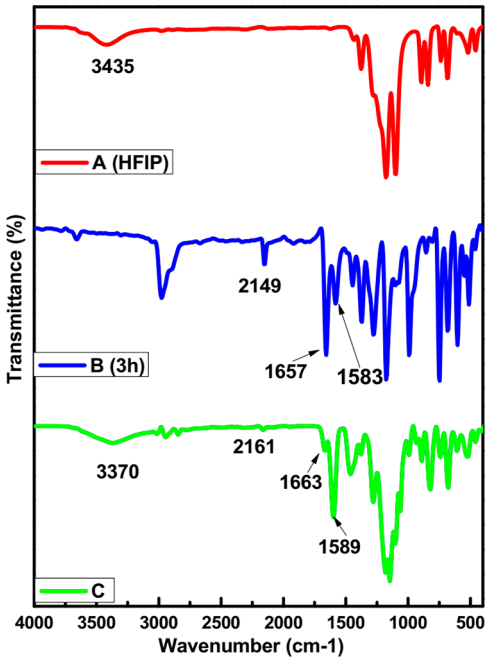
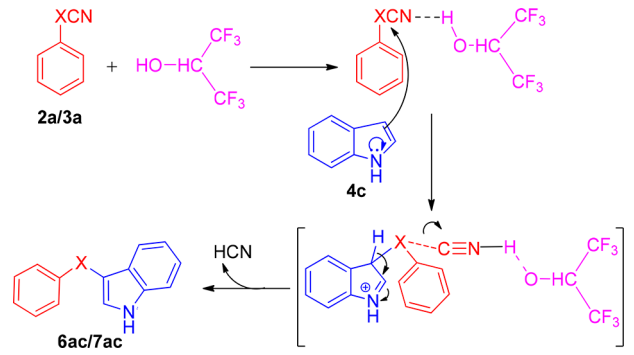


Figure 2. IR spectra for **A** = HFIP, **B** = **3h**, and **C** = During the reaction of **3h** with **4a** in HFIP (after 2 h).

On the basis of control experiments, a plausible mechanism for the chalcogenation is depicted in the Scheme 6. The hydrogen atom of the hydroxyl group in HFIP forms a strong H-bond with the nitrogen atom of the thio/selenocyanate group appended to the aryl ring and, eventually, triggers the electrophilicity of the sulfur/selenium atom of thio-/selenocyanates by weakening the X−CN bond. Subsequently, the nucleophilic indole/arene attacks the electrophilic thio/seleno center, leading to the formation of the desired product with the release of a cyanide group (Scheme 6).

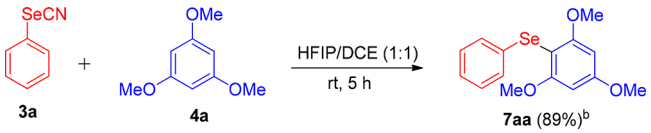
Finally, the gram-scale synthesis of **7aa** was performed under the optimized reaction conditions to illustrate the general applicability and large-scale productivity of the protocol. It was

Scheme 6. Probable Mechanism for the Formation of Compounds 6/7



observed that reaction of phenyl selenocyanate **3a** with arene **4a** underwent smoothly to deliver the desired cycloadduct **7aa** in 89% yield (Scheme 7).

Scheme 7. Gram-Scale Synthesis of Unsymmetrical Selenide 7aa[a]



[a]Reaction conditions: **3a** (0.914 g, 5 mmol), **4a** (0.907 g, 5.4 mmol), HFIP/DCE (7 mL, 1:1), inert conditions, rt, 5 h. [b]Isolated yield.

CONCLUSIONS

In summary, metal-free HFIP-mediated chalcogenation reactions (thio- and selenation) between thio-/selenocyanates with arenes/indoles have been disclosed. The protocol provides the access to the thio-/selenoethers in good to excellent yields under mild reaction conditions. The protocol can also be utilized for the large-scale synthesis of aryl (hetero)aryl thio-/selenoethers. The said methodology will be a remarkable example for the HFIP-mediated metal-free C−H activation reactions.

EXPERIMENTAL SECTION

General Information. All chemicals and reagents were purchased from commercial suppliers and used without further purification. Thin layer chromatography (TLC) was performed using precoated plates purchased from E. Merck (silica gel 60 PF254, 0.25 mm). Column chromatography was performed using E. Merck silica gel 60 (100−200 mesh). GCMS analyses were carried out on a SHIMADZU GCMS-QP Ultra 2010 instrument. NMR spectra were recorded in $CDCl_3$, on a JEOL JNM-ECS spectrometer at operating frequencies of 400 MHz (^1H) or 100 MHz ($^{13}C\{^1H\}$) as indicated in the individual spectrum. Chemical shifts (δ) are reported in ppm relative to the residual solvent (chloroform, δ = 7.26 for ^1H and 77.16 for proton decoupled $^{13}C\{^1H\}$ NMR) and coupling constants (J) in Hz. Multiplicity is tabulated as s for singlet, d for doublet, dd for doublet of doublet, t for triplet, q for quartet, and m for multiplet. High-resolution mass spectra (HRMS) were recorded using electron spray ionization (ESI) methods on a Waters mass spectrometer. Melting points were determined using a BIBBY-SMP30 melting point meter. Single crystal X-ray structural data were collected on a CMOS based Bruker D8 Venture PHOTON 100 diffractometer equipped with in INCOATEC micro-focus source with graphite monochromated Mo Kα radiation (λ = 0.71073 Å) operating at 50 kV and 30 mA. All the aryl thiocyanates (**2a−d**)[25] and aryl selenocyanates (**3a−j**)[18] were

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J. Org. Chem. 2021, 86, 9317−9327

prepared according to the reported literature procedures. The rest of the chemicals and solvents were purchased from the Sigma, GLR Innovations, Avra, Spectrochem, and TCI, and used as received.

Experimental Procedures. *General Procedure for Sulfenylation of Arenes/Indoles with Aryl Thiocyanates.* A mixture of aryl thiocyanate (0.5 mmol), arene/indole (0.6 mmol), and HFIP/DCE (1 mL, 1:1), contained in a Schlenk tube, was stirred at 60 °C (oil bath temperature) for 4 h. After completion of the reaction checked by TLC, the solvent was removed under reduced pressure. The crude reaction mixture was purified through column chromatography over silica gel using hexane/ethyl acetate as eluents to obtain the desired product.

General Procedure for Selenylation of Arenes/Indoles with Aryl Selenocyanates. To a Schlenk flask were added aryl selenocyanate (0.5 mmol), arene/indole (0.6 mmol), and HFIP/DCE (1 mL, 1:1), and the reaction mixture was allowed to stir at room temperature under a nitrogen atmosphere. The reaction was monitored by TLC. After the completion, the mixture was concentrated *in vacuo* and the product was purified by column chromatography on silica gel using hexane/ethyl acetate as eluents to obtain the desired product.

*Gram-Scale Synthesis of **7aa**.* Phenyl selenocyanate **3a** (0.914 g, 5 mmol) and arene **4a** (0.907 g, 5.4 mmol) were dissolved in HFIP/DCE (7 mL, 1:1), and the mixture was heated at room temperature under a nitrogen atmosphere. After completion of the reaction checked by TLC, evaporation of solvent gave the crude product **7aa** (1.441 g, 89%), which was further purified by column chromatography. The pure compound was analyzed by ^{1}H NMR and ^{13}C{^{1}H} NMR and mass spectroscopy.

*Characterization Data of Compounds. Phenyl(2,4,6-trimethoxyphenyl)sulfane (**6aa**).* White solid (109.1 mg, 79% yield). R_f = 0.20 (EtOAc/Hexane = 2:8). Mp: 105−107 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.15 (t, J = 8.2 Hz, 2H), 7.04−7.00 (m, 3H), 6.21 (s, 2H), 3.87 (s, 3H), 3.81 (s, 6H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 163.0, 162.6, 138.7, 128.6, 125.7, 124.4, 98.6, 91.2, 56.4, 55.5. IR (neat): $\tilde{\nu}$ = 2959, 2931, 2839, 1578, 1455, 1409, 1337, 1226, 1121, 1024, 809 cm^{-1}. HRMS m/z: [M + H]$^+$ calcd for $C_{15}H_{17}O_3S$ 277.0898; found 277.0899.

The values of the characterization data are in accordance with reported literature data.[17b]

*p-Tolyl(2,4,6-trimethoxyphenyl)sulfane (**6ba**).* White solid (111.7 mg, 77% yield). R_f = 0.22 (EtOAc/Hexane = 2:8). Mp: 110−112 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.10 (d, J = 7.9 Hz, 2 H), 6.95 (d, J = 8.2 Hz, 2H), 6.19 (s, 2H), 3.86 (s, 3H), 3.79 (s, 6H), 2.25 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 162.9, 162.0, 135.2, 129.6, 129.3, 126.0, 97.7, 91.2, 56.4, 55.5, 21.1. IR (neat): $\tilde{\nu}$ = 2961, 2924, 2852, 1588, 1453, 1407, 1333, 1226, 1121, 1021, 806 cm^{-1}. HRMS m/z: [M + H]$^+$ calcd for $C_{16}H_{19}O_3S$ 291.1055; found 291.1052.

The values of the characterization data are in accordance with reported literature data.[17b]

*(2,4-Dimethoxyphenyl)(phenyl)sulfane (**6ab**).* White solid (87.4 mg, 71% yield). R_f = 0.24 (EtOAc/Hexane = 2:8). Mp: 63−65 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.35 (d, J = 8.5 Hz, 1H), 7.23−7.19 (m, 2H), 7.13−7.11 (m, 3H), 6.52−6.48 (m, 2H), 3.83 (s, 3H), 3.81 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 162.0, 160.5, 137.8, 136.9, 128.9, 127.7, 125.5, 112.1, 105.4, 99.3, 56.1, 55.6. IR (neat): $\tilde{\nu}$ = 3058, 3002, 2957, 1593, 1460, 1266, 1150, 1049, 836, 736 cm^{-1}. HRMS m/z: [M + H]$^+$ calcd for $C_{14}H_{15}O_2S$ 247.0793; found 247.0778.

The values of the characterization data are in accordance with reported literature data.[17e]

*3-(Phenylthio)-1H-indole (**6ac**).* White solid (90.0 mg, 80% yield). R_f = 0.30 (EtOAc/Hexane = 2:8). Mp: 146−148 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.42 (bs, 1H), 7.61 (d, J = 8.7 Hz, 1H), 7.50 (d, J = 2.4 Hz, 1H), 7.45 (d, J = 8.3 Hz, 1H), 7.29−7.27 (m, 1H), 7.17−7.14 (m, 3H), 7.13−7.10 (m, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 139.3, 136.6, 130.8, 129.2, 128.8, 125.8, 124.8, 123.2, 121.0, 119.7, 111.7, 102.9. IR (neat): $\tilde{\nu}$ = 3405, 2965, 2918, 2820, 1578, 1454, 1406, 1236, 1085, 823, 738 cm^{-1}. HRMS m/z: [M + H]$^+$ calcd for $C_{14}H_{12}NS$ 226.0690; found 226.0679.

The values of the characterization data are in accordance with reported literature data.[6b]

*5-Bromo-3-(phenylthio)-1H-indole (**6ag**).* White solid (124.7 mg, 82% yield). R_f = 0.40 (EtOAc/Hexane = 2:8). Mp: 140−142 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.30 (bs, 1H), 7.61 (s, 1H), 7.29 (d, J = 2.7 Hz, 1H), 7.19 (m, 1H), 7.13−7.10 (m, 1H), 7.04−7.01 (m, 2H), 6.95−6.92 (m, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 138.8, 135.2, 132.0, 131.0, 128.9, 126.1, 125.9, 125.1, 122.3, 114.5, 113.2, 102.7. IR (neat): $\tilde{\nu}$ = 3408, 2921, 2852, 1580, 1455, 1366, 1206, 1082, 799, 737 cm^{-1}. HRMS m/z: [M + H]$^+$ calcd for $C_{14}H_{12}NS^{79}Br$ 302.9717; found 302.9713. HRMS m/z: [M + H]$^+$ calcd for $C_{14}H_{12}NS^{81}Br$ 304.9697; found 304.9693.

The values of the characterization data are in accordance with reported literature data.[6b]

*3-(Phenylselanyl)-1H-indole (**7ac**).* White solid (122.4 mg, 90% yield). R_f = 0.35 (EtOAc/Hexane = 2:8). Mp: 133−135 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.41 (bs, 1H), 7.65 (d, J = 8.4 Hz, 1H), 7.47 (d, J = 3.6 Hz, 1H), 7.44 (d, J = 8.4 Hz, 1H), 7.28−7.10 (m, 7H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): 136.5, 133.9, 131.3, 130.0, 129.0, 128.7, 125.6, 123.0, 121.0, 120.5, 111.4, 98.2. IR (neat): $\tilde{\nu}$ = 3410, 3123, 3049, 2921, 1646, 1573, 1451, 1236, 1020, 825, 730, 684 cm^{-1}. HRMS m/z: [M + H]$^+$ calcd for $C_{14}H_{11}NSe$ 273.0057; found 273.0052.

The values of the characterization data are in accordance with reported literature data.[17d]

*3-(o-Tolylselanyl)-1H-indole (**7ic**).* White solid (121.6 mg, 85% yield). R_f = 0.36 (EtOAc/Hexane = 2:8). Mp: 109−111 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.43 (bs, 1H), 7.52 (d, J = 8.0 Hz, 1H), 7.37−7.35 (m, 2H), 7.21−7.16 (m, 1H), 7.11−7.03 (m, 2H), 6.95−6.91 (m, 1H), 6.78−6.74 (m, 2H), 2.39 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 136.5, 136.1, 134.6, 131.6, 130.2, 129.9, 128.0, 126.6, 125.4, 123.1, 121.0, 120.5, 111.5, 97.3, 21.4. IR (neat): $\tilde{\nu}$ = 3406, 2955, 2922, 2852, 1567, 1463, 1237, 1093, 802, 743 cm^{-1}. HRMS m/z: [M + H]$^+$ calcd for $C_{15}H_{13}NSe$ 287.0213; found 287.0194.

The values of the characterization data are in accordance with reported literature data.[19b]

*3-((4-Methoxyphenyl)selanyl)-1H-indole (**7cc**).* White solid (140.5 mg, 93% yield). R_f = 0.36 (EtOAc/Hexane = 2:8). Mp: 113−115 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.39 (bs, 1H), 7.57 (d, J = 8.1 Hz, 1H), 7.38 (d, J = 2.8 Hz, 1H), 7.34 (d, J = 8.1, 1H), 7.19−7.14 (m, 4H), 7.08 (t, J = 7.6 Hz, 1H), 6.63 (d, J = 8.7 Hz, 2H), 3.64 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 158.4, 136.4, 131.2, 130.8, 129.9, 123.3, 123.0, 120.8, 120.5, 114.9, 111.3, 99.6, 55.2. IR (neat): $\tilde{\nu}$ = 3408, 2956, 2922, 2853, 1488, 1451, 1239, 1094, 1025, 812, 740 cm^{-1}. HRMS m/z: [M + H]$^+$ calcd for $C_{15}H_{14}NOSe$ 304.0241; found 304.0220.

The values of the characterization data are in accordance with reported literature data.[17d]

*3-((4-Bromophenyl)selanyl)-1H-indole (**7ec**).* Brown solid (154.4 mg, 88% yield). R_f = 0.45 (EtOAc/Hexane = 2:8). Mp: 133−135 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.46 (bs, 1H), 7.58 (d, J = 8.1 Hz, 1H), 7.49 (d, J = 2.6 Hz, 1H), 7.44−7.16 (m, 5H), 7.08 (d, J = 8.3 Hz, 2H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 136.5, 132.8, 131.9, 131.3, 130.3, 129.7, 123.2, 121.0, 120.3, 119.4, 111.5, 97.9. IR (neat): $\tilde{\nu}$ = 3380, 3052, 2922, 2853, 1451, 1336, 1069, 1002, 803, 749 cm^{-1}. HRMS m/z: [M + H]$^+$ calcd for $C_{14}H_{11}NSe^{79}Br$ 351.9240; found 351.9217. HRMS m/z: [M + H]$^+$ calcd for $C_{14}H_{11}NSe^{81}Br$ 353.9220; found 353.9204.

The values of the characterization data are in accordance with reported literature data.[12]

*3-((2-Iodophenyl)selanyl)-1H-indole (**7fc**).* Brown solid (171.1 mg, 87% yield). R_f = 0.48 (EtOAc/Hexane = 2:8). Mp: 160−162 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.61 (bs, 1H), 7.70 (d, J = 8.0 Hz, 1H), 7.61 (d, J = 7.7 Hz, 1H), 7.51−7.47 (m, 2H), 7.29 (t, J = 8.0 Hz, 1H), 7.19 (t, J = 7.7 Hz, 1H), 6.96 (t, J = 7.7 Hz, 1H), 6.78 (t, J = 7.7 Hz, 1H), 6.67 (d, J = 9.2 Hz, 1H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 141.2, 139.1, 136.5, 132.1, 129.8, 128.6, 128.5, 126.7, 123.3, 121.2, 120.4, 111.5, 100.3, 96.5. IR (neat): $\tilde{\nu}$ = 3368, 3030, 2927, 2850, 1447, 1331, 1063, 1001, 801, 744 cm^{-1}. HRMS m/z: [M + H]$^+$ calcd for $C_{17}H_{16}NO_2Se$ 399.9101; found 399.9099.

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*Ethyl 4-((1H-Indol-3-yl)selanyl)benzoate (**7gc**).* Gray solid (148.0 mg, 86% yield). R_f = 0.60 (EtOAc/Hexane = 2:8). Mp: 142−144 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.57 (bs, 1H), 7.70 (d, J = 7.6 Hz, 2H), 7.49 (d, J = 8.2 Hz, 1H), 7.42−7.38 (m, 2H), 7.22−7.14 (m, 4H), 4.23 (q, J = 7.2 Hz, 2H), 1.26 (t, J = 7.0 Hz, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 166.7, 141.5, 136.5, 131.7, 129.9, 129.7, 127.8, 127.6, 123.3, 121.2, 120.3, 111.6, 96.9, 60.9, 14.4. IR (neat): $\tilde{\nu}$ = 3317, 2922, 2852, 1698, 1588, 1455, 1278, 1105, 1014, 844, 755 cm^{-1}. HRMS m/z: [M + H]$^+$ calcd for $C_{17}H_{16}NO_2Se$ 346.0346; found 346.0323.

*5-Methyl-3-(o-tolylselanyl)-1H-indole (**7id**).* Yellow solid (123.1 mg, 82% yield). R_f = 0.39 (EtOAc/Hexane = 2:8). Mp: 140−142 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.39 (bs, 1H), 7.43 (d, J = 2.5 Hz, 1H), 7.39−7.34 (m, 2H), 7.11 (t, J = 7.9 Hz, 2H), 7.01 (t, J = 7.4 Hz, 1H), 6.87−6.79 (m, 2H), 2.47 (s, 3H), 2.42 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 135.9, 134.9, 134.8, 131.8, 130.5, 130.4, 129.9, 127.7, 126.6, 125.3, 124.8, 120.1, 111.1, 96.6, 21.6, 21.3. IR (neat): $\tilde{\nu}$ = 3398, 2960, 2921, 2852, 1568, 1455, 1260, 1092, 1032, 800 cm^{-1}. HRMS m/z: [M + H]$^+$ calcd for $C_{16}H_{16}NSe$ 302.0448; found 302.0439.

*3-((4-Bromophenyl)selanyl)-5-methyl-1H-indole (**7ed**).* Gray solid (158.8 mg, 87% yield). R_f = 0.44 (EtOAc/Hexane = 2:8). Mp: 116−118 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.31 (bs, 1H), 7.32−7.29 (m, 2H), 7.23 (d, J = 8.7 Hz, 1H), 7.15−7.12 (m, 2H), 7.02−6.96 (m, 3H), 2.34 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 134.8, 133.2, 132.0, 131.6, 130.6, 130.1, 130.0, 124.9, 119.8, 119.3, 111.2, 97.0, 21.6. IR (neat): $\tilde{\nu}$ = 3397, 2956, 2922, 2853, 1577, 1463, 1260, 1069, 1005, 795 cm^{-1}. HRMS m/z: [M + H]$^+$ calcd for $C_{15}H_{13}NSe^{79}Br$ 365.9397; found 365.9391. HRMS m/z: [M + H]$^+$ calcd for $C_{15}H_{13}NSe^{81}Br$ 367.9376; found 367.9378.

*Ethyl 4-((5-Methyl-1H-indol-3-yl)selanyl)benzoate (**7gd**).* White solid (150.4 mg, 84% yield). R_f = 0.62 (EtOAc/Hexane = 2:8). Mp: 145−147 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.69 (bs, 1H), 7.79 (d, J = 8.8 Hz, 2H), 7.44 (d, J = 2.6 Hz, 1H), 7.35−7.33 (m, 2H), 7.22 (d, J = 8.6 Hz, 2H), 7.09 (d, J = 8.3 Hz, 1H), 4.32 (q, J = 7.1 Hz, 2H), 2.42 (s, 3H), 1.35 (t, J = 7.0 Hz, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 166.8, 141.9, 134.8, 131.9, 130.6, 130.0, 129.9, 127.5, 127.4, 124.8, 119.7, 111.3, 96.0, 60.9, 21.6, 14.4. IR (neat): $\tilde{\nu}$ = 3382, 2955, 2923, 2854, 1698, 1586, 1461, 1396, 1269, 1175 1104, 1012, 843 754 cm^{-1}. HRMS m/z: [M + H]$^+$ calcd for $C_{18}H_{18}NO_2Se$ 360.0503; found 360.0493.

*5-Methoxy-3-(o-tolylselanyl)-1H-indole (**7ie**).* Yellow solid (135.9 mg, 86% yield). R_f = 0.40 (EtOAc/Hexane = 2:8). Mp: 78−80 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.42 (bs, 1H), 7.42 (d, J = 2.5 Hz, 1H), 7.34 (d, J = 8.6 Hz, 1H), 7.12 (d, J = 7.8 Hz, 1H), 7.03−7.02 (m, 2H), 6.94−6.83 (m, 3H), 3.80 (s, 3H), 2.47 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 155.2, 136.0, 132.3, 131.0, 129.9, 127.8, 126.6, 125.3, 113.6, 112.3, 101.6, 96.8, 55.9, 21.3. IR (neat): $\tilde{\nu}$ = 3401, 3054, 2930, 2830, 1623, 1580, 1481, 1454, 1282, 1206, 1163, 917, 837, 790 cm^{-1}. HRMS m/z: [M + H]$^+$ calcd for $C_{16}H_{16}NOSe$ [M + H]$^+$ 318.0397; found 318.0388.

*3-((4-Bromophenyl)selanyl)-5-methoxy-1H-indole (**7ee**).* White solid (165.7 mg, 87% yield). R_f = 0.47 (EtOAc/Hexane = 2:8). Mp: 108−110 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.39 (bs, 1H), 7.46 (d, J = 2.8 Hz, 1H), 7.33 (d, J = 8.9 Hz, 1H), 7.25−7.22 (m, 2H), 7.06 (d, J = 8.7 Hz, 2H), 7.00 (d, J = 2.8 Hz, 1H), 6.91 (dd, J = 9.9 Hz, 1H), 3.79 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 155.3, 133.1, 132.0, 131.4, 131.1, 130.6, 130.1, 119.4, 113.7, 112.4, 101.4, 97.3, 55.9. IR (neat): $\tilde{\nu}$ = 3390, 3051, 2924, 2827, 1619, 1572, 1449, 1275, 1201, 1069, 803, 785 cm^{-1}. HRMS m/z: [M + H]$^+$ calcd for $C_{15}H_{13}NOSe^{79}Br$ 381.9346; found 381.9324. HRMS m/z: [M + H]$^+$ calcd for $C_{15}H_{13}NOSe^{81}Br$ 383.9325; found 383.9313.

*Ethyl 4-((5-Methoxy-1H-indol-3-yl)selanyl)benzoate (**7ge**).* White solid (159.0 mg, 85% yield). R_f = 0.64 (EtOAc/Hexane = 2:8). Mp: 144−146 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.63 (bs, 1H), 7.78 (d, J = 8.4 Hz, 2H), 7.46 (d, J = 1.8 Hz, 1H), 7.34 (d, J = 8.8 Hz, 1H), 7.22 (d, J = 8.4 Hz, 2H), 6.99 (s, 1H), 6.92 (d, J = 9.8 Hz, 1H), 4.32 (q, J = 7.0 Hz, 2H), 3.79 (s, 3H), 1.34 (t, J = 7.8 Hz, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 166.7, 155.3, 141.6, 132.2, 131.4, 130.5, 129.9, 127.6, 127.5, 113.7, 112.4, 101.3, 96.3, 61.0, 55.8, 14.4. IR (neat): $\tilde{\nu}$ = 3316, 2998, 2922, 2840, 1700, 1582, 1484, 1264, 1103, 802, 756 cm^{-1}. HRMS m/z: [M + H]$^+$ calcd for $C_{18}H_{17}NO_3Se$ 375.0374; found 375.0353.

*5-Chloro-3-(o-tolylselanyl)-1H-indole (**7if**).* Yellow solid (136.4 mg, 85% yield). R_f = 0.38 (EtOAc/Hexane = 2:8). Mp: 96−98 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.63 (bs, 1H), 7.57 (d, J = 2.04 Hz, 1H), 7.47 (d, J = 2.5 Hz, 1H), 7.36 (d, J = 8.7 Hz, 1H), 7.21 (d, J = 9.1 Hz, 1H), 7.14−7.12 (m, 1H), 7.03 (t, J = 7.6 Hz, 1H), 6.87 (t, J = 6.8 Hz, 1H), 6.78−6.76 (m, 1H), 2.46 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 136.2, 134.9, 134.2, 133.0, 131.6, 130.0, 127.8, 126.9, 126.6, 125.6, 123.5, 120.0, 112.6, 97.1, 21.4. IR (neat): $\tilde{\nu}$ = 3414, 2954, 2923, 2853, 1566, 1454, 1292, 1094, 1032, 892, 797 cm^{-1}. HRMS m/z: [M + H]$^+$ calcd for $C_{15}H_{12}NClSe$ [M + H]$^+$ 320.9823; found 320.9803.

*3-((4-Bromophenyl)selanyl)-5-chloro-1H-indole (**7ef**).* Brown solid (173.4 mg, 90% yield). R_f = 0.49 (EtOAc/Hexane = 2:8). Mp: 113−115 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.54 (s, 1H), 7.51−7.49 (m, 2H), 7.36 (d, J = 8.3 Hz, 1H), 7.26−7.20 (m, 4H), 7.05 (d, J = 8.3 Hz, 2H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 134.9, 132.8, 132.5, 132.1, 131.1, 130.3, 128.3, 127.0, 123.7, 119.8, 112.6, 97.7. IR (neat): $\tilde{\nu}$ = 3421, 2961, 2922, 2852, 1659, 1447, 1260, 1094, 797 cm^{-1}. HRMS m/z: [M]$^+$ calcd for $C_{14}H_9NClSe^{79}Br$ 384.8772; found 384.8755. HRMS m/z: [M]$^+$ calcd for $C_{14}H_9NClSe^{81}Br$ 386.8752; found 386.8741.

The values of the characterization data are in accordance with reported literature data.[3b]

*Ethyl 4-((5-Chloro-1H-indol-3-yl)selanyl)benzoate (**7gf**).* Brown solid (166.6 mg, 88% yield). R_f = 0.65 (EtOAc/Hexane = 2:8). Mp: 143−145 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.66 (bs, 1H), 7.79 (d, J = 8.2 Hz, 2H), 7.52−7.54 (m, 2H), 7.38 (d, J = 8.7 Hz, 1H), 7.18−7.24 (m, 3H), 4.32 (q, J = 7.2 Hz, 2H), 1.34 (t, J = 7.2 Hz, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 166.6, 141.0, 134.9, 133.0, 131.1, 130.0, 127.8, 127.1, 123.6, 119.7, 112.7, 96.7, 61.0, 14.4. IR (neat): $\tilde{\nu}$ = 3294, 2956, 2923, 2853, 1695, 1589, 1565, 1331, 1106, 1013, 887, 798 cm^{-1}. HRMS m/z: [M + H]$^+$ calcd for $C_{17}H_{15}NO_2ClSe$ 379.9957; found 379.9937.

*2-((5-Chloro-1H-indol-3-yl)selanyl)-1-phenylethanone (**7hf**).* Brown solid (142.9 mg, 82% yield). R_f = 0.55 (EtOAc/Hexane = 2:8). Mp: 86−88 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.44 (bs, 1H), 7.81 (d, J = 7.2 Hz, 2H), 7.54−7.52 (m, 2H), 7.39 (t, J = 8.2 Hz, 2H), 7.27 (s, 1H), 7.21 (d, J = 2.4 Hz, 1H), 7.17−7.15 (m, 1H), 3.92 (s, 2H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 195.5, 135.4, 134.6, 133.3, 132.8, 131.1, 128.9, 128.6, 126.7, 123.3, 119.5, 112.6, 97.5, 32.5. IR (neat): $\tilde{\nu}$ = 3421, 2956, 2922, 2852, 1669, 1581, 1374, 1278, 1176, 992, 880, 796 cm^{-1}. HRMS m/z: [M + H]$^+$ calcd for $C_{16}H_{13}NOClSe$ 349.9851; found 349.9841.

*5-Bromo-3-(phenylselanyl)-1H-indole (**7ag**).* White solid (161.5 mg, 92% yield). R_f = 0.48 (EtOAc/Hexane = 2:8). Mp: 136−138 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.47 (bs, 1H), 7.78 (s, 1H), 7.47 (d, J = 2.3 Hz, 1H), 7.33−7.21 (m, 2H), 7.20−7.17 (m, 2H), 7.16−7.12 (m, 2H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 135.1, 133.4, 132.4, 132.0, 129.1, 128.7, 126.1, 125.9, 123.1, 114.5, 113.0, 97.9. IR (neat): $\tilde{\nu}$ = 3414, 2955, 2922, 2853, 1576,1439, 1397, 1095, 1022, 871, 795 cm^{-1}. HRMS m/z: [M − H]$^-$ calcd for $C_{14}H_9NSe^{79}Br$ 349.9084; found 349.9081. HRMS m/z: [M − H]$^-$ calcd for $C_{14}H_9NSe^{81}Br$ 351.9063; found 351.9070.

The values of the characterization data are in accordance with reported literature data.[17d]

*5-Bromo-3-(p-tolylselanyl)-1H-indole (**7bg**).* White solid (173.4 mg, 95%, yield). R_f = 0.50 (EtOAc/Hexane = 2:8). Mp: 119−123 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.51 (bs, 1H), 7.77 (s, 1H), 7.47 (d, J = 2.5 Hz, 1H), 7.32−7.30 (m, 2H), 7.14 (d, J = 7.7 Hz, 2H), 6.97 (d, J = 8.3 Hz, 2H), 2.24 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 135.9, 135.1, 132.3, 132.0, 130.0, 129.4, 129.2, 126.0, 123.1, 114.4, 112.9, 98.5, 21.0. IR (neat): $\tilde{\nu}$ = 3414, 2962, 2920, 2850, 1562, 1442, 1259, 1015, 797 cm^{-1}. HRMS m/z: [M + H]$^+$ calcd for $C_{15}H_{13}NSe^{79}Br$ 365.9397; found 365.9373. HRMS m/z: [M + H]$^+$ calcd for $C_{15}H_{13}NSe^{81}Br$ 367.9376; found 367.9360.

The values of the characterization data are in accordance with reported literature data.[17d]

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*5-Bromo-3-(o-tolylselanyl)-1H-indole (**7ig**).* Brown solid (162.4 mg, 89%, yield). R_f = 0.51 (EtOAc/Hexane = 2:8). Mp: 94−96 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.58 (s, 1H), 7.74−7.73 (m, 1H), 7.46 (s, 1H), 7.34−7.33 (m, 2H), 7.13 (d, *J* = 7.3 Hz, 1H), 7.03 (t, *J* = 7.7 Hz, 1H), 6.87 (t, *J* = 7.5 Hz, 1H), 6.78−6.75 (m, 1H), 2.46 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 136.2, 135.2, 134.2, 132.8, 132.1, 130.0, 127.8, 126.6, 126.1, 125.6, 123.1, 114.5, 113.0, 96.9, 21.4. IR (neat): $\tilde{\nu}$ = 3394, 2956, 2922, 2853, 1456, 1260, 1033, 866, 793 cm^{-1}. HRMS *m*/*z*: [M + H]$^+$ calcd for $C_{15}H_{12}NSe^{79}Br$ 364.9318; found 364.9297. HRMS *m*/*z*: [M + H]$^+$ calcd for $C_{15}H_{12}NSe^{81}Br$ 366.9298; found 366.9286.

The values of the characterization data are in accordance with reported literature data.[3b]

*5-Bromo-3-((4-methoxyphenyl)selanyl)-1H-indole (**7cg**).* White solid (177.2 mg, 93%, yield). R_f = 0.53 (EtOAc/Hexane = 2:8). Mp: 135−137 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.44 (bs, 1H), 7.79 (s, 1H), 7.46 (d, *J* = 2.5 Hz, 1H), 7.31−7.23 (m, 4H), 6.73 (d, *J* = 9.5 Hz, 2H), 3.73 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 158.5, 135.5, 135.1, 131.8, 131.5, 125.9, 123.1, 123.0, 114.9, 114.3, 112.9, 99.4, 55.4. IR (neat): $\tilde{\nu}$ = 3414, 2955, 2923, 2852, 1589, 1489, 1455, 1243, 1174, 1097, 883, 796 cm^{-1}. HRMS *m*/*z*: [M − H]$^-$ calcd for $C_{15}H_{11}NOSe^{79}Br$ 379.9189; found 379.9176. HRMS *m*/*z*: [M − H]$^-$ calcd for $C_{15}H_{11}NOSe^{81}Br$ 381.9169; found 381.9159.

*5-Bromo-3-((4-bromophenyl)selanyl)-1H-indole (**7eg**).* White solid (197.8 mg, 92%, yield). R_f = 0.58 (EtOAc/Hexane = 2:8). Mp: 140−142 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.52 (bs, 1H), 7.71 (s, 1H), 7.46 (s, 1H), 7.32 (d, *J* = 6.7 Hz, 2H), 7.23 (d, *J* = 7.7 Hz, 2H), 7.04 (d, *J* = 8.5 Hz, 2H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 135.1, 132.6, 132.4, 132.1, 131.6, 130.3, 126.2, 122.9, 119.8, 114.6, 113.0, 97.5. IR (neat): $\tilde{\nu}$ = 3416, 2959, 2925, 2853, 1675, 1441, 1380, 1291, 1069, 873, 807, 793 cm^{-1}. HRMS *m*/*z*: [M − H]$^-$ calcd for $C_{14}H_8NSe^{79}Br_2$ 427.8189; found 427.8218. HRMS *m*/*z*: [M − H]$^-$ calcd for $C_{14}H_8NSe^{81}Br_2$ 429.8168; found 429.8198.

*Ethyl 4-((5-Bromo-1H-indol-3-yl)selanyl)benzoate (**7gg**).* Brown solid (190.4 mg, 90%, yield). R_f = 0.69 (EtOAc/Hexane = 2:8). Mp: 146−148 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.61 (bs, 1H), 7.79 (d, *J* = 8.5 Hz, 2H), 7.71 (s, 1H), 7.51 (d, *J* = 2.8 Hz, 1H), 7.35 (s, 2H), 7.19 (d, *J* = 8.2 Hz, 2H), 4.32 (q, *J* = 7.0 Hz, 2H), 1.34 (t, *J* = 7.2 Hz, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 166.6, 140.8, 135.2, 132.8, 131.7, 130.0, 127.8, 127.7, 126.3, 122.8, 114.6, 113.1, 96.7, 61.0, 14.4. IR (neat): $\tilde{\nu}$ = 3325, 2957, 2923, 2853, 1697, 1586, 1448, 1268, 1105, 1012, 844, 793 cm^{-1}. HRMS *m*/*z*: [M + H]$^+$ calcd for $C_{17}H_{15}NO_2Se^{79}Br$ 423.9451; found 423.9431. HRMS *m*/*z*: [M + H]$^+$ calcd for $C_{17}H_{15}NO_2Se^{81}Br$ 425.9431; found 425.9420.

*3-(p-Tolylselanyl)-1H-indole (**7ah**).* White solid (132.1 mg, 92%, yield). R_f = 0.37 (EtOAc/Hexane = 2:8). Mp: 66−68 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.66 (s, 1H), 7.11−7.39 (m, 9H), 3.83 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 137.5, 135.7, 134.3, 131.5, 130.8, 129.0, 128.6, 125.6, 122.3, 120.5, 109.5, 95.6, 33.2. IR (neat): $\tilde{\nu}$ = 3109, 1573, 1503, 1474, 1236, 1021, 738 cm^{-1}. HRMS *m*/*z*: [M + H]$^+$ calcd for $C_{15}H_{13}NSe$ 287.0213; found 287.0227.

The values of the characterization data are in accordance with reported literature data.[17d]

*Phenyl(2,4,6-trimethoxyphenyl)selane (**7aa**).* Yellow oil (140.6 mg, 87% yield). R_f = 0.23 (EtOAc/Hexane = 2:8). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.19−7.08 (m, 5H), 6.20 (s, 2H), 3.86 (s, 3H), 3.79 (s, 6H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 163.1, 162.0, 133.6, 128.8, 128.7, 125.3, 97.1, 91.2, 56.4, 55.6. IR (neat): $\tilde{\nu}$ = 3001, 2920, 2849, 1575, 1452, 1335, 1226, 1160, 1076, 813 cm^{-1}. HRMS *m*/*z*: [M + H]$^+$ calcd for $C_{15}H_{17}O_3Se$ 325.0343; found 325.0321.

The values of the characterization data are in accordance with reported literature data.[17d]

*p-Tolyl(2,4,6-trimethoxyphenyl)selane (**7ba**).* Yellow oil (150.0 mg, 89% yield). R_f = 0.24 (EtOAc/Hexane = 2:8). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.11 (d, *J* = 8.2 Hz, 2H), 6.94 (d, *J* = 8.2 Hz, 2H), 6.19 (s, 2H), 3.85 (s, 3H), 3.78 (s, 6H), 2.24 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 162.9, 162.0, 135.2, 129.7, 129.6, 129.3, 97.7, 91.1, 56.4, 55.5, 21.1. IR (neat): $\tilde{\nu}$ = 2960, 2919, 2849, 1583, 1450, 1260, 1223, 1161, 1014, 794 cm^{-1}. HRMS *m*/*z*: [M + H]$^+$ calcd for $C_{16}H_{19}O_3Se$ 339.0499; found 339.0486.

*(4-Methoxyphenyl)(2,4,6-trimethoxyphenyl)selane (**7ca**).* Colorless oil (160.7 mg, 91% yield). R_f = 0.24 (EtOAc/Hexane = 2:8). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.23 (d, *J* = 8.5 Hz, 2H), 6.71 (d, *J* = 8.7 Hz, 2H), 6.17 (s, 2H), 3.84 (s, 3H), 3.79 (s, 6H), 3.74 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 162.8, 161.8, 158.2, 131.9, 123.4, 114.5, 98.7, 91.2, 56.4, 55.5, 55.3. IR (neat): $\tilde{\nu}$ = 2999, 2925, 2838, 1580, 1456, 1225, 1205, 1159, 1030, 811 cm^{-1}. HRMS *m*/*z*: [M + H]$^+$ calcd for $C_{16}H_{19}O_4Se$ 355.0449; found 355.0432.

*(4-Bromophenyl)(2,4,6-trimethoxyphenyl)selane (**7ea**).* White solid (168.8 mg, 84% yield). R_f = 0.28 (EtOAc/Hexane = 2:8). Mp: 100−102 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.23 (d, *J* = 8.3 Hz, 2H), 7.03 (d, *J* = 8.3 Hz, 2H), 6.20 (s, 2H), 3.86 (s, 3H), 3.78 (s, 6H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 163.1, 161.8, 132.9, 131.7, 130.4, 119.1, 96.7, 91.2, 56.4, 55.6. IR (neat): $\tilde{\nu}$ = 2985, 2922, 2853, 1578, 1452, 1250, 1157, 1022, 805, 750 cm^{-1}. HRMS *m*/*z*: [M + H]$^+$ calcd for $C_{15}H_{16}O_3Se^{79}Br$ 402.9442; found 402.9448. HRMS *m*/*z*: [M + H]$^+$ calcd for $C_{15}H_{16}O_3Se^{81}Br$ 402.9428; found 402.9449.

*Ethyl 4-((2,4,6-Trimethoxyphenyl)selanyl)benzoate (**7ga**).* Brown oil (164.0 mg, 83% yield). R_f = 0.30 (EtOAc/Hexane = 2:8). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.78 (d, *J* = 8.2 Hz, 2H), 7.17 (d, *J* = 8.2 Hz, 2H), 6.22 (s, 2H), 4.32 (q, *J* = 7.1 Hz, 2H), 3.88 (s, 3H), 3.78 (s, 6H), 1.35 (t, *J* = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 166.7, 163.5, 162.0, 141.4, 129.8, 127.6, 127.2, 95.8, 91.1, 60.8, 56.4, 55.5, 14.4. IR (neat): $\tilde{\nu}$ = 2958, 2928, 2851, 1708, 1582, 1455, 1269, 1159, 1014, 811, 757 cm^{-1}. HRMS *m*/*z*: [M + H]$^+$ calcd for $C_{18}H_{21}O_5Se$ 397.0554; found 397.0542.

*1-Phenyl-2-((2,4,6-trimethoxyphenyl)selanyl)ethanone (**7ha**).* Yellow solid (147.9 mg, 81% yield). R_f = 0.34 (EtOAc/Hexane = 2:8). Mp: 68−70 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.84 (d, *J* = 7.3 Hz, 2H), 7.50 (t, *J* = 6.0 Hz, 1H), 7.38 (t, *J* = 9.0 Hz, 2H), 6.08 (s, 2H), 3.96 (s, 2H), 3.81 (s, 3H), 3.69 (s, 6H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 195.6, 162.8, 161.8, 136.0, 132.8, 128.6, 128.3, 96.8, 90.9, 56.1, 55.4, 31.2. IR (neat): $\tilde{\nu}$ = 2999, 2941, 2839, 1663, 1589, 1459, 1196, 1146, 1063, 818, 751 cm^{-1}. HRMS *m*/*z*: [M + H]$^+$ calcd for $C_{17}H_{19}O_4Se$ 367.0449; found 367.0434.

*2-Hydroxy-4-methoxy-5-((2,4,6-trimethoxyphenyl)selanyl)-benzaldehyde (**7ja**).* Yellow solid (198.6 mg, 78% yield). R_f = 0.39 (EtOAc/Hexane = 2:8). Mp: 103−105 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 11.41 (s, 1H), 9.48 (s, 1H), 6.75 (s, 1H), 6.41 (s, 1H), 6.27 (s, 2H), 3.95 (s, 3H), 3.91 (s, 3H), 3.83 (s, 6H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 194.1, 163.5, 163.4, 163.0, 162.3, 132.5, 115.9, 113.6, 98.9, 94.4, 90.9, 57.2, 56.3, 55.4. IR (neat): $\tilde{\nu}$ = 3480, 2990, 2940, 2842, 1695, 1480, 1270, 1162, 1012, 813, 756 cm^{-1}. HRMS *m*/*z*: [M + H]$^+$ calcd for $C_{17}H_{18}O_6Se$ 398.0269; found 398.0266.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge at https://pubs.acs.org/doi/10.1021/acs.joc.1c00478.

NMR spectra, experimental information, and X-ray data (PDF)

Accession Codes

CCDC 1990128, 2035467, 2045884, 2062449, and 2062452 contain the supplementary crystallographic data for this paper. These data can be obtained free of charge via www.ccdc.cam.ac.uk/data_request/cif, or by emailing data_request@ccdc.cam.ac.uk, or by contacting The Cambridge Crystallographic Data Centre, 12 Union Road, Cambridge CB2 1EZ, UK; fax: +44 1223 336033.

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Notes

The authors declare no competing financial interest.

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