Synthesis and Structure of Thia and Selena Heterocycles Containing Cycloamidine Substructures

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Received 23 May 2007; revised 7 June 2007

SYNTHESIS 2007, No. 18, pp 2839–2848
Advanced online publication: 08.08.2007
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SYNTHESIS

Abstract: Cyclization of a bis-arylimidoyl chloride with an acylselenourea leads to the construction of a 1,3-selenazolidine with a heteroradialene structure. Another reaction of the bis-arylimidoyl chloride (hydrazinolysis) leads to the formation of \( \Delta^2-1,2 \)-diazetines, which we have shown previously to be reactive precursors for ring transformation reactions that yield unusual heterocycles. We now demonstrate that the reaction of these \( \Delta^2-1,2 \)-diazetines with various isothio- or isoselenocyanates affords an efficient entry to highly substituted 1,3,4-thia- or -selenadiazines. The structures of these novel derivatives were confirmed by NMR and mass spectrometry, elemental analysis, and X-ray structural analysis. Detailed multidimensional \( ^7 \)Se NMR experiments as well as density functional theory (DFT) calculations show structural specifics of these compounds.

Key words: ring expansion, heterocycles, selenium, sulfur, non-covalent chalcogen interactions

Se is an essential trace element and is incorporated in organisms via the non-proteinogenic amino acid selecysteine and in the active site of redox enzymes such as glutathione peroxidase.\(^1\) Ever since this discovery, there has been increasing scientific interest in the synthesis of selenium compounds and investigation of their pharmacological potential. This has led to quite a few pharmaceutical compounds and agricultural chemicals based on selenium- or sulfur-containing organic compounds. Examples of this interest are the compounds selenazofurine and thiazofurine, which are potent antitumor and antiviral drugs.\(^2\) The antithyroid activity of pharmaceuticals in the methimazol series, based also on the thiazole/selenazole substructure, should be mentioned in this context.\(^2g\)

We are now investigating the potential of \( 1 \) for providing further entry points for obtaining novel selenium- and sulfur-containing heterocycles (Schemes 1 and 2).

A bis-imidoyl chloride \( 1 \) condenses easily with an acylselenourea \( 2 \) to give a 1,3-selenazolidine (Scheme 1). Heating a mixture of \( 1 \) and \( 2 \) in acetonitrile in the presence of triethylamine thus leads to a red product \( 3 \) in acceptable yield (Table 1).

Elemental analysis and mass spectroscopy data of \( 3 \) indicated a 1:1 cyclization product. A \( C=\text{Se} \) signal (ca. \( \delta = 185.5 \)) was missing in the \( ^{13} \)C NMR spectrum and only one signal at \( \delta = 762.1 \) was detected in the \( ^7 \)Se NMR spectrum. A single-crystal X-ray analysis showed that selenium had been incorporated into the ring (Figure 1). The

![Scheme 1](image-url)

Scheme 1 Synthesis of 1,3-selenazolidines \( 3 \) and \( \Delta^2-1,2 \)-diazetines \( 4a-c \) [\( Ar = 4-n\text{-BuC}_6\text{H}_4 (4a), 4-r\text{-BuC}_6\text{H}_4 (4b), 4\text{-EtO}_2\text{CC}_6\text{H}_4 (4c) \)]
unambiguous structural assignment of 3 is shown in Figure 1. The acyl moiety shows a cis arrangement with respect to the chalcogen atom (d_{Se-OAc} = 2.591 Å), and the C1–Se–C3 bond angle is 86.6°. 1,3-Selenazolidines such as 3 cannot be obtained by classical synthetic routes. Until now, access to 3 as well as analogous 1,3,4-thia- or -sel-enadiazines has been limited mainly to the cyclization of α-halo ketones with thio- or selenoureas or thio- or selenosemicarbazides.3b,6

We have previously shown that a controlled hydrazinolysis of 1 conveniently yields Δ2-1,2-diazetines7 4 (Scheme 1), which are quite useful in a number of versatile ring-transformation reactions due to their inherent ring strain.8 Compounds 4 react with isocyanates to yield semicyclic urea derivatives.9 In contrast to this, isothiocyanates immediately lead to ring-transformed products, e.g. 1,3,4-thiadiazines 5 (Scheme 2).9 Animated by this different reactivity, we have now extended our investigations to include acylisothiocyanates, isoselenocyanates, and acylisoselenocyanates.

There are very few existing procedures for obtaining isoselenocyanates.10 We used the protocol of Barton et al. in which gray selenium is added to in situ generated isocyanides.10b The isoselenocyanates obtained in this manner were unstable towards column chromatography and were thus used directly, without further purification, in ring-transformation reactions according to Scheme 2. Upon workup of the reaction mixtures by repetitive crystallization (MeOH–H2O), the 1,3,4-selenadiazines 6a–c were obtained in good yields. The selenadiazine structure was confirmed by elemental analysis, mass spectra, and NMR experiments.

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<th>Compound E (in 5–8)</th>
<th>Ar</th>
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<th>δ(77Se NMR) (ppm)</th>
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* See Schemes 1 and 2 for the reactions.
We then explored the reactivity of 4 towards acylheterocumulenes such as R’CON=C=E (R’ = alkyl, aryl; E = S, Se) (Scheme 2). The acylheterocumulenes were generated in situ by addition of the corresponding carboxylic chlorides to a solution of sodium thiocyanate or potassium selenocyanate in dry acetone at 0 °C. Addition of 4 to the solution and stirring for one hour at room temperature yielded the corresponding 1,3,4-thiadiazines 7 or 1,3,4-selenadiazines 8. The success of this reaction depends significantly on the purity of the carboxylic acid chloride employed. The in situ generated isoselenocyanates decompose rapidly in the presence of traces of hydrochloric acid under extrusion of red amorphous selenium. When the carboxylic acid chlorides were purged by distillation and immediately used, good to excellent yields of the acyl derivatives 7 or 8 were obtained (50–96%; not optimized).

To test the scope and limitations of this reaction, a variety of Δ²-1,2-diazetines 4 as well as acylheterocumulenes were employed. Table 1 demonstrates that we could vary the chalcogen atom E, the aryl groups Ar, and substituents R’ widely within this synthetic route. In addition, we succeeded in expanding the pool of accessible Δ²-1,2-diazetines 4 to include the 4-n-butyphenyl-, 4-tert-butyphenyl-, and 4-(ethoxycarbonyl)phenyl-substituted derivatives 4a, 4b, and 4c, respectively.

Compounds 5–8 are yellow crystalline solids that are remarkably stable in solution. Even after standing in deuterated chloroform for longer periods, decomposition of the in situ generated isoselenocyanates could not be detected by NMR-spectroscopy. Mass spectra of 5–8 show characteristic fragmentation patterns independent of the identity of the chalcogen. The structures shown in Scheme 2 could be confirmed by single-crystal X-ray structural analyses of compounds 7g and 8j (Figure 2).

In both 7g and 8j, the proton is located on the exocyclic N5 and forms an intramolecular hydrogen bond to N4 [N4–H, 2.298 Å (7g) and 2.156 Å (8j)] (Figure 2). The central ring in 1,3,4-thiadizine 7g is very slightly twisted in a boat conformation in which the sulfur atom juts out ca. 10° more than N1 (Figure 3). In contrast, the ring in 1,3,4-selenadizaine 8j is nearly planar (Figure 3).

The ring-bonding angles are significantly influenced by the chalcogen atom. A relatively small C3–E–C2 angle (7g, 101.93°; 8j, 97.72°) is compensated by a widening of the C1–C2–N1 and N1–N2–C3 angles (Figure 2). As in 3, the acyl moiety shows a cis arrangement with respect to the chalcogen. The distance between E and O1 is shorter than expected when compared to classical van der Waals radii [d_EO1 = 2.603 Å (7g), 2.560 Å (8j)]. This noncovalent interaction has been rationalized by a simple p→σ* model between the chalcogen centers. The lone pair on the donor chalcogen (occupied p orbital on O1) interacts ‘through space’ with a properly positioned σ* orbital on the acceptor (S/Se).12 Newer theoretical studies (Bleiholzer et al.) show that noncovalent chalcogen interactions can be described as the sum of several interactions: electrostatics, induction, electronic dispersion, and exchange correlation energies.13 Thus, electrostatics and ‘through space’ hyperconjugation could possibly play a major bonding role in acceptor-substituted systems such as these 1,3,4-thia- or -selenadiazines 7 and 8.

Animated by these results, we performed calculations of the smallest system 7a/8a, in which R’=Me. We optimized both the cis and the trans isomers of these systems at the TPSS(RI)/def2-TZVP (density functional) level of theory (Figure 4).

In accord with experiment, the cis isomer is with ΔE = 33.9 kJ/mol for 7a (S) and 41.8 kJ/mol for 8a (Se) clearly energetically favored (Table 2). An NBO analysis carried out at the B3LYP/6-31++G(d,p) level of theory shows that the ‘through space’ p_O1→σ*C3,E interaction between the divalent chalcogen centers plays a major role and provides ca. 28 (S) or 50 (Se) kJ/mol of stabilization energy. It is quite interesting that this interaction energy doubles upon exchanging S for Se, although the O1–E distance is somewhat less affected [2.535 Å (S) vs 2.516 Å].
The selenium nucleus. However, [1H,77Se]-HMBC correlation experiments showed this to be due to the ortho protons of the N4-aryl substituents (see Figure 2), which are close enough to the selenium nucleus for through-space coupling to occur (Figure 5).

In summary, we have described two new synthetic routes for the preparation of selenacycles. Furthermore, we have enlarged the pool of available ring transformations starting from $\Delta^1$-1,2-diazetines 4. We expect that the new compounds presented in this article would show interesting follow-up chemistry; e.g., pyrazoles could possibly be obtained by a ring-contraction reaction. The feasibility of these reactions will be topics of further articles. Finally, we would like to point out the structural relationship of these new compounds with pharmaceuticals based on thiadiazines (potent matrix-metalloproteinase inhibitors). We are now investigating the biological potential of these compounds.

All solvents were dried and purified by standard techniques. The reagents employed were of commercial quality (Aldrich, Lancaster, Fluka, Merck). Reactions were monitored by TLC (aluminum plates coated with alumina or silica, from Fluka). Melting points were measured on a KSPS 1000 digital detector system from Krüss and a B-545 (Boetius system) from Büchi and are uncorrected. The 1H and 13C NMR spectra were obtained on a Bruker AC 250 (250 MHz) or Bruker DRX-400 (400 MHz) spectrometer. 77Se NMR spectra (76 MHz) were obtained on a Bruker DRC-400 spectrometer. 77Se NMR spectra were obtained in the proton-decoupled mode. This observation is in direct contrast to our proposed structures, which contain no protons in the positions $\alpha$ or $\beta$ to the selenium nucleus. However, [1H,77Se]-HMBC correlation experiments showed this to be due to the ortho protons of the N4-aryl substituents (see Figure 2), which are close enough to the selenium nucleus for through-space coupling to occur (Figure 5).

In summary, we have described two new synthetic routes for the preparation of selenacycles. Furthermore, we have enlarged the pool of available ring transformations starting from $\Delta^1$-1,2-diazetines 4. We expect that the new compounds presented in this article would show interesting follow-up chemistry; e.g., pyrazoles could possibly be obtained by a ring-contraction reaction. The feasibility of these reactions will be topics of further articles. Finally, we would like to point out the structural relationship of these new compounds with pharmaceuticals based on thiadiazines (potent matrix-metalloproteinase inhibitors). We are now investigating the biological potential of these compounds.

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Quantum Chemical Methodology

The density functional programs provided by the ORCA suite were used for all calculations except the NBO analyses. Geometry optimizations were carried out employing the TPSS functional with the def2-TZVP basis set featuring a split valence triple-$
\zeta$ basis set with polarization functions on all atoms. For the TPSS calculations the split resolution of identity approximation (Split-RI-J) was employed. NBO analyses were carried out using an NBO5.0 version employing the B3LYP functional with the 6-31+G(d,p) Basis set.

Crystal Structure Determination

Intensity data for the compounds were collected on a Nonius Kappa CCD diffractometer using graphite-monochromated Mo-K$_\alpha$ radiation. The data were corrected for Lorentz and polarization effects but not for absorption effects. The structures were solved using direct methods (SHELXS) and refined by full-matrix least-squares techniques against $F^2$ (SHELXL-97). For the amine group N5 of compounds 7g and 8i the hydrogen atoms were located by difference Fourier synthesis and refined isotropically. The other hydrogen atoms were included at calculated positions with fixed thermal parameters. All non-hydrogen atoms were refined anisotropically. The program Xp was used for structure representations.

\textbf{N-[4,5-Bis-(phenylimino)-3-p-tolyl-1,3-selenazolidin-2-ylidene]benzamide (3)}

A soln of I (2.77 g, 10 mmol), 2 (3.17 g, 10 mmol), and Et$_3$N (5 mL) in MeCN (80 mL) was heated under reflux for 4 h. Et$_3$N·HCl was removed by filtration, the solvent was then evaporated, and the residue was purified by recrystallization (CHCl$_3$–heptane).

Yield: 58%; yellow crystals; mp 110.5–115.7 °C.

\begin{align}
\text{1H NMR (250 MHz, THF-d$_8$):} & \delta = 9.03 (s, 1 H, NH), 7.42 (d, J = 8.4 Hz, 2 H, CH), 7.26–6.96 (m, 6 H, CH), 2.68–2.48 (m, 7 H, CH$_2$N, CH$_3$), 1.68–1.49 (m, 4 H, CH$_3$), 1.45–1.25 (m, 5 H, CH$_2$), 1.00–0.84 (m, 6 H, CH$_3$).
\end{align}

\begin{align}
\text{13C NMR (63 MHz, THF-d$_8$):} & \delta = 155.1, 154.1, 139.3, 138.6, 135.6, 134.2, 126.8, 126.7, 121.8, 115.7 (CH, C=quat), 37.8 (CH(N)), 33.1, 32.9, 31.9, 23.0, 20.2 (CH$_3$), 11.4 (CH$_2$).
\end{align}

MS (DEI): $m/z = 362$ [M$^+$], 319, 263, 214, 203, 188, 131, 106, 91, 77. Anal. Calcld for C$_{25}$H$_{28}$N$_4$: C, 76.20; H, 8.43; N, 15.46. Found: C, 76.16; H, 8.46; N, 15.45.

1-Methyl-3-[4-(4-tert-butylphenylimino)-4-(4-tert-butylphenylimino)]-$\Lambda^2$-1,2-diazetine (4b)

Yield: 64%; yellow crystals; mp 136.3 °C (dec).

1H NMR (250 MHz, THF-d$_8$): $\delta =$ 9.04 (s, 1 H, NH), 7.50–7.30 (m, 6 H, CH), 7.14 (d, $J =$ 8.4 Hz, 2 H, CH), 2.61 (s, 3 H, CH$_3$N), 1.33, 1.31 (2 s, 18 H, (CH$_3$)$_3$C).

13C NMR (63 MHz, THF-d$_8$): $\delta =$ 155.2, 154.2, 146.8, 142.4, 139.1, 135.3, 123.7, 123.6, 121.6, 115.4 (CH, C=quat), 32.3, 32.0 [(CH$_3$)$_3$C], 28.9, 28.8 [(CH$_3$)$_2$C].


1-Methyl-3-[4-(ethoxy carbonylphenylimino)-4-[4-(ethoxycarbonylphenylimino)]-$\Lambda^2$-1,2-diazetine (4c)

Yield: 50%; orange crystals; mp 128.4–130.8 °C (dec).

1H NMR (250 MHz, THF-d$_8$): $\delta =$ 9.60 (s, 1 H, NH), 8.08–7.91 (m, 4 H, CH), 7.56 (d, $J =$ 8.9 Hz, 2 H, CH), 7.22 (d, $J =$ 8.2 Hz, 2 H, CH), 4.39–4.25 (m, 4 H, CH$_2$), 2.61 (s, 3 H, CH$_3$N), 1.40–1.31 (m, 6 H, CH$_3$).

13C NMR (63 MHz, THF-d$_8$): $\delta =$ 163.2, 163.1 (C=O), 155.0, 145.8, 145.1, 128.7, 128.4, 126.0, 122.3, 120.7, 115.2 (CH, C=quat), 58.5, 58.2 (CH$_2$), 37.8 (CH$_4$N), 11.8, 11.7 (CH$_3$).


Heterodiines 5 and 6a–c; General Procedure

A THF soln (60 mL) of the appropriate I (5 mmol) and Et$_3$N (3 mL, 20 mmol) was cooled to 0 °C and a soln of MeNHNNH$_2$ (5 mmol) in THF (20 mL) was added dropwise. After complete conversion of I (by TLC), the reaction mixture was filtered to remove the Et$_3$N·HCl. The solvent was then removed in vacuo at r.t. and the residue was purified by recrystallization (MeOH–H$_2$O).

1-Methyl-3-[4-(4-n-butylphenylimino)-4-(4-n-butylphenylimino)]-$\Lambda^2$-1,2-diazetine (4a)

Yield: 58%; yellow crystals; mp 110.5–115.7 °C.

1H NMR (250 MHz, THF-d$_8$): $\delta =$ 7.78 (s, 1 H, NH), 7.51 (d, $J =$ 8.4 Hz, 2 H, CH), 7.20–7.10 (m, 4 H, CH), 6.85–6.72 (m, 6 H, CH), 3.77, 3.74 (2 s, 6 H, CH$_2$N, CH$_3$O), 2.37, 2.34 (2 s, 6 H, CH$_3$).

13C NMR (100 MHz, THF-d$_8$): $\delta =$ 156.0, 144.6, 144.2, 141.8, 140.4, 137.4, 135.6, 134.6, 131.0, 129.4, 122.8, 119.8, 118.5, 114.6 (CH, C=quat), 55.4 (CH$_3$O), 43.4 (CH$_3$N), 21.0, 20.8 (CH$_3$).


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Yield: 84%; yellow crystals; mp 208.7–212.3 °C.

1H NMR (250 MHz, CDCl3): δ = 8.2 (s, 1 H, NH), 7.64 (d, J = 8.4 Hz, 2 H, CH), 7.28–7.13 (m, 4 H, CH), 6.85 (d, J = 8.2 Hz, 2 H, CH). 3.83 (s, 3 H, CH3N), 2.37, 2.35 (2 s, 6 H, CH3). 18.2 (CO), 153.4, 145.1, 144.0, 138.2, 136.2, 135.9, 132.5, 130.3, 129.5, 119.6, 119.2 (CH, Cquat). 45.7 (CH3N), 33.5 (CH), 21.0, 20.8 (CH3).


Anal. Calcd for C20H21N5O5: C, 63.30; H, 5.51; N, 18.29; S, 8.11.

2-(4-Methoxyphenylimino)-3-methyl-N-p-tolyl-6-(p-tolylimino)-3,6-dihydro-2H-1,3,4-selenadiazin-5-amine (6a)

Yield: 63%; yellow crystals; mp 179.8–182.3 °C.

1H NMR (250 MHz, CDCl3): δ = 0.8 (s, 1 H, NH), 7.51 (d, J = 8.4 Hz, 2 H, CH), 7.28–7.13 (m, 4 H, CH), 6.85 (d, J = 8.2 Hz, 2 H, CH), 3.83 (s, 3 H, CH3N), 2.37, 2.35 (2 s, 6 H, CH3). 18.2 (CO), 153.4, 145.1, 144.0, 138.2, 136.2, 135.9, 132.5, 130.3, 129.5, 119.6, 119.2 (CH, Cquat). 45.7 (CH3N), 33.5 (CH), 21.0, 20.8 (CH3).


Anal. Calcd for C20H21N5O5: C, 63.30; H, 5.51; N, 18.29; S, 8.11.

Acylheterodiazines 7a–k and 8b–l; General Procedure
To an acetone soln (30 mL) of NaSCN or KSeCN (2 mmol) the appropriate carboxylic chloride (2 mmol) was added and the soln was stirred for 1 h. The reaction mixture was diluted with CHCl3 (25 mL) and filtered. The solvent was removed in vacuo and the residue was purified by column chromatography (alumina, CHCl3–heptane, 2:1). Recrystallization (CHCl3–heptane) yielded the acylheterodiazines 7 and 8.

N-[3-Methyl-5-(p-tolylamino)-6-(p-tolylamino)-3,6-dihydro-2H-1,3,4-thiadiazin-2-ylidene]acetamide (7a)

Yield: 92%; pale-yellow crystals; mp 201.4–203.9 °C.

1H NMR (250 MHz, CDCl3): δ = 8.08 (s, 1 H, NH), 7.55 (d, J = 8.4 Hz, 2 H, CH), 7.26–7.13 (m, 4 H, CH), 6.88 (d, J = 8.2 Hz, 2 H, CH), 3.83 (s, 3 H, CH3N), 2.37, 2.35 (2 s, 6 H, CH3). 18.2 (CO), 153.4, 145.1, 144.0, 138.2, 136.2, 135.9, 132.5, 130.3, 129.5, 119.6, 119.2 (CH, Cquat). 45.7 (CH3N), 33.5 (CH), 21.0, 20.8 (CH3).


Anal. Calcd for C20H21N5O5: C, 63.30; H, 5.51; N, 18.29; S, 8.11.

N-[3-Methyl-5-(p-tolylamino)-6-(p-tolylamino)-3,6-dihydro-2H-1,3,4-thiadiazin-2-ylidene]pivalamide (7d)

Yield: 49%; pale-yellow crystals; mp 170.3 °C.

1H NMR (250 MHz, CDCl3): δ = 8.08 (s, 1 H, NH), 7.51 (d, J = 8.4 Hz, 2 H, CH), 7.26–7.13 (m, 4 H, CH), 6.88 (d, J = 8.3 Hz, 2 H, CH), 3.83 (s, 3 H, CH3N), 2.47 (q, J = 7.5 Hz, 2 CH3), 2.37, 2.34 (2 s, 6 H, CH3). 12.99. Found: C, 65.40; H, 6.13; N, 17.80; S, 7.87.

Found: C, 64.03; H, 6.66; N, 17.72; S, 7.94.

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CH), 3.83 (s, 3 H, CH₃N), 3.23, 3.24 (2 s, 6 H, CH₃), 1.85–1.74 (m, 1 H, CH), 1.04–0.97 (m, 2 H, CH₂), 0.93–0.86 (m, 2 H, CH₂).

¹³C NMR (63 MHz, CDCl₃): δ = 138.9 (CO), 152.6, 145.0, 143.9, 138.2, 136.2, 135.9, 132.5, 130.3, 129.5, 119.6, 119.2 (CH, C_quat), 45.7 (CH₃), 21.0, 20.8 (CH₂), 18.9 (CH₃), 9.5 (CH₃).


Anal. Calcd for C₁₉H₂₁N₂O₂S: C, 66.22; H, 5.34; N, 14.85; S, 6.80.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Yield</th>
<th>Color/MP</th>
<th>Anal. Calcd</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-[3-Methyl-5-(p-tolyloxy)-6-(p-tolyloxy)-3,6-dihydro-2H-1,3,4-thiadiazin-2-ylidene]-cyclobutanecarboxamide (7f)</td>
<td>Yield: 51%; pale-yellow crystals; mp 166.0 °C.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N-[3-Methyl-5-(p-tolyloxy)-6-(p-tolyloxy)-3,6-dihydro-2H-1,3,4-thiadiazin-2-ylidene]-cyclobutanecarboxamide (7f)</td>
<td>Yield: 80%; yellow crystals; mp 166.0 °C.</td>
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</tr>
<tr>
<td>N-[3-Methyl-5-(p-tolyloxy)-6-(p-tolyloxy)-3,6-dihydro-2H-1,3,4-thiadiazin-2-ylidene]-2,2-diphenylacetamide (7g)</td>
<td>Yield: 62%; pale-yellow crystals; mp 166.0 °C.</td>
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<td></td>
</tr>
<tr>
<td>N-[3-Methyl-5-(p-tolyloxy)-6-(p-tolyloxy)-3,6-dihydro-2H-1,3,4-thiadiazin-2-ylidene]-biphenyl-4-carboxamide (7k)</td>
<td>Yield: 86%; yellow crystals; mp 238.0 °C.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

X-ray crystallography data for 91, 65.

Yield: 80%; yellow crystals; mp 166.0 °C.

¹¹H NMR (250 MHz, CDCl₃): δ = 8.08 (s, 1 H, NH), 7.51 (d, J = 8.4 Hz, 2 H, CH), 7.26–7.10 (m, 4 H, CH), 6.88 (d, J = 8.3 Hz, 2 H, CH), 3.83 (s, 3 H, CH₃N), 3.25 (m, 1 H, CH), 2.40–2.10 (m, 10 H, CH₂, CH₃), 2.10–1.80 (m, 2 H, CH₂).

¹³C NMR (63 MHz, CDCl₃): δ = 153.3, 145.0, 144.0, 138.3, 136.2, 136.0, 132.5, 129.5, 119.6, 119.2 (CH, C_quat), 45.7 (CH₃), 25.8, 18.1 (CH₂), 21.0, 20.8 (CH₃).

MS (DEI): m/z = 441 [M⁺], 366, 324, 247, 161, 105, 77, 65.


Found: C, 67.82; H, 5.26; N, 15.89; S, 7.13.

4-Methyl-N-[3-methyl-5-(p-tolyloxy)-6-(p-tolyloxy)-3,6-dihydro-2H-1,3,4-thiadiazin-2-ylidene]benzamide (7i) Yield: 62%; pale-yellow crystals; mp 238.0 °C (dec).
Anal. Calcd for C36H30N4O4Se: C, 57.27; H, 5.26; N, 15.90. Found: C, 57.08; H, 5.28; N, 15.78.

N-[3-Methyl-5-(p-tolylimino)-6-(p-tolylimino)-3,6-dihydro-1H-1,3,4-selenadiazin-2-ylidene]isobutylamide (8c)

Yield: 97%; pale-yellow crystals; mp 167.0 °C.

1H NMR (250 MHz, CDCl3): δ = 8.06 (s, 1 H, NH), 7.52 (d, J = 8.6 Hz, 2 H, CH), 7.25–7.10 (m, 4 H, CH), 2.38, 2.35 (2 s, 6 H, CH3), 1.22 (s, 9 H, C(CH3)3).

13C NMR (63 MHz, CDCl3): δ = 186.2 (CO), 155.7, 149.7, 145.8, 138.6, 136.4, 136.0, 134.0, 130.0, 129.5, 119.3, 119.3, 118.8 (CH, Cquat), 47.1 (CH2N), 43.4 (CH), 29.7, 18.2 (CH2), 21.0, 20.8 (CH3).

77Se NMR (76 MHz, CDCl3): δ = 596.05 (t, J = 2.5 Hz).

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**N-(3-Methyl-5-(p-tolylamino)-6-(p-tolylamino)-3,6-dihydro-2H-1,3,4-selenadiazin-2-ylidene)-2,2-diphenylenacetamide (8j)**

Yield: 86%; yellow crystals; mp 180.0 °C (dec).

1H NMR (250 MHz, CDC13): δ = 8.10 (s, 1 H, NH), 7.52 (d, J = 8.4 Hz, 2 H, CH), 7.39–7.10 (m, 14 H, CH), 6.85 (d, J = 8.2 Hz, 2 H, CH), 5.24 (s, 1 H, CH), 3.85 (s, 3 H, CH3N), 2.39, 2.36 (2 s, 6 H, CH3).

13C NMR (63 MHz, CDC13): δ = 145.8, 138.6, 136.4, 135.9, 132.4, 131.6, 130.5, 129.5, 129.1, 128.9, 128.3, 126.7, 119.4, 118.8 (CH, Cquat), 62.1 (CH), 47.4 (CH3N), 21.1, 20.9 (CH3).

1H NMR (250 MHz, CDCl3): δ = 8.10 (s, 1 H, NH), 7.52 (d, J = 8.4 Hz, 2 H, CH), 7.39–7.10 (m, 14 H, CH), 6.85 (d, J = 8.2 Hz, 2 H, CH), 5.24 (s, 1 H, CH), 3.85 (s, 3 H, CH3N), 2.39, 2.36 (2 s, 6 H, CH3).

13C NMR (63 MHz, CDCl3): δ = 145.8, 138.6, 136.4, 135.9, 132.4, 131.6, 130.5, 129.5, 129.1, 128.9, 128.3, 126.7, 119.4, 118.8 (CH, Cquat), 62.1 (CH), 47.4 (CH3N), 21.1, 20.9 (CH3).

**References**


