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Copper-Promoted Carbon−Nitrogen Bond Formation with 2-Iodo-selenophene and Amides

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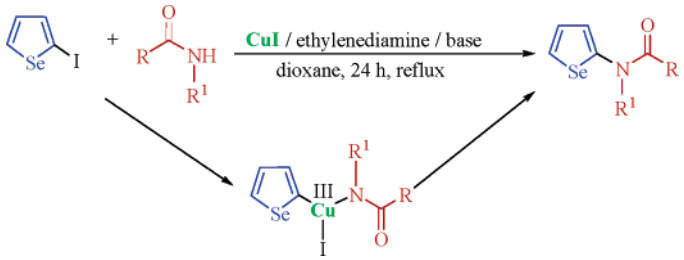

We present here carbon−nitrogen bond formation via a coupling reaction of 2-iodo-selenophene catalyzed by Cu(I) in the presence of a base and an inexpensive ligand, and establish the first route to obtaining 2-nitrogen-selenophene derivatives in good yields. We can anticipate that this reaction works well with oxazolidinones, lactams, and aliphatic and aromatic amides, as nitrogen sources, in the absence of any supplementary additives. In addition, the reaction proceeded cleanly under mild reaction conditions and was sensitive to the ratio of amide/2-iodo-selenophene, as well as the nature of the ligand, base, and solvent.

Introduction

Organoselenium chemistry is a very broad and exciting field, with many opportunities for research and development of applications. Organoselenium compounds have become attractive synthetic targets because of their chemio-, regio-, and stereoselective reactions and their useful biological activities.[1] Furthermore, organoselenium compounds can usually be used in a wide variety of functional groups, thus avoiding protection group chemistry.[2]

Among organoselenium compounds, the selenophene derivatives play an important role in organic synthesis because of their excellent electrical properties, processibility, and environmental stability. However, studies of their chemistry are hampered by poor availability of the material.

The carbon−heteroatom bond formation by the transition-metal-catalyzed cross-coupling was the subject of significant interest during the past few years.[3] Although recent progress in palladium-catalyzed reactions has solved some problems in this area,[4] copper catalysts still hold the advantage of being low cost for use with large-scale industrial applications. Even though

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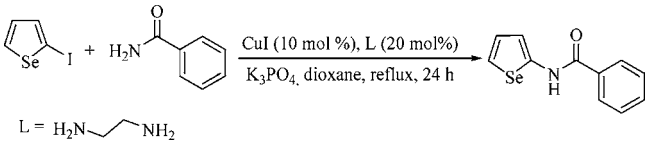
SCHEME 1



a number of traditional methods exist for the carbon−nitrogen bond construction,[5] they typically undergo problems, such as limited generality, harsh conditions, the need to employ stoichiometric quantities of expensive reagents, numerous synthetic steps, and regiochemical doubts. Over the past few years, great progress has been made in carbon−nitrogen bond formation via the cross-coupling reaction of nitrogen compounds with halides, using a copper-catalyzed system.[6] These improvements are certainly a consequence of the studies regarding the effects of several ligands, such as aliphatic diamines, 1,10-phenanthroline, amino acids and their derivatives, and others. These important findings allow the use of common organic solvents (dichloromethane, chloroform, toluene, benzene, DMF, and DMSO) and weaker bases (K_2CO_3, Cs_2CO_3, and K_3PO_4), and they also allow the use of not only aryl iodide, but also aryl bromides and chlorides. After that, these reactions became more attractive being that nowadays they can be carried out at lower temperatures, under milder conditions, and using a catalytic amount of the copper salts.

Our continuing interest in the synthesis[7] and applications[8] of organochalcogens in organic synthesis led us to find out that the 2-iodo-selenephene can effectively be applied to the preparation of carbon−nitrogen bond formation using CuI as a catalyst and an inexpensive aliphatic diamine as a ligand (Scheme 1).

Results and Discussion

The starting 2-iodo-selenophene **2** was readily available using the metalation of selenophene,[9] **1**, with *n*-butyllithium to give the 2-(lithium)-selenophene derivative. The treatment of 2-(lithium)-selenophene with iodine led to the formation of the 2-iodo-selenophene, **2**, isolated in 60% yield after purification (Scheme 2).[10]

SCHEME 2

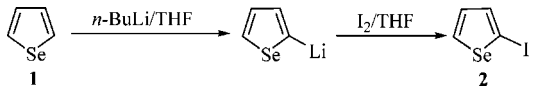
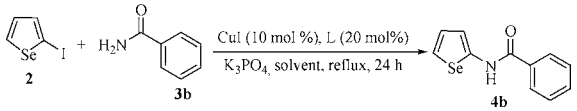


TABLE 1. Study of Solvent Effect on the Coupling Reaction



entry	solvent	time (h)	yield (%)
1	DME	24	31
2	DMSO	24	nr
3	DMF	24	16
4	toluene	24	nr
5	dioxane	6	38
6	dioxane	8	41
7	dioxane	12	46
8	dioxane	24	77

Because our initial studies have focused on the development of an optimum set of reaction conditions, the coupling reaction of 2-iodo-selenophene with benzamide, **3b**, was examined to optimize the reaction conditions. Therefore, 2-iodo-selenophene **2** (0.5 mmol) and benzamide (0.6 mmol) were treated with different copper catalysts, bases, solvents, amounts of catalyst, and ligands. The results of these studies follow.

Determination of the Best Catalyst and Amount of Amide/Ligand. In comparison to the corresponding palladium-catalyzed cross-coupling reactions, the copper-catalyzed version seems to be less sensitive toward the choice of the metal source. In many cases, precursors as different as copper powder and air-sensitive copper(I) salts proved to be suitable for the conversion of reagents in high yields. We then made a study of the effects of different simple copper salts and their amounts on the coupling of 2-iodo-selenophene **2** with benzamide **3b**. All the copper (I) salts tested gave the product with essentially the same level of yield. We chose CuI as the copper source as a result of its low cost. In the optimization process, the effect of the copper amount was investigated, and further experiments showed that the best results for this coupling reaction were obtained with CuI (10 mmol %). The influence of the amide and ligand amounts was also determined. We observed that this coupling reaction required the use of 1.1 equiv of amide and 20 mol % of ligand relative to 2-iodo-selenophene. When 1.5, 2.0, or a large excess of 3.0 equiv of amide was used, unsatisfactory yields of the desired product were obtained.

Determination of the Best Solvent. It is very important to select the proper solvent in the carbon−nitrogen bond formation using CuI as a catalyst. In view of previous methods, toluene is commonly used; however, in certain cases it can be replaced by dioxane or polar solvents, such as *N*-methylpyrrolidone or DMF. We first selected DME, DMSO, DMF, and toluene as reaction solvents, unfortunately, none of the desired products or unsatisfactory yields of the desired products were obtained

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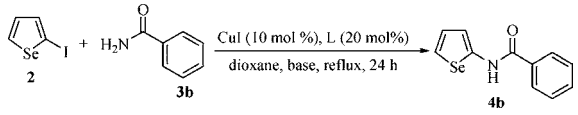
TABLE 2. Study of Base Effect on the Coupling Reaction



2 3b 4b

entry	base	yield[a] (%)
1	K_2CO_3	16
2	Cs_2CO_3	nr
3	KOH	nr
4	K_3PO_4	77
5	none	nr

[a] Reaction conditions: CuI (10 mmol %) in 1,4-dioxane (3 mL), base (0.6 mmol), ethylenediamine (20 mmol %), amide **3b** (0.6 mmol), and 2-iodo-selenophene (0.5 mmol) at reflux for 24 h.

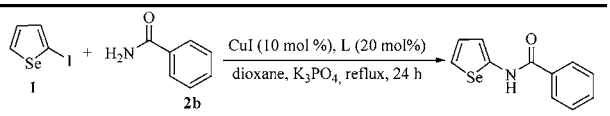
in the catalytic system (Table 1, entries 1−4), while the use of dioxane (3 mL) led to a good yield of the cross-coupling product (Table 1, entry 8). We also concluded that the reaction is sensitive to the reaction time, because the longer the reaction time (from 6 to 24 h), the higher the yield that was obtained (Table 1, entries 5−8).

Determination of the Best Base. For the selection of the appropriate base, a careful choice and a comparison with literature procedures are essential. Generally, in the carbon−nitrogen bond formation, copper-coupling weak bases were employed, given that the use of strong bases can inhibit the catalytic process. Accordingly, K_2CO_3 is applied in many procedures, but Cs_2CO_3, K_3PO_4, KO*t*-Bu, and NaOMe can also be employed with excellent results. In our procedure, when the reaction was carried out with bases such as K_2CO_3, Cs_2CO_3, and KOH, they afforded unsatisfactory yields (Table 2, entries 1−3). Gratifyingly, the use of K_3PO_4, an inexpensive base, resulted in the coupled product in 77% yield (Table 2, entry 4). It is also interesting to note that no coupling was observed when the reaction was carried out in the absence of base (Table 2, entry 5).

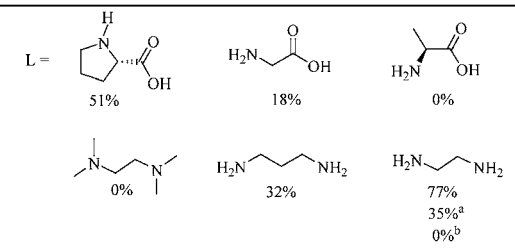
Determination of the Best Ligand. The copper coupling of halides with nitrogen compounds is a traditional choice for the carbon−nitrogen bond formation, but earlier, this procedure required high reaction temperatures, an excess of halides, and stoichiometric quantities of the copper salts. However, a few years later, a series of approaches have shown that the use of ligands (such as aliphatic diamines, 1,10-phenanthroline, amino acids and their derivatives, and others) for copper catalysts resulted in numerous advantages. After that, this coupling became effective with a catalytic amount of copper salts under mild reaction conditions, giving the products in high yields.[6] Thus, we believe that the success of this coupling is highly dependent on the ligand choice. For this reason, we investigated the influence of some inexpensive ligands, such as amino acids and aliphatic diamines. As shown in Table 3, the amino acids L-proline and L-glycine gave unsatisfactory yields of the desired products. The amino acids L-alanine and other amino acids tested did not exhibit catalytic activity in this reaction, and only the starting materials were recovered, even though a long reaction time was used. In addition, either no coupling reaction or a poor yield was observed when the reaction was carried out using TMEDA and 1,3-diaminopropane as ligands. The optimal ligand was ethylenediamine, where the reaction was greatly improved by using ethylenediamine from 10 to 20 mol %. Furthermore, no coupling was observed when the reaction was carried out in the absence of a ligand or at room temperature.

Thus, the careful analysis of the optimized reaction revealed

TABLE 3. Study of Ligand Effect on the Coupling Reaction



1 2b



[a] 10 mol % of ligand. [b] Reaction carried out at room temperature.

that the optimum conditions for this carbon−nitrogen coupling were the use of CuI (10 mmol %) in 1,4-dioxane (3 mL) with K_3PO_4 (0.6 mmol) as the base, ethylenediamine as the ligand (20 mmol %), amide **3b** (0.6 mmol), and 2-iodo-selenophene **2** (0.5 mmol). This was refluxed for 24 h, affording the product **4b** in 77% yield. To demonstrate the efficiency of this reaction, we explored the generality of our method, extending the conditions to aliphatic and aromatic amides, lactams, lactones, as well as aniline and morphopline, and the results are summarized in Table 4.

Inspections of Table 4 show that the reaction worked well for a variety of amides. Both aliphatic and aromatic amides gave the desired product in good yields. A closer inspection of the results revealed that aromatic amides afforded the product in a little higher yield then aliphatic amides (Table 4, entries 1−3). The differentiation in the reactivity between nitrogen from amine or nitrogen from amides can be seen by the coupling of 4-aminobenzamide with 2-iodo-selenophene to provide only the amide **4d** in 45% yield, without any side reaction observed (Table 4, entry 4). To the best of our knowledge, aryl iodide could efficiently react with amines to afford carbon−nitrogen products using copper catalysts.[11] In our case, 2-iodo-selenophene did not react, even though a long reaction time was used. It is important to note that the reaction is sensitive to the size of the lactams, because six- and seven-membered lactams gave lower yields than those of the corresponding five-membered lactams (Table 4, entries 5−8). These results demonstrated that the efficiency of this cross-coupling could significantly depend on the steric effect of the lactam ring. The oxazolidinones were excellent substrates to this protocol, producing the coupling products from moderate to good yields (Table 4, entries 9−12). It is noteworthy that the chiral (*S*)-2-oxazolidinones produced the desired product in excellent yields without any loss of enantiomeric purity, as determined by chiral HPLC. Checking Table 4, we also observed that the reaction worked well with pyrrole, which provides *N*-selenophene-substituted pyrrole **3l** in 50% yield (Table 4, entry 13). Finally, aniline and morphopline (Table 4, entries 7 and 8) did not react under our standard conditions, even after many modifications (change in the base, amount of CuI, solvent, temperature, and

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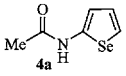
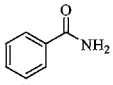
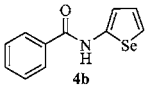
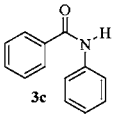
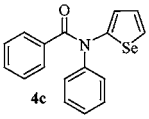
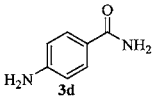
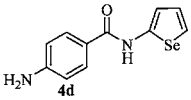
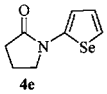
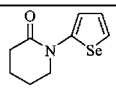
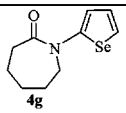
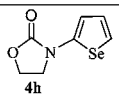
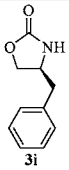
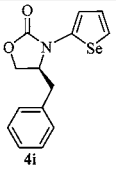
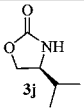
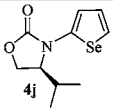
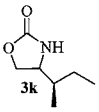
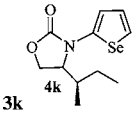
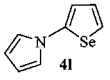
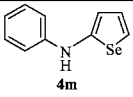
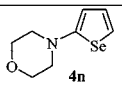
TABLE 4. 2-Nitrogen-selenophene Derivatives Prepared from 2-Iodo-selenophene and Amides

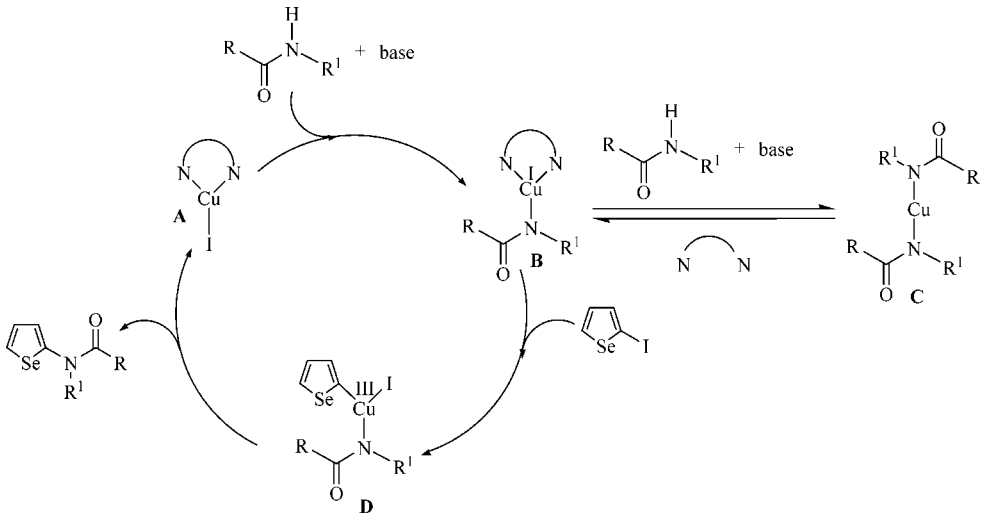
entry	amides	product	yield (%)[a]
1	 **3a**	 **4a**	48
2	 **3b**	 **4b**	77
3	 **3c**	 **4c**	70
4	 **3d**	 **4d**	45
5	 **3e**	 **4e**	77
6	 **3f**	 **4f**	23
7	 **3g**	 **4g**	21
8	 **3h**	 **4h**	90
9	 **3i**	 **4i**	95
10	 **3j**	 **4j**	43
11	 **3k**	 **4k** **3k**	65
12	 **3l**	 **4l**	50
13	 **3m**	 **4m**	-
14	 **3n**	 **4n**	-

[a] Isolated yields.

time), and we observed that if any amount of the desired product was obtained, many side products were formed.

Plausible Mechanism. Although the details of the mechanism, which explains the carbon−nitrogen bond formation using the 2-iodo-selenophene with copper catalysts, are not yet known, an approximated presentation of what may occur in this reaction is shown in Scheme 3. This hypothesis was proposed on the basis of an analogous catalytic process on the amidation of aryl iodide.[12] The reaction pathways leading to selenophene derivative products seem to depend on the amount of both amide

SCHEME 3



substrate and ligand, because the amide excess can inhibit the coupling reaction, probably because the formation of an unreactive cuprate complex, **C**, that inhibits the catalytic process.

Thus, the catalytic cycle starts with a Cu(I) diamine complex, **A**. The mechanism includes mainly three steps: (a) the formation of the intermediate Cu(I) amidate, **B**, which can be formed either through the amide coordination to **A**, followed by depronotation or through the ethylenenediamine association and the subsequent amide dissociation from **C**; (b) the addition of iodide generates the Cu(III) species, **D**; (c) the reductive elimination which leads to the final amination product, **E**.

Conclusion

In summary, we have explored the carbon−nitrogen bond formation via a coupling reaction of 2-iodo-selenophene with Cu(I) and established the first route to obtaining 2-nitrogen-selenophene derivatives in good yields. To our knowledge, this is the first report on copper-catalyzed reactions of 2-iodo-selenophene with amides under such mild condition. The reaction works well with oxazolidinones, lactams, aliphatic and aromatic amides, and in the absence of any supplementary additives. The advantages of using Cu(I) and an inexpensive ligand include their lower cost, which is important when considering the scale-up of a reaction. In addition, the reaction proceeded cleanly under mild reaction conditions and was sensitive to the ratio of amide and the nature of ligand, base, and solvent. This novel approach to functionalized selenophenes could open economical routes to biologically important systems. The pharmacological activities of these compounds are under study in our laboratory. The analysis of the ^{1}H and ^{13}C NMR spectra showed that all of the obtained products presented data in full agreement with their assigned structures.

Experimental Section

General Procedure for the Preparation of the Carbon−Nitrogen Bond Formation. To a stirred solution of benzamide **3b** (0.073 g 0.6 mmol) and 2-iodo-selenophene **2** (0.128 g, 0.5 mmol) in 1,4-dioxane (3 mL) under an argon atmosphere were added CuI (0.01 g, 10 mol %) and ethylenediamine (0.0067 g, 20 mmol %), followed by K_3PO_4 (0.127 g, 0.6 mmol). This was stirred at reflux for 24 h. The reaction mixture was filtered, and the filtrate was concentrated in vacuo. The crude product was separated by SiO_2 column chromatography using hexane and EtOAc (3:1) as eluents to afford the coupled products as white needles.

***N*-(Selenophen-2-yl)benzamide (4b).** Yield: 0.096 g (77%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.31 (s, 1H), 7.89 (d, J = 7.4 Hz, 2H), 7.6 (d, J = 6.16 Hz, 1H), 7.55−7−16 (m, 1H), 7.46−7.42 (m, 2H), 7.16−7.13 (m, 1H), 6.9 (d, J = 3.39 Hz, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 163.6, 141.6, 132.9, 132.2, 128.9, 127.1, 126.0, 123.7, 112.6. MS (relative intensity) *m*/*z*: 251 (39), 105 (100), 95 (8.7), 77 (69), 51 (35). HRMS calcd for $C_{11}H_9NOSe$: 250.9849. Found: 250.9855.

***N*-(Selenophen-2-yl)acetamide (4a).** Yield: 0.47 g (48%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.94 (d, J = 6.0 Hz, 1H), 7.55 (d, J = 4.7 Hz, 1H), 7.09−7.07 (m, 1H), 6.96 (s, 1H), 2.21 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 166.5, 141.4, 125.8, 123.2, 111.8, 23.15. MS (EI, 70 eV, relative intensity) *m*/*z*: 189 (4.7), 147 (3.8), 44 (100), 40 (66). HRMS calcd for C_6H_7NOSe: 188.9692. Found: 188.9701.

***N*-Phenyl-*N*-(selenophen-2-yl)benzamide (4c).** Yield: 0.12 g (70%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.71 (dd, J = 0.92 Hz and J = 6.0 Hz, 1H), 7.39−7.16 (m, 10H), 7.05 (dd, J = 6.16 Hz and J = 4.16 Hz, 1H), 6.3 (dd, J = 0.92 Hz and J = 4.16 Hz, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 167.7, 146.8, 141.4, 135.2, 129.7, 129.6, 129.4, 128.5, 128.4, 127.8, 127.7, 125.7, 125.4. MS (relative intensity) *m*/*z*: 327 (8.3), 105 (100), 95 (12.5), 77 (41.6), 51 (16). HRMS calcd for $C_{17}H_{13}NOSe$: 327.0162. Found: 327.0169.

4-Amino-*N*-(selenophen-2-yl)benzamide (4d). Yield: 0.06 g (45%). ^{1}H NMR (DMSO-d_6, 400 MHz): δ 11.27 (s, 1H), 7.76 (d, J = 8.77 Hz, 2H), 7.49 (d, J = 6.2 Hz, 1H), 7.09 (dd, J = 0.8 Hz and J = 4.09 Hz, 1H), 6.96 (dd, J = 0.8 Hz and J = 4.09 Hz, 1H), 6.62 (d, J = 8.77 Hz, 2H), 5.81 (s, 2H). ^{13}C NMR (DMSO-d_6, 100 MHz): δ 163.32, 152.9, 143.5, 129.8, 126.6, 122.4, 119.4, 113.1, 111.9. MS (relative intensity) *m*/*z*: 265 (0.88), 207 (9), 105 (85), 77 (47), 40 (100). HRMS calcd for $C_{11}H_{10}N_2OSe$: 265.9958. Found: 265. 9964.

1-(Selenophen-2-yl)pyrrolidin-2-one (4e). Yield: 0.08 g (77%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.61 (d, J = 5.85 Hz, 1H), 7.04 (dd, J = 4.06 Hz and J = 6.06 Hz, 1H), 6.50 (d, J = 3.9 Hz, 1H), 3.83 (t, J = 7.2 Hz, 2H), 2.56 (t, J = 8.16 Hz, 2H), 2.16 (quint, J = 7.55 Hz, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 171.9, 142.06, 126.73, 123.10, 111.14, 48.55, 31.08, 17.44. MS (relative intensity) *m*/*z*: 215 (100), 160 (62), 106 (45.8). HRMS calcd for C_8H_9NOSe: 214.9849. Found: 214.9855.

1-(Selenophen-2-yl)piperidin-2-one (4f). Yield: 0.026 g (23%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.6 (d, J = 6.10 Hz, 1H), 7.14 (dd, J = 4.03 Hz and J = 6.07 Hz, 1H), 6.67 (d, J = 3.76 Hz, 1H), 3.86 (t, J = 6.24 Hz, 2H), 2.65 (t, J = 6.62 Hz, 2H), 1.89−1.78 (m, 4H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 171.93, 145.7, 125.8, 123.1, 111.3, 49.8, 37.1, 29.8, 23.3. MS (relative intensity) *m*/*z*: 229 (100), 200 (23), 173 (23), 160 (19), 120 (69), 93 (19). HRMS calcd for $C_9H_{11}NOSe$: 229.0006. Found: 229.0012.

1-(Selenophen-2-yl)azepan-2-one (4g). Yield: 0.025 g (21%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.51 (d, J = 1.02 Hz and J = 6.10 Hz, 1H), 7.14 (dd, J = 4.26 Hz and J = 6.17 Hz, 1H), 6.65 (dd, J = 0.82 Hz and J = 4.19 Hz, 1H), 3.97−3.92 (m, 2H), 2.75−2.70 (m, 2H), 1.73 (s br, 6H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 172.9, 145.7, 125.4, 124.8, 111.3, 49.9, 37.1, 29.2, 27.0, 23.3. MS (relative intensity) *m*/*z*: 243 (3.25), 207 (12), 147 (23), 96 (47), 44 (83), 41 (84), 40 (100). HRMS calcd for $C_{10}H_{13}NOSe$: 243.0162. Found: 243.0169.

3-(Selenophen-2-yl)oxazolidin-2-one (4h). Yield: 0.092 g (90%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.56 (d, J = 5.8 Hz, 1H), 7.07 (dd, J = 4.02 Hz and J = 6.13 Hz, 1H), 6.42 (d, J = 3.8 Hz, 1H), 4.49 (t, J = 7.89 Hz, 2H), 4.02 (t, J = 8.18 Hz, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 155.1, 142.1, 126.7, 123.1, 111.1, 62.3, 45.7. MS (relative intensity) *m*/*z*: 216 (100), 158 (58), 93 (24). HRMS calcd for $C_7H_7NO_2Se$: 216.9641. Found: 216.9649.

(*S*)-4-Benzyl-3-(selenophen-2-yl)oxazolidin-2-one (4i). Yield: 0.15 g (95%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.65 (d, J = 0.8 Hz and J = 5.36 Hz, 1H), 7.36−7.27 (m, 4H), 7.20−7.16 (m, 2H), 6.74 (d, J = 4.09 Hz, 1H), 4.61−4.58 (m, 1H), 4.31 (t, J = 8.20 Hz, 1H), 4.28 (dd, J = 2.9 Hz and J = 6.6 Hz, 1H), 3.27 (dd, J = 2.9 Hz and J = 14.0 Hz, 1H), 2.96 (dd, J = 8.14 Hz and J = 14 Hz, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 154.8, 142.4, 134.9, 129.4, 129.0, 127.5, 126.9, 123.7, 112.2, 66.5, 58.0, 36.1. MS (relative intensity) *m*/*z*: 307 (23), 216 (45), 207 (32), 172 (56), 91 (89), 80 (60), 44 (100). HRMS calcd for $C_{14}H_{14}NO_2Se$: 307.0111. Found: 307.0119. $[\alpha]^{20}_D$ +23° (*c* 1.14, CH_2Cl_2).

(*S*)-4-Isopropyl-3-(selenophen-2-yl)oxazolidin-2-one (4j). Yield: 0.10 g (78%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.55 (dd, J = 0.80 Hz and J = 6.17 Hz, 1H), 7.02 (dd, J = 4.08 Hz and J = 6.13 Hz, 1H), 6.49 (dd, J = 0.80 Hz and J = 4.2 Hz, 1H), 4.44−4.31 (m, 3H), 2.47 (sept, J = 6.72 Hz, 1H), 0.91 (d, J = 7.06 Hz, 3H), 0.79 (d, J = 6.72 Hz, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 155.2, 142.4, 126.7, 123.7, 112.7, 63.6, 61.8, 26.5, 17.5, 14.1. MS (relative intensity) *m*/*z*: 259 (100), 216 (65), 172 (91), 145 (23), 80 (50). HRMS calcd for $C_{10}H_{14}NO_2Se$: 259.0112. Found: 259.0118. $[\alpha]^{20}_D$ +35° (*c* 0.9, CH_2Cl_2).

(12) Strieter, E. R.; Blackmond, D. G.; Buchwald, S. L. *J. Am. Chem. Soc.* **2005**, *127*, 4120−4121.

4-(*S*)-*sec*-Butyl-3-(selenophen-2-yl)oxazolidin-2-one (4k). Yield: 0.088 g (65%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.62 (dd, J = 0.9 Hz and J = 6.0 Hz, 1H), 7.11 (dd, J = 4.09 Hz and J = 6.13 Hz, 1H), 6.82 (dd, J = 0.8 Hz and J = 3.08 Hz, 1H), 4.48−4.45 (m, 1H), 4.41 (t, J = 8.47 Hz, 1H), 4.32 (dd, J = 2.63 Hz and J = 8.08 Hz, 1H), 2.31 (sept, J = 2.98 Hz, 1H), 1.30 (quint, J = 7.30 Hz, 2H), 1.01 (t, J = 7.30 Hz, 3H), 0.86 (d, J = 7.01 Hz, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 155.3, 142.6, 126.7, 123.7, 112.5, 60.1, 63.6, 33.2, 25.3, 11.9, 11.6. MS (relative intensity) *m*/*z*: 273 (30), 216 (41.0), 172 (74.5), 145 (29), 80 (67), 55 (86), 41 (100). HRMS calcd for $C_{11}H_{16}O_2NSe$: 273.0267. Found: 273.0274. $[\alpha]^{20}_D$ +47° (*c* 0.9, CH_2Cl_2).

1-(Selenophen-2-yl)-1*H*-pyrrole (4l). Yield: 0.049 g (50%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.68 (dd, J = 1.02 Hz and J = 5.88 Hz, 1H), 7.20−7.15 (m, 1H), 7.00−6.97 (m, 3H), 6.31−6.28 (m, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 136.5, 128.3, 124.7, 121.6, 117.3, 110.6. MS (relative intensity) *m*/*z*: 197 (100), 169 (19.5), 117 (91), 90 (23). HRMS calcd for C_8H_7NSe: 196.9744. Found: 196.9751.

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Supporting Information Available: Experimental procedures, additional experimental details for the preparation of compounds **4a**−**l**, and ^{1}H and ^{13}C NMR spectra for all reaction products. This material is available free of charge via the Internet at http://pubs.acs.org.

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