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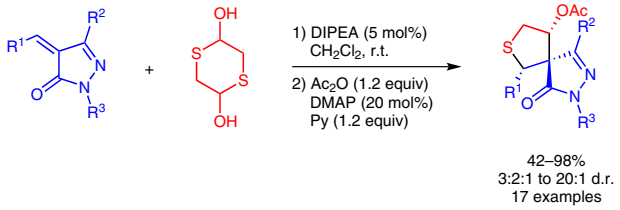
Diastereoselective Synthesis of Spiro[pyrazolone-4,3′-tetrahydrothiophenes] via a Sulfa-Michael/Aldol Domino Reaction

Uğur Kaya[a]
Suruchi Mahajan[a]
Jan-Hendrik Schöbel[a]
Arto Valkonen[b]
Kari Rissanen[b]
Dieter Enders*[a]

[a] Institute of Organic Chemistry, RWTH Aachen University, Landoltweg 1, 52074 Aachen, Germany
enders@rwth-aachen.de
[b] Department of Chemistry, Nanoscience Center, University of Jyvaskyla, 40014 JYU, Finland



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Abstract A new approach for the diastereoselective synthesis of spiro[pyrazolone-4,3′-tetrahydrothiophenes] was developed. The *N*,*N*-diisopropylethylamine-catalyzed reaction of arylidenepyrazolones with *in situ* generated 2-sulfanylacetaldehyde provides the corresponding spiro-heterocycles via a domino sulfa-Michael/aldol reaction in 42–98% yield and 3:2:1 to 20:1 d.r. under mild reaction conditions.

Key words spiro compounds, domino reaction, tetrahydrothiophene, pyrazolone, sulfa-Michael addition

The development of new and efficient synthetic routes to access bioactive heterocyclic compounds is fundamental for the synthesis of valuable natural products, pharmaceuticals and agrochemicals. Tetrahydrothiophenes are present in many natural products and pharmaceuticals,[1] such as the essential coenzyme biotin[2] or analogues of penicillin.[3] In addition, bioactive compounds bearing a pyrazolone moiety display a wide range of biological and pharmaceutical properties, and especially spiro-pyrazolones,[4] such as the spiro compounds **A**,[5] with antimicrobial activity, **B**, a phosphodiesterase inhibitor,[6] **C**, with antitumor activity,[7] and **D**, with antibacterial activity,[8] have attracted much interest in medicinal chemistry (Figure 1).

Recently, arylidenepyrazolones have been recognized as very good substrates to provide new pyrazole and pyrazolone derivatives.[9] 1,4-Dithiane-2,5-diol, the dimer of 2-sulfanylacetaldehyde, emerged as an excellent precursor for the development of domino sulfa-Michael/aldol reactions to provide tetrahydrothiophene rings (Scheme 1).[10] Similar domino transformations of 1,4-dithiane-2,5-diol resulted in the construction of spiro-tetrahydrothiophenes containing

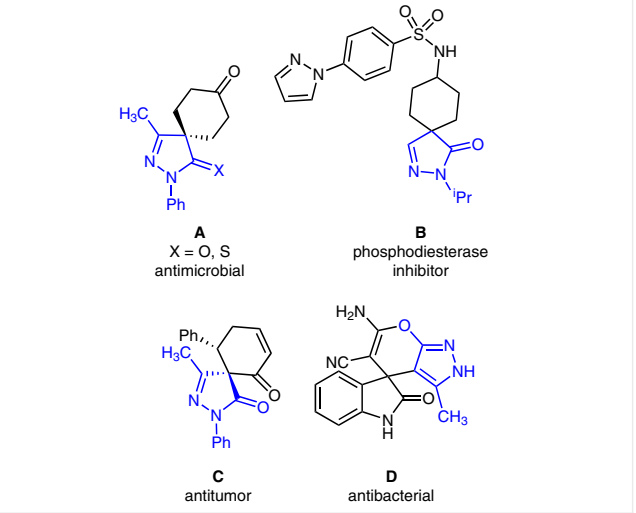
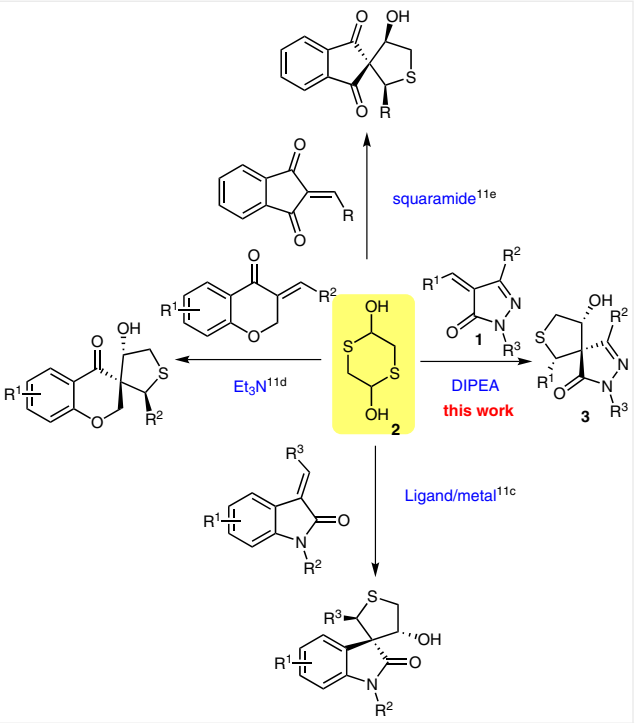


Figure 1 Typical examples of bioactive spiro-pyrazolone compounds

oxindole,[11a,c] 1,3-indanedione,[11e] and chromanone cores.[11b,d] However, to the best of our knowledge, there is no report in the literature on the formation of spiro-tetrahydrothiophenes bearing a pyrazolone moiety.

Herein we report a diastereoselective sulfa-Michael/aldol domino reaction of arylidenepyrazolones **1** and 1,4-dithiane-2,5-diol (**2**) to provide spiro[pyrazolone-4,3′-tetrahydrothiophenes] **3** (Scheme 1). In our initial investigations, different organic and inorganic bases were tested (Table 1). The first attempt using DMAP (10 mol%) in CH_2Cl_2 at room temperature afforded the spirocyclic product **3a** in 83% yield and 12:2:1 d.r (entry 1). The product was acetylated *in situ* to ease the analysis of the NMR spectra. The screening of other organic bases such as Et_3N, DABCO, or DBU provided **3a** in moderate to very good yields and good diastereomeric ratios, but the reaction time extended to 19 hours when the base DABCO was used (entries 2–4). The sulfa-



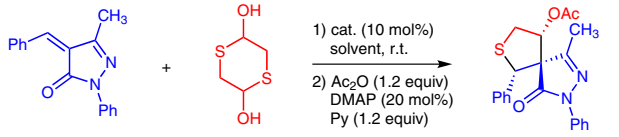
Scheme 1 Synthetic catalytic approaches to spirocyclic tetrahydrothiophenes

Michael/aldol domino reaction proceeded well when the inorganic base K_2CO_3 was used, to afford **3a** in 97% yield and 9:2:1 d.r., but in a longer reaction time (entry 5).

After further screening of organic bases, DIPEA was found to be the best catalyst, providing the spirocyclic product **3a** in 98% yield and 12:2:1 d.r. within 15 minutes (Table 1, entry 9). The reaction was further optimized by conducting the reaction in different solvents and varying the catalyst loading to determine the optimal reaction conditions. We found that DIPEA (5 mol%) in CH_2Cl_2 at room temperature provided **3a** in the best yield of 98% and a d.r. of 15:2:1 within 15 minutes (entry 16).

The optimized reaction conditions were then used to probe the general applicability of the domino sequence (Scheme 2). The sulfa-Michael/aldol reaction of arylidenepyrazolones bearing electron-donating (**1a–f**) and electron-withdrawing groups (**1g–j**) provided the spirocyclic compounds **3a–j** in good to excellent yields and moderate to excellent diastereomeric ratios. Good results in terms of yield and d.r. were also obtained by using a thionyl substituent at the arylidenepyrazolone, showing the presence of heterocyclic substituents in this reaction. The substrate scope was extended by varying the substituents at the N-1 and C-3 positions of the alkylidenepyrazolone. The reaction with different aryl substituents at the N-1 position provided good yields and moderate to very good diastereomeric ratios (**3l–n**). Moderate to good yields and moderate to excellent diastereomeric ratios were achieved by varying the alkyl substituent at C-3 (**3o–q**). It was observed that an increase in the steric hindrance at C-3 resulted in a lower yield (**3n–p**).

Table 1 Catalyst and Solvent Screening[a]

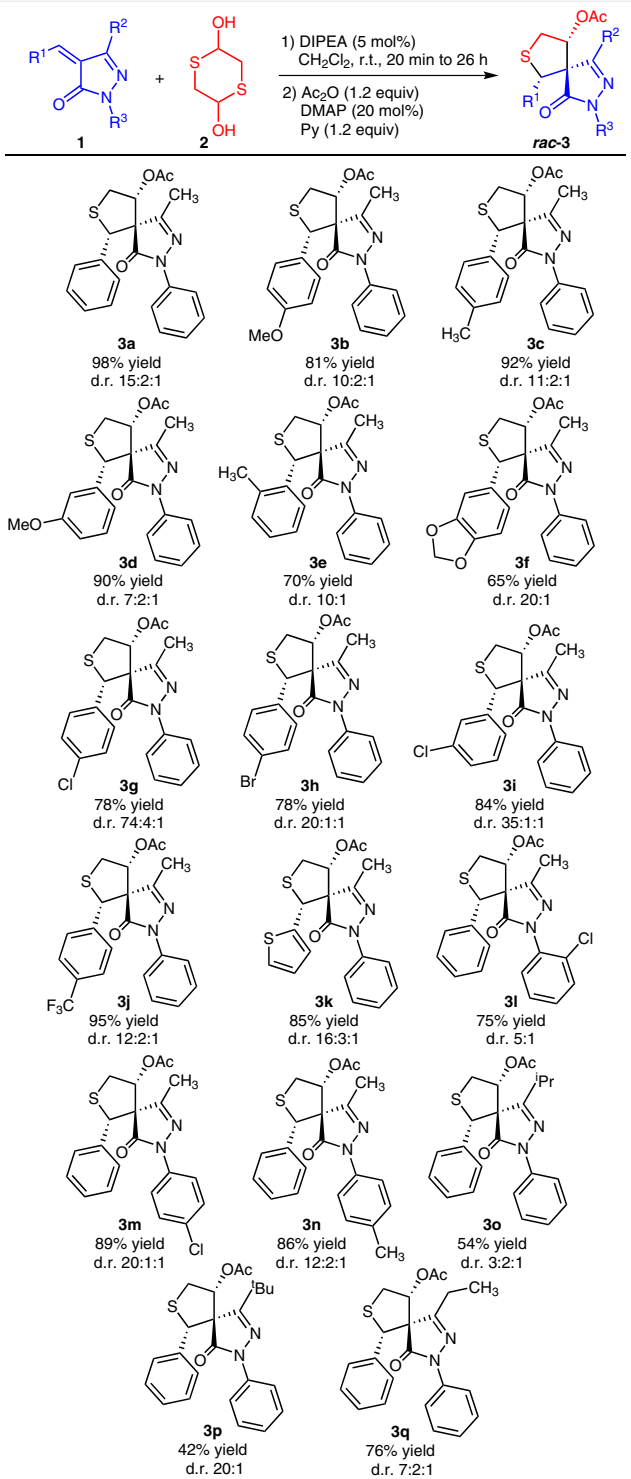


1a 2 *rac*-3a

Entry	Catalyst	Solvent	Reaction time	Yield (%)[b]	d.r.[c]
1	DMAP	CH_2Cl_2	55 min	83	12:2:1
2	Et_3N	CH_2Cl_2	50 min	73	7:2:1
3	DABCO	CH_2Cl_2	19 h	93	10:2:1
4	DBU	CH_2Cl_2	90 min	81	12:2:1
5	K_2CO_3	CH_2Cl_2	48 h	97	9:2:1
6	DBN	CH_2Cl_2	3.5 h	83	11:2:1
7	HMTA[d]	CH_2Cl_2	4 h	77	13:2:1
8	TMEDA	CH_2Cl_2	30 min	98	12:2:1
9	DIPEA	CH_2Cl_2	15 min	98	12:2:1
10	DIPEA	DCE	30 min	79	15:2:1
11	DIPEA	toluene	5 h	96	15:2:1
12	DIPEA	THF	20 min	74	6:1:1
13[e]	DIPEA	CH_2Cl_2	7 d	n.d.	n.d.
14[f]	DIPEA	CH_2Cl_2	20 min	37	17:2:1
15[g]	DIPEA	CH_2Cl_2	25 min	55	16:2:1
16[h]	DIPEA	CH_2Cl_2	15 min	98	15:2:1

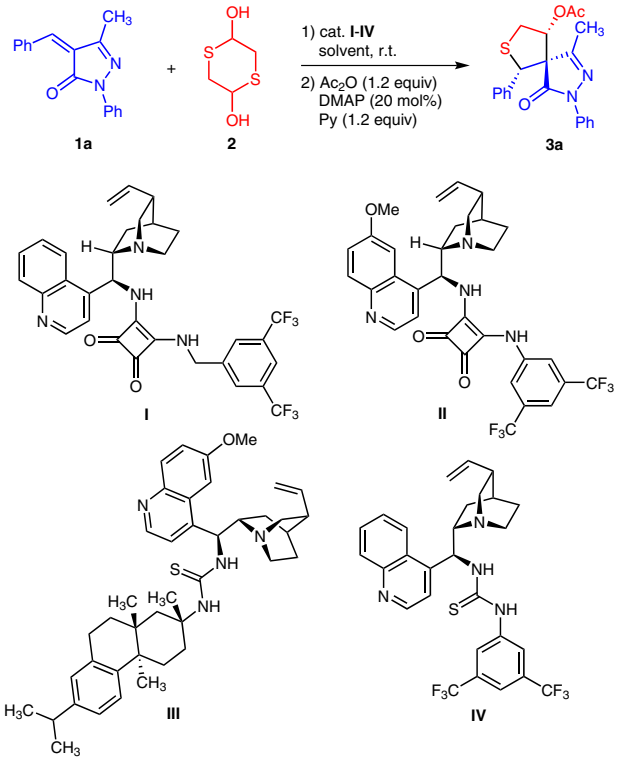
[a] Reaction conditions: **1a** (0.25 mmol), **2** (0.15 mmol), cat. (10 mol%), solvent (2.5 mL, 0.1 M).
[b] Yield of **3a** after flash chromatography.
[c] The diastereomeric ratio was determined by ^{1}H NMR.
[d] HMTA = hexamethylenetetramine.
[e] The reaction was carried out at 0 °C.
[f] The reaction was carried out with DIPEA (30 mol%) at 0 °C.
[g] The reaction was carried out with DIPEA (1 mol%).
[h] The reaction was carried out with DIPEA (5 mol%).

Furthermore, an enantioselective sulfa-Michael/aldol domino sequence was investigated, catalyzed by different chiral bifunctional organocatalysts such as squaramides[12] and thioureas.[13] Initially different squaramide and thiourea catalysts (Table 2, **I–IV**) were tested to provide the product **3a**. In all approaches good to excellent yields could be achieved with good diastereomeric ratios, but the best enantioselectivity of only 19% *ee* was obtained with catalyst **I**. The reaction was then conducted in different solvents and at low temperature employing catalyst **I**, but so far the *ee* value could not be increased beyond 23% (entry 6).



Scheme 2 Substrate scope of the sulfa-Michael/aldol domino reaction

Table 2 Test of an Enantioselective Sulfa-Michael/Aldol Domino Reaction[a]



Entry	Catalyst	Solvent	Reaction time	Yield (%)[b]	*ee* (%)[c]	d.r.[d]
1	**I**	CH_2Cl_2	1 h	98	19	10:2:1
2	**II**	CH_2Cl_2	2.5 h	88	4	12:2:1
3	**III**	CH_2Cl_2	5.5 h	98	18	8:2:1
4	**IV**	CH_2Cl_2	5.5 h	98	14	10:2:1
5	**I**	toluene	3 d	97	17	6:1:1
6	**I**	THF	24 h	66	23	12:3:1
7[e]	**I**	THF	2 d	45	21	13:3:1

[a] Reaction conditions: **1a** (0.25 mmol), **2** (0.15 mmol), cat. (5 mol%), solvent (2.5 mL, 0.1 M).
[b] Yield of **3a** after flash chromatography.
[c] The enantiomeric excess was determined by HPLC on a chiral stationary phase.
[d] The diastereomeric ratio was determined by ^{1}H NMR.
[e] The reaction was carried out at –65 °C.

The relative *cis*-configuration of the spiro[pyrazolone-4,3′-tetrahydrothiophenes] was determined by X-ray crystal structure analysis of compound **3i** (Figure 2).[14]

In conclusion, we have developed a diastereoselective sulfa-Michael/aldol domino reaction of arylidenepyrazolones with 1,4-dithiane-2,5-diol to afford spiro[pyrazolone-4,3′-tetrahydrothiophenes] in moderate to excellent yields and diastereomeric ratios. An attempt to develop an enantioselective variant of this protocol has also been carried out, but so far only 23% *ee* could be reached.

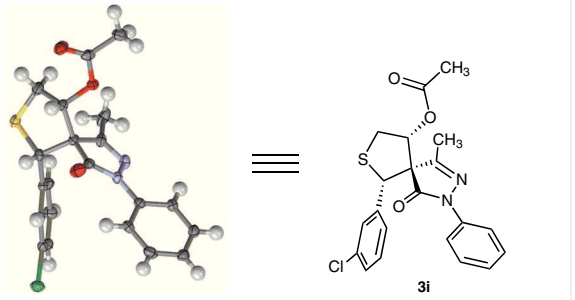


Figure 2 X-ray crystal structure of spiro[pyrazolone-4,3′-tetrahydrothiophene] **3i**. Interestingly, one enantiomer of **3i** was obtained after crystallization from *n*-hexane–ethyl acetate (1:1).

Unless otherwise noted, all commercially available chemicals were used without purification. All solvents were distilled and purified according to standard procedures. Analytical TLC was performed using SIL G-25 UV_{254} from Macherey & Nagel (particle size 0.040–0.063 nm; 230–240 mesh flash) and visualized with UV radiation at 254 nm. ^1H, ^{13}C, and ^{19}F NMR spectra were recorded at ambient temperature on a Varian Innova 400 or Innova 600 instrument. Chemical shifts of the major diastereomer for the ^1H NMR and ^{13}C NMR spectra are reported in ppm with coupling constants given in Hz. Melting points were measured on a LLG MPM-H2 melting point instrument. Mass spectra were acquired on a Finnigan SSQ7000 (EI, 70 eV) spectrometer and on a ThermoFinnigan LCQ Deca XP plus (ESI) spectrometer, and high resolution ESI spectra were obtained on a ThermoFisher Scientific LTQ Orbitrap XL. Analytical HPLC was performed on a Agilent 1260 instrument by using chiral stationary phases (Daicel Chiralpak IA column). The alkylidenepyrazolones **1** were prepared according to known procedures.[15]

Compounds *rac*-3a–q; General Procedure

1,4-Dithiane-2,5-diol (**2**; 0.15 mmol) and DIPEA (5 mol%) were added to a solution of **1** (0.25 mmol) in CH_2Cl_2 (2.5 mL). The reaction mixture was stirred at r.t. until **1** was completely consumed as indicated by TLC. The solution of the crude product was cooled to 0 °C and treated with Ac_2O (0.30 mmol), DMAP (0.05 mmol), and pyridine (0.30 mmol). The crude product was then subjected to flash chromatography (silica gel, *n*-pentane–Et_2O, 20:1 to 6:1); this afforded the spiro product **3**.

1-Methyl-4-oxo-3,6-diphenyl-7-thia-2,3-diazaspiro[4.4]non-1-en-9-yl Acetate (3a)

Yield: 93 mg (98%); colorless solid; mp 78–80 °C; R_f = 0.60 (*n*-pentane–Et_2O, 1:1).

IR (ATR): 1750, 1709, 1595, 1495, 1452, 1401, 1364, 1323, 1292, 1216, 1148, 1053, 918, 839, 798, 758, 696 cm^{-1}.

^1H NMR (600 MHz, $CDCl_3$): δ = 7.70 (m, 2 H, Ar-H), 7.39–7.33 (m, 4 H, Ar-H), 7.25–7.15 (m, 4 H, Ar-H), 5.75 (t, *J* = 8.5 Hz, 1 H, C*H*OAc), 5.14 (s, 1 H, C*H*Ar), 3.81 (dd, *J* = 11.1, 8.3 Hz, 1 H, SCH*H*), 3.19 (dd, *J* = 11.1, 8.8 Hz, 1 H, SC*H*H), 2.38 (s, 3 H, CH_3), 1.98 (s, 3 H, CH_3).

^{13}C NMR (151 MHz, $CDCl_3$): δ = 170.9 (C=O), 169.3 (C=O), 157.5 (C_q), 137.4 (C_q), 133.1 (C_q), 128.9 (2 C, Ar-C), 128.8 (Ar-C), 128.6 (2 C, Ar-C), 127.2 (2 C, Ar-C), 125.5 (Ar-C), 119.2 (2 C, Ar-C), 79.3 (*C*HOAc), 69.2 (C_q), 54.3 (*C*HAr), 33.0 (SCH_2), 20.6 (CH_3), 17.8 (CH_3).

MS (EI, 70 eV): *m*/*z* (%) = 381.3 (7) $[M + H]^+$, 380.1 (33) $[M]^+$, 320.1 (55) $[M – OAc]^+$, 263.1 (100) $[M – C_4H_5O_2S]^+$.

HRMS (ESI): *m*/*z* $[M + H]^+$ calcd for $C_{21}H_{21}N_2O_3S$: 381.1267; found: 381.1268.

6-(4-Methoxyphenyl)-1-methyl-4-oxo-3-phenyl-7-thia-2,3-diazaspiro[4.4]non-1-en-9-yl Acetate (3b)

Yield: 83 mg (81%); yellow solid; mp 38–40 °C; R_f = 0.47 (*n*-pentane–Et_2O, 1:1).

IR (ATR): 2944, 1719, 1596, 1493, 1363, 1216, 1044, 918, 829, 753, 692 cm^{-1}.

^1H NMR (600 MHz, $CDCl_3$): δ = 7.72 (d, *J* = 8.6 Hz, 2 H, Ar-H), 7.36 (m, 2 H, Ar-H), 7.29–7.23 (m, 2 H, Ar-H), 7.17 (m, 1 H, Ar-H), 6.74 (t, *J* = 7.7 Hz, 2 H, Ar-H), 5.72 (t, *J* = 8.5 Hz, 1 H, C*H*OAc), 5.09 (s, 1 H, C*H*Ar), 3.80 (dd, *J* = 11.0, 8.5 Hz, 1 H, SCH*H*), 3.72 (s, 3 H, OCH_3), 3.17 (m, 1 H, SC*H*H), 2.40 (s, 3 H, CH_3), 1.97 (s, 3 H, CH_3).

^{13}C NMR (151 MHz, $CDCl_3$): δ = 171.0 (C=O), 169.3 (C=O), 159.7 (C_q), 157.6 (C_q), 137.4 (C_q), 129.6 (C_q), 128.8 (2 C, Ar-C), 128.4 (2 C, Ar-C), 125.4 (Ar-C), 119.1 (2 C, Ar-C), 113.9 (2 C, Ar-C), 79.2 (*C*HOAc), 69.2 (C_q), 55.2 (OCH_3), 53.9 (*C*HAr), 33.0 (SCH_2), 20.6 (CH_3), 17.8 (CH_3).

MS (EI, 70 eV): *m*/*z* (%) = 411.1 (16) $[M + H]^+$, 410.1 (62) $[M]^+$, 350.1 (50) $[M – HOAc]^+$, 293.1 (100) $[M – C_4H_5O_2S]^+$.

HRMS (ESI): *m*/*z* $[M + Na]^+$ calcd for $C_{22}H_{22}N_2O_4SNa$: 433.1193; found: 433.1192.

1-Methyl-4-oxo-3-phenyl-6-*p*-tolyl-7-thia-2,3-diazaspiro[4.4]non-1-en-9-yl Acetate (3c)

Yield: 91 mg (92%); colorless solid; mp 35–37 °C; R_f = 0.68 (*n*-pentane–Et_2O, 1:1).

IR (ATR): 2951, 1750, 1709, 1596, 1497, 1434, 1402, 1364, 1291, 1216, 1146, 1052, 920, 821, 798, 757, 727, 689 cm^{-1}.

^1H NMR (600 MHz, $CDCl_3$): δ = 7.72 (m, 2 H, Ar-H), 7.36 (m, 2 H, Ar-H), 7.22 (d, *J* = 8.1 Hz, 2 H, Ar-H), 7.18 (m, 1 H, Ar-H), 7.01 (d, *J* = 7.9 Hz, 2 H, Ar-H), 5.73 (t, *J* = 8.5 Hz, 1 H, C*H*OAc), 5.11 (s, 1 H, C*H*Ar), 3.80 (dd, *J* = 11.1, 8.3 Hz, 1 H, SCH*H*), 3.17 (dd, *J* = 11.1, 8.8 Hz, 1 H, SC*H*H), 2.39 (s, 3 H, CH_3), 2.25 (s, 3 H, CH_3), 1.98 (s, 3 H, CH_3).

^{13}C NMR (151 MHz, $CDCl_3$): δ = 171.0 (C=O), 169.3 (C=O), 157.6 (C_q), 138.6 (C_q), 137.5 (C_q), 129.9 (C_q), 129.3 (2 C, Ar-C), 128.8 (2 C, Ar-C), 127.0 (2 C, Ar-C), 125.4 (Ar-C), 119.1 (2 C, Ar-C), 79.4 (*C*HOAc), 69.2 (C_q), 54.1 (*C*HAr), 33.0 (SCH_2), 21.1 (CH_3), 20.6 (CH_3), 17.8 (CH_3).

MS (EI, 70 eV): *m*/*z* (%) = 395.2 (11) $[M + H]^+$, 394.2 (31) $[M]^+$, 334.1 (64) $[M – HOAc]^+$, 277.1 (100) $[M – C_4H_5O_2S]^+$.

HRMS (ESI): *m*/*z* $[M + Na]^+$ calcd for $C_{22}H_{22}N_2O_3SNa$: 417.1243; found: 417.1240.

6-(3-Methoxyphenyl)-1-methyl-4-oxo-3-phenyl-7-thia-2,3-diazaspiro[4.4]non-1-en-9-yl Acetate (3d)

Yield: 92 mg (90%); brown oil; R_f = 0.55 (*n*-pentane–Et_2O, 1:1).

IR (ATR): 2951, 1751, 1709, 1595, 1493, 1458, 1433, 1402, 1366, 1270, 1216, 1153, 1045, 923, 872, 756, 713, 692 cm^{-1}.

^1H NMR (400 MHz, $CDCl_3$): δ = 7.72 (d, *J* = 7.8 Hz, 2 H, Ar-H), 7.34 (t, *J* = 7.9 Hz, 2 H, Ar-H), 7.19–7.08 (m, 2 H, Ar-H), 6.93 (d, *J* = 7.5 Hz, 1 H, Ar-H), 6.84 (s, 1 H, Ar-H), 6.75 (d, *J* = 8.4 Hz, 1 H, Ar-H), 5.72 (t, *J* = 8.6 Hz, 1 H, C*H*OAc), 5.09 (s, 1 H, C*H*Ar), 3.78 (dd, *J* = 11.0, 8.3 Hz, 1 H, SC*H*H), 3.56 (s, 3 H,OCH_3), 3.16 (dd, *J* = 10.9, 9.0 Hz, 1 H, SCH*H*), 2.36 (s, 3 H, CH_3), 1.96 (s, 3 H, CH_3).

^{13}C NMR (101 MHz, $CDCl_3$): δ = 171.0 (C=O), 169.2 (C=O), 159.6 (C_q), 157.5 (C_q), 137.4 (C_q), 134.6 (C_q), 129.6 (Ar-C), 128.8 (2 C, Ar-C), 125.4 (Ar-C), 119.3 (Ar-C), 119.0 (2 C, Ar-C), 114.8 (Ar-C), 112.2 (Ar-C), 79.3 (*C*HOAc), 69.1 (C_q), 55.0 (OCH_3), 54.1 (*C*HAr), 33.0 (SCH_2), 20.6 (CH_3), 17.8 (CH_3).

MS (EI, 70 eV): *m*/*z* (%) = 411.0 (9) [M + H]$^+$, 410.0 (21) [M]$^+$, 350.0 (38) [M – HOAc]$^+$, 292.9 (100) [M – $C_4H_5O_2S$]$^+$.

HRMS (ESI): *m*/*z* [M + Na]$^+$ calcd for $C_{22}H_{22}N_2O_4SNa$: 433.1193; found: 433.1193.

1-Methyl-4-oxo-3-phenyl-6-*o*-tolyl-7-thia-2,3-diazaspiro[4.4]non-1-en-9-yl Acetate (3e)

Yield: 69 mg (70%); colorless solid; mp 127–129 °C; R_f = 0.59 (*n*-pentane–Et_2O, 1:1).

IR (ATR): 2958, 2312, 2093, 1724, 1476, 1361, 1212, 1025, 737 cm^{-1}.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.75–7.65 (m, 3 H, Ar-H), 7.35–7.28 (m, 2 H, Ar-H), 7.17–7.09 (m, 3 H, Ar-H), 7.02 (m, 1 H, Ar-H), 5.73 (t, *J* = 8.3 Hz, 1 H, *CH*OAc), 5.41 (s, 1 H, *CH*Ar), 3.82 (dd, *J* = 11.2, 8.1 Hz, 1 H, SC*H*H), 3.21 (dd, *J* = 11.2, 8.5 Hz, 1 H, SCH*H*), 2.53 (s, 3 H, CH_3), 2.26 (s, 3 H, CH_3), 1.98 (s, 3 H, CH_3).

^{13}C NMR (101 MHz, $CDCl_3$): δ = 170.9 (C=O), 169.2 (C=O), 157.8 (C_q), 137.5 (C_q), 137.3 (C_q), 131.6 (C_q), 131.0 (Ar-C), 128.8 (2 C, Ar-C), 128.5 (Ar-C), 128.1 (Ar-C), 125.9 (Ar-C), 125.3 (Ar-C), 118.8 (2 C, Ar-C), 79.6 (*C*HOAc), 68.2 (C_q), 50.3 (*C*HAr), 33.4 (SCH_2), 20.7 (CH_3), 19.6 (CH_3), 18.6 (CH_3).

MS (EI, 70 eV): *m*/*z* (%) = 395.2 (1) [M + H]$^+$, 335.0 (1) [M – OAc]$^+$.

HRMS (ESI): *m*/*z* [M + Na]$^+$ calcd for $C_{22}H_{22}N_2O_3SNa$: 417.1243; found: 417.1226.

6-(Benzo[*d*][1,3]dioxol-5-yl)-1-methyl-4-oxo-3-phenyl-7-thia-2,3-diazaspiro[4.4]non-1-en-9-yl Acetate (3f)

Yield: 69 mg (65%); orange solid; mp 42–44 °C; R_f = 0.63 (*n*-pentane–Et_2O, 1:1).

IR (ATR): 2902, 1717, 1598, 1488, 1362, 1221, 1037, 922, 758 cm^{-1}.

^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.73 (m, 2 H, Ar-H), 7.40–7.34 (m, 2 H, Ar-H), 7.18 (m, 1 H, Ar-H), 6.91 (d, *J* = 1.8 Hz, 1 H, Ar-C), 6.80 (dd, *J* = 8.2, 1.9 Hz, 1 H, Ar-H), 6.62 (d, *J* = 8.1 Hz, 1 H, Ar-H), 5.90 (dd, *J* = 12.0, 1.5 Hz, 2 H, -OCH_2O-), 5.70 (t, *J* = 8.6 Hz, 1 H, *CH*OAc), 5.05 (s, 1 H, *CH*Ar), 3.79 (dd, *J* = 11.1, 8.3 Hz, 1 H, SC*H*H), 3.17 (dd, *J* = 11.1, 8.9 Hz, 1 H, SCH*H*), 2.42 (s, 3 H, CH_3), 1.98 (s, 3 H, CH_3).

^{13}C NMR (151 MHz, $CDCl_3$): δ = 170.8 (C=O), 169.2 (C=O), 157.5 (C_q), 147.9 (C_q), 147.8 (C_q), 137.4 (C_q), 128.9 (2 C, Ar-C), 126.6 (C_q), 125.5 (Ar-C), 121.0 (Ar-C), 119.2 (2 C, Ar-C), 108.2 (Ar-C), 107.5 (Ar-C), 101.3 (-OCH_2O-), 79.1 (*C*HOAc), 69.2 (C_q), 54.2 (*C*HAr), 33.0 (SCH_2), 20.6 (CH_3), 17.9 (CH_3).

MS (EI, 70 eV): *m*/*z* (%) = 425.3 (2) [M + H]$^+$, 424.2 (7) [M]$^+$, 364.2 (16) [M – HOAc]$^+$, 307.1 (100) [M – $C_4H_5O_2S$]$^+$.

HRMS (ESI): *m*/*z* [M + Na]$^+$ calcd for $C_{22}H_{20}N_2O_5SNa$: 447.0985; found: 447.0984.

6-(4-Chlorophenyl)-1-methyl-4-oxo-3-phenyl-7-thia-2,3-diazaspiro[4.4]non-1-en-9-yl Acetate (3g)

Yield: 81 mg (78%); colorless solid; mp 37–39 °C; R_f = 0.50 (*n*-pentane–Et_2O, 1:1).

IR (ATR): 2939, 2291, 2083, 1715, 1596, 1491, 1361, 1213, 1043, 917, 828, 751, 691 cm^{-1}.

^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.74–7.70 (m, 2 H, Ar-H), 7.37 (m, 2 H, Ar-H), 7.31–7.27 (m, 2 H, Ar-H), 7.22–7.18 (m, 3 H, Ar-H), 5.73 (t, *J* = 8.6 Hz, 1 H, *CH*OAc), 5.09 (s, 1 H, *CH*Ar), 3.81 (dd, *J* = 11.1, 8.3 Hz, 1 H, SC*H*H), 3.19 (dd, *J* = 11.1, 8.9 Hz, 1 H, SCH*H*), 2.37 (s, 3 H, CH_3), 1.98 (s, 3 H, CH_3).

^{13}C NMR (151 MHz, $CDCl_3$): δ = 170.7 (C=O), 169.2 (C=O), 157.2 (C_q), 137.3 (C_q), 134.6 (C_q), 131.8 (C_q), 128.9 (2 C, Ar-C), 128.8 (2 C, Ar-C), 128.6 (2 C, Ar-C), 125.6 (Ar-C), 119.1 (2 C, Ar-C), 79.2 (*C*HOAc), 69.1 (C_q), 53.5 (*C*HAr), 33.1 (SCH_2), 20.6 (CH_3), 17.8 (CH_3).

MS (EI, 70 eV): *m*/*z* (%) = 416.1 (16) [M, ^{37}Cl]$^+$, 414.1 (39) [M, ^{35}Cl]$^+$, 356.0 (17) [M – HOAc, ^{37}Cl]$^+$, 354.0 (65) [M – HOAc, ^{35}Cl]$^+$, 299.1 (31) [M – $C_4H_5O_2S$, ^{37}Cl]$^+$, 297.0 (100) [M – $C_4H_5O_2S$, ^{35}Cl]$^+$.

HRMS (ESI): *m*/*z* [M + Na]$^+$ calcd for $C_{21}H_{19}ClN_2O_3SNa$: 437.0697; found: 437.0698.

6-(4-Bromophenyl)-1-methyl-4-oxo-3-phenyl-7-thia-2,3-diazaspiro[4.4]non-1-en-9-yl Acetate (3h)

Yield: 90 mg (78%); colorless solid; mp 38–40 °C; R_f = 0.53 (*n*-pentane–Et_2O, 1:1).

IR (ATR): 1750, 1708, 1595, 1492, 1430, 1398, 1365, 1279, 1214, 1147, 1105, 1054, 1009, 955, 920, 881, 827, 793, 757, 725, 691 cm^{-1}.

^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.74–7.70 (m, 2 H, Ar-H), 7.40–7.33 (m, 4 H, Ar-H), 7.24–7.17 (m, 3 H, Ar-H), 5.73 (t, *J* = 8.6 Hz, 1 H, *CH*OAc), 5.07 (s, 1 H, *CH*Ar), 3.80 (dd, *J* = 11.1, 8.3 Hz, 1 H, SC*H*H), 3.19 (dd, *J* = 11.1, 8.9 Hz, 1 H, SCH*H*), 2.37 (s, 3 H, CH_3), 1.98 (s, 3 H, CH_3).

^{13}C NMR (151 MHz, $CDCl_3$): δ = 170.7 (C=O), 169.2 (C=O), 157.1 (C_q), 137.3 (C_q), 132.3 (C_q), 131.8 (2 C, Ar-C), 128.9 (2 C, Ar-C), 128.9 (2 C, Ar-C), 125.6 (Ar-C), 122.8 (C_q), 119.1 (2 C, Ar-C), 79.2 (*C*HOAc), 68.98 (C_q), 53.5 (*C*HAr), 33.1 (SCH_2), 20.6 (CH_3), 17.8 (CH_3).

MS (EI, 70 eV): *m*/*z* (%) = 460.1 (34) [M, ^{81}Br]$^+$, 458.0 (33) [M, ^{79}Br]$^+$, 400.0 (62) [M – OAc, ^{81}Br]$^+$, 398.0 (60) [M – OAc, ^{79}Br]$^+$, 343.1 (94) [M – $C_4H_6O_2S$, ^{81}Br]$^+$, 341.0 (100) [M – $C_4H_6O_2S$, ^{79}Br]$^+$.

HRMS (ESI): *m*/*z* [M + Na]$^+$ calcd for $C_{21}H_{19}N_2O_3S^{79}BrNa$: 481.0192; found: 481.0193.

6-(3-Chlorophenyl)-1-methyl-4-oxo-3-phenyl-7-thia-2,3-diazaspiro[4.4]non-1-en-9-yl Acetate (3i)

Yield: 87 mg (84%); colorless solid; mp 119–121 °C; R_f = 0.59 (*n*-pentane–Et_2O, 1:1).

IR (ATR): 2950, 1728, 1589, 1489, 1361, 1219, 1041, 913, 768, 698 cm^{-1}.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.72–7.66 (m, 2 H, Ar-H), 7.43 (m, 1 H, Ar-H), 7.39–7.32 (m, 2 H, Ar-H), 7.23–7.10 (m, 4 H, Ar-H), 5.71 (t, *J* = 8.6 Hz, 1 H, *CH*OAc), 5.07 (s, 1 H, *CH*Ar), 3.79 (dd, *J* = 11.1, 8.3 Hz, 1 H, SC*H*H), 3.18 (dd, *J* = 11.1, 8.9 Hz, 1 H, SCH*H*), 2.36 (s, 3 H, CH_3), 1.97 (s, 3 H, CH_3).

^{13}C NMR (101 MHz, $CDCl_3$): δ = 170.7 (C=O), 169.2 (C=O), 157.1 (C_q), 137.2 (C_q), 135.4 (C_q), 134.6 (C_q), 129.9 (Ar-C), 129.0 (Ar-C), 128.9 (2 C, Ar-C), 127.3 (Ar-C), 125.7 (Ar-C), 125.5 (Ar-C), 119.3 (2 C, Ar-C), 79.1 (*C*HOAc), 69.0 (C_q), 53.5 (*C*HAr), 33.1 (SCH_2), 20.6 (CH_3), 17.7 (CH_3).

MS (EI, 70 eV): *m*/*z* (%) = 415.9 (14) [M, ^{37}Cl]$^+$, 414.0 (35) [M, ^{35}Cl]$^+$, 356.0 (19) [M – HOAc, ^{37}Cl]$^+$, 354.0 (48) [M – HOAc, ^{35}Cl]$^+$, 298.9 (29) [M – $C_4H_5O_2S$, ^{37}Cl]$^+$, 297.0 (100) [M – $C_4H_5O_2S$, ^{35}Cl]$^+$.

HRMS (ESI): *m*/*z* [M + Na]$^+$ calcd for $C_{21}H_{19}N_2O_3SClNa$: 437.0697; found: 437.0696.

1-Methyl-4-oxo-3-phenyl-6-[4-(trifluoromethyl)phenyl]-7-thia-2,3-diazaspiro[4.4]non-1-en-9-yl Acetate (3j)

Yield: 107 mg (95%); colorless solid; mp 40–42 °C; R_f = 0.53 (*n*-pentane–Et_2O, 1:1).

IR (ATR): 2101, 1712, 1600, 1497, 1322, 1219, 1119, 1053, 921, 846, 755, 688 cm^{-1}.

^1H NMR (600 MHz, $CDCl_3$): δ = 7.70 (m, 2 H, Ar-H), 7.48 (m, 4 H, Ar-H), 7.37 (m, 2 H, Ar-H), 7.20 (t, *J* = 7.4 Hz, 1 H, Ar-H), 5.75 (t, *J* = 8.6 Hz, 1 H, C*H*OAc), 5.16 (s, 1 H, C*H*Ar), 3.83 (dd, *J* = 11.1, 8.3 Hz, 1 H, SC*H*H), 3.21 (dd, *J* = 11.1, 8.9 Hz, 1 H, SCH*H*), 2.37 (s, 3 H, CH_3), 1.99 (s, 3 H, CH_3).

^{13}C NMR (151 MHz, $CDCl_3$): δ = 170.6 (C=O), 169.2 (C=O), 157.0 (C_q), 137.46 (C_q), 137.2 (C_q), 130.9 (q, *J* = 32.7 Hz, C_q), 128.9 (2 C, Ar-C), 127.7 (2 C, Ar-C), 125.7 (Ar-C), 125.6 (2 C, Ar-C), 123.7 (q, *J* = 272.3 Hz, CF_3), 119.1 (2 C, Ar-C), 79.3 (*C*HOAc), 69.0 (C_q), 53.5 (*C*HAr), 33.1 (SCH_2), 20.6 (CH_3), 17.7 (CH_3).

^{19}F NMR (376 MHz, $CDCl_3$): δ = –62.78 (s).

MS (EI, 70 eV): *m*/*z* (%) = 449.0 (7) $[M + H]^+$, 447.9 (31) $[M]^+$, 387.9 (33) $[M – HOAc]^+$, 330.6 (100) $[M – C_4H_6O_2S]^+$.

HRMS (ESI): *m*/*z* $[M + Na]^+$ calcd for $C_{22}H_{19}N_2O_3S\ F_3Na$: 471.0961; found: 471.0961.

1-Methyl-4-oxo-3-phenyl-6-(2-thienyl)-7-thia-2,3-diazaspiro[4.4]non-1-en-9-yl Acetate (3k)

Yield: 82 mg (85%); orange solid; mp 39–41 °C; R_f = 0.46 (*n*-pentane–Et_2O, 1:1).

IR (ATR): 3073, 2953, 1750, 1708, 1595, 1495, 1431, 1363, 1274, 1215, 1141, 1050, 919, 849, 800, 757, 697 cm^{-1}.

^1H NMR (600 MHz, $CDCl_3$): δ = 7.81–7.77 (m, 2 H, Ar-H), 7.40–7.35 (m, 2 H, Ar-H), 7.19 (m, 1 H, Ar-H), 7.16 (m, 1 H, Ar-$H_{2\text{-Thienyl}}$), 6.97 (m, 1 H, Ar-$H_{2\text{-Thienyl}}$), 6.85 (m, 1 H, Ar-$H_{2\text{-Thienyl}}$), 5.69 (t, *J* = 8.6 Hz, 1 H, C*H*OAc), 5.32 (s, 1 H, C*H*Ar), 3.80 (dd, *J* = 11.1, 8.3 Hz, 1 H, SC*H*H), 3.21 (dd, *J* = 11.0, 9.0 Hz, 1 H, SCH*H*), 2.47 (s, 3 H, CH_3), 1.98 (s, 3 H, CH_3).

^{13}C NMR (151 MHz, $CDCl_3$): δ = 170.4 (C=O), 169.2 (C=O), 157.4 (C_q), 137.5 (C_q), 136.6 (C_q), 128.9 (2 C, Ar-C), 127.1 (Ar-C), 126.4 (Ar-C), 125.8 (Ar-C), 125.5 (Ar-C), 119.1 (2 C, Ar-C), 78.8 (*C*HOAc), 69.0 (C_q), 49.3 (*C*HAr), 33.3 (SCH_2), 20.6 (CH_3), 17.8 (CH_3).

MS (EI, 70 eV): *m*/*z* (%) = 387.0 (10) $[M + H]^+$, 385.9 (36) $[M]^+$, 325.8 (38) $[M – HOAc]^+$, 268.7 (100) $[M – C_4H_5O_2S]^+$.

HRMS (ESI): *m*/*z* $[M + Na]^+$ calcd for $C_{19}H_{18}N_2O_3S_2Na$: 409.0651; found: 409.0651.

3-(2-Chlorophenyl)-1-methyl-4-oxo-6-phenyl-7-thia-2,3-diazaspiro[4.4]non-1-en-9-yl Acetate (3l)

Yield: 78 mg (75%); colorless solid; mp 153–155 °C; R_f = 0.50 (*n*-pentane–Et_2O, 1:1).

IR (ATR): 3016, 2969, 2040, 1740, 1592, 1486, 1443, 1366, 1218, 1052, 919, 763, 701 cm^{-1}.

^1H NMR (400 MHz, $CDCl_3$): δ = 7.43 (m, 3 H, Ar-H), 7.31–7.25 (m, 5 H, Ar-H), 7.08–7.04 (m, 1 H, Ar-H), 5.76 (t, *J* = 8.6 Hz, 1 H, C*H*OAc), 5.14 (s, 1 H, C*H*Ar), 3.78 (dd, *J* = 11.0, 8.3 Hz, 1 H, SC*H*H), 3.20 (dd, *J* = 11.0, 8.9 Hz, 1 H, SCH*H*), 2.39 (s, 3 H, CH_3), 2.02 (s, 3 H, CH_3).

^{13}C NMR (101 MHz, $CDCl_3$): δ = 169.7 (C=O), 168.9 (C=O), 156.5 (C_q), 133.9 (C_q), 133.8 (C_q), 131.9 (C_q), 130.3 (Ar-C), 129.8 (Ar-C), 128.7 (4 C, Ar-C), 128.5 (2 C, Ar-C), 127.3 (Ar-C), 75.8 (*C*HOAc), 66.5 (C_q), 49.6 (*C*HAr), 30.9 (SCH_2), 20.7 (CH_3), 13.7 (CH_3).

MS (EI, 70 eV): *m*/*z* (%) = 356.1 (11) $[M – HOAc, {}^{37}Cl]^+$, 354.1 (27) $[M – HOAc, {}^{35}Cl]^+$, 299.1 (35) $[M – C_4H_5O_2S, {}^{37}Cl]^+$, 297.1 (100) $[M – C_4H_5O_2S, {}^{35}Cl]^+$.

HRMS (ESI): *m*/*z* $[M + Na]^+$ calcd for $C_{21}H_{19}N_2O_3SClNa$: 437.0697; found: 437.0685.

3-(4-Chlorophenyl)-1-methyl-4-oxo-6-phenyl-7-thia-2,3-diazaspiro[4.4]non-1-en-9-yl Acetate (3m)

Yield: 92 mg (89%); yellow oil; R_f = 0.61 (*n*-pentane–Et_2O, 1:1).

IR (ATR): 2951, 1723, 1595, 1490, 1357, 1215, 1143, 1044, 929, 825, 769, 697 cm^{-1}.

^1H NMR (400 MHz, $CDCl_3$): δ = 7.70–7.64 (m, 2 H, Ar-H), 7.29 (m, 4 H, Ar-H), 7.23–7.17 (m, 3 H, Ar-H), 5.72 (t, *J* = 8.5 Hz, 1 H, C*H*OAc), 5.10 (s, 1 H, C*H*Ar), 3.79 (dd, *J* = 11.2, 8.3 Hz, 1 H, SC*H*H), 3.17 (dd, *J* = 11.2, 8.7 Hz, 1 H, SCH*H*), 2.36 (s, 3 H, CH_3), 1.96 (s, 3 H, CH_3).

^{13}C NMR (101 MHz, $CDCl_3$): δ = 170.9 (C=O), 169.2 (C=O), 157.8 (C_q), 135.9 (C_q), 132.9 (C_q), 130.5 (C_q), 128.8 (3 C, Ar-C), 128.6 (2 C, Ar-C), 127.1 (2 C, Ar-C), 120.1 (2 C, Ar-C), 79.3 (*C*HOAc), 69.3 (C_q), 54.5 (*C*HAr), 33.1 (SCH_2), 20.6 (CH_3), 17.8 (CH_3).

MS (EI, 70 eV): *m*/*z* (%) = 416.0 (14) $[M, {}^{37}Cl]^+$, 414.0 (36) $[M, {}^{35}Cl]^+$, 356.0 (18) $[M – HOAc, {}^{37}Cl]^+$, 354.0 (47) $[M – HOAc, {}^{35}Cl]^+$, 299.0 (31) $[M – C_4H_5O_2S, {}^{37}Cl]^+$, 297.0 (100) $[M – C_4H_5O_2S, {}^{35}Cl]^+$.

HRMS (ESI): *m*/*z* $[M + Na]^+$ calcd for $C_{21}H_{19}N_2O_3SClNa$: 437.0697; found: 437.0697.

1-Methyl-4-oxo-6-phenyl-3-*p*-tolyl-7-thia-2,3-diazaspiro[4.4]non-1-en-9-yl Acetate (3n)

Yield: 85 mg (86%); brown solid; mp 37–39 °C; R_f = 0.56 (*n*-pentane–Et_2O, 1:1).

IR (ATR): 3479, 2940, 2655, 2333, 2099, 1719, 1613, 1510, 1362, 1215, 1044, 919, 814, 698 cm^{-1}.

^1H NMR (600 MHz, $CDCl_3$): δ = 7.59–7.54 (m, 2 H, Ar-H), 7.36–7.33 (m, 2 H, Ar-H), 7.24–7.20 (m, 3 H, Ar-H), 7.17–7.14 (m, 2 H, Ar-H), 5.74 (t, *J* = 8.5 Hz, 1 H, C*H*OAc), 5.13 (s, 1 H, C*H*Ar), 3.81 (dd, *J* = 11.1, 8.3 Hz, 1 H, SC*H*H), 3.18 (dd, *J* = 11.1, 8.8 Hz, 1 H, SCH*H*), 2.37 (s, 3 H, CH_3), 2.33 (s, 3 H, $ArCH_3$), 1.98 (s, 3 H, CH_3).

^{13}C NMR (151 MHz, $CDCl_3$): δ = 170.7 (C=O), 169.3 (C=O), 157.3 (C_q), 135.3 (C_q), 135.0 (C_q), 133.1 (C_q), 129.3 (2 C, Ar-C), 128.7 (Ar-C), 128.6 (2 C, Ar-C), 127.2 (2 C, Ar-C), 119.2 (2 C, Ar-C), 79.3 (*C*HOAc), 69.1 (C_q), 54.2 (*C*HAr), 33.0 (SCH_2), 21.0 (CH_3), 20.6 (CH_3), 17.8 (CH_3).

MS (EI, 70 eV): *m*/*z* (%) = 395.2 (10) $[M + H]^+$, 394.2 (26) $[M]^+$, 334.1 (21) $[M – HOAc]^+$, 277.1 (100) $[M – C_4H_5O_2S]^+$.

HRMS (ESI): *m*/*z* $[M + Na]^+$ calcd for $C_{22}H_{22}N_2O_3SNa$: 395.1424; found: 395.1423.

1-Isopropyl-4-oxo-3,6-diphenyl-7-thia-2,3-diazaspiro[4.4]non-1-en-9-yl Acetate (3o)

Yield: 55 mg (54%); yellow solid; mp 101–103 °C; R_f = 0.63 (*n*-pentane–Et_2O, 1:1).

IR (ATR): 2973, 1749, 1710, 1596, 1495, 1452, 1355, 1217, 1148, 1051, 979, 921, 883, 753, 693 cm^{-1}.

^1H NMR (600 MHz, $CDCl_3$): δ = 7.79 (m, 2 H, Ar-H_{Diast}), 7.52 (m, 2 H, Ar-H), 7.47–7.43 (m, 2 H, Ar-H, Ar-H), 7.39 (m, 2 H, Ar-H_{Diast}), 7.33 (m, 2 H, Ar-H, Ar-H_{Diast}), 7.30–7.25 (m, 4 H, Ar-H, Ar-H_{Diast}), 7.24–7.19 (m, 4 H, Ar-H, Ar-H_{Diast}), 7.17 (m, 1 H, Ar-H_{Diast}), 7.11 (m, 1 H, Ar-H), 5.75 (dd, *J* = 10.1, 7.8 Hz, 1 H, C*H*OAc$_{Diast}$), 5.68 (dd, *J* = 9.9, 7.1 Hz, 1 H, C*H*OAc), 5.19 (s, 1 H, C*H*Ar$_{Diast}$), 4.95 (s, 1 H, C*H*Ar), 3.99 (t, *J* = 9.7 Hz, 1 H, SC*H*H), 3.75 (dd, *J* = 10.6, 7.8 Hz, 1 H, SC*H*H$_{Diast}$), 3.44 (dd, *J* = 9.5, 7.1

Hz, 1 H, SCH*H*), 3.23 (t, *J* = 10.3 Hz, 1 H, SCHH_{Diast}), 3.12 (m, 1 H, C*H*$(CH_3)_{2Diast}$), 2.91 (m, 1 H, C*H*$(CH_3)_2$), 1.98 (s, 3 H, CH_3), 1.96 (s, 3 H, CH_{3Diast}), 1.43 (d, *J* = 6.8 Hz, 3 H, CH_3 (^{i}Pr)), 1.31 (d, *J* = 6.8 Hz, 3 H, CH_3 (^{i}Pr)$_{Diast}$), 1.21 (d, *J* = 6.8 Hz, 3 H, CH_3 (^{i}Pr)), 0.80 (d, *J* = 6.7 Hz, 3 H, CH_3 (^{i}Pr)$_{Diast}$).

^{13}C NMR (151 MHz, $CDCl_3$): δ = 171.0 (C=O$_{Diast}$), 169.9 (C=O), 169.1 (C=O), 168.7 (C=O$_{Diast}$), 165.4 ($C_{q\ Diast}$), 163.6 (C_q), 137.7 ($C_{q\ Diast}$), 137.3 (C_q), 134.0 ($C_{q\ Diast}$), 133.8 (C_q), 128.8 (2 C, Ar-C$_{Diast}$), 128.7 (2 C, Ar-C), 128.6 (2 C, Ar-C$_{Diast}$), 128.5 (2 C, Ar-C), 128.3 (2 C, Ar-C), 127.3 (2 C, Ar-C$_{Diast}$), 125.4 (2 C, Ar-C$_{Diast}$), 125.2 (2 C, Ar-C), 119.3 (2 C, Ar-C), 119.1 (2 C, Ar-C$_{Diast}$), 79.8 (*C*HOAc$_{Diast}$), 76.5 (*C*HOAc), 69.5 ($C_{q\ Diast}$), 67.7 (C_q), 53.0 (*C*HAr$_{Diast}$), 49.7 (*C*HAr), 32.3 ($SCH_{2\ Diast}$), 30.7 (SCH_2), 29.7 (*C*H$(CH_3)_{2\ Diast}$), 27.2 (*C*H$(CH_3)_2$), 22.8 (*C*H$_{3\ Diast}$), 22.3 (CH_3), 20.8 (2 C, CH(*C*H$_3)_{2\ Diast}$), 20.6 (2 C, CH(*C*H$_3)_2$).

MS (EI, 70 eV): *m*/*z* (%) = 408.1 (3) $[M]^+$, 348.1 (13) $[M - HOAc]^+$, 291.2 (67) $[M - C_4H_5O_2S]^+$.

HRMS (ESI): *m*/*z* $[M + Na]^+$ calcd for $C_{23}H_{24}N_2O_3SNa$: 409.1580; found: 409.1573.

1-*tert*-Butyl-4-oxo-3,6-diphenyl-7-thia-2,3-diazaspiro[4.4]non-1-en-9-yl Acetate (3p)

Yield: 44 mg (42%); orange solid; mp 155–157 °C; R_f = 0.70 (*n*-pentane–Et_2O, 1:1).

IR (ATR): 2965, 1721, 1596, 1490, 1373, 1218, 1044, 967, 849, 748 cm^{-1}.

^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.45 (m, 4 H, Ar-H), 7.28–7.24 (m, 2 H, Ar-H), 7.21 (m, 2 H, Ar-H), 7.17–7.12 (m, 1 H, Ar-H), 7.09 (m, 1 H, Ar-H), 5.91 (dd, *J* = 9.7, 7.2 Hz, 1 H, C*H*OAc), 5.32 (s, 1 H, C*H*Ar), 4.01 (t, *J* = 9.6 Hz, 1 H, SC*H*H), 3.43 (dd, *J* = 9.5, 7.2 Hz, 1 H, SCH*H*), 1.98 (s, 3 H, CH_3), 1.47 (s, 9 H, ^{t}Bu).

^{13}C NMR (151 MHz, $CDCl_3$): δ = 170.0 (C=O), 168.9 (C=O), 163.6 (C_q), 137.1 (C_q), 134.3 (C_q), 128.5 (Ar-C), 128.5 (2 C, Ar-C), 128.4 (2 C, Ar-C), 128.1 (2 C, Ar-C), 125.2 (Ar-C), 119.2 (2 C, Ar-C), 77.0 (*C*HOAc), 68.4 (C_q), 48.5 (*C*HAr), 37.1 (*C*$(CH_3)_3$), 30.5 (SCH_2), 29.8 (3 C, ^{t}Bu), 20.7 (CH_3).

MS (EI, 70 eV): *m*/*z* (%) = 423.2 (36) $[M + H]^+$, 422.2 (18) $[M]^+$, 362.1 (89) $[M - HOAc]^+$, 305.0 (100) $[M - C_4H_5O_2S]^+$.

HRMS (ESI): *m*/*z* $[M + H]^+$ calcd for $C_{24}H_{27}N_2O_3S$: 423.1737; found: 423.1736.

1-Ethyl-4-oxo-3,6-diphenyl-7-thia-2,3-diazaspiro[4.4]non-1-en-9-yl Acetate (3q)

Yield: 74 mg (76%); colorless oil; R_f = 0.65 (*n*-pentane–Et_2O, 1:1).

IR (ATR): 2978, 2940, 2106, 1751, 1708, 1596, 1495, 1453, 1353, 1218, 1142, 1049, 957, 913, 837, 800, 757, 728, 696 cm^{-1}.

^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.74 (m, 2 H, Ar-H), 7.39–7.31 (m, 5 H, Ar-H), 7.24–7.20 (m, 3 H, Ar-H), 5.73 (t, *J* = 8.6 Hz, 1 H, C*H*OAc), 5.13 (s, 1 H, C*H*Ar), 3.79 (dd, *J* = 11.0, 8.2 Hz, 1 H, SC*H*H), 3.17 (dd, *J* = 10.9, 9.1 Hz, 1 H, SCH*H*), 2.68–2.58 (m, 2 H, CH_2CH3), 1.97 (s, 3 H, CH_3), 1.12 (t, *J* = 7.2 Hz, 3 H, CH_2CH_3).

^{13}C NMR (151 MHz, $CDCl_3$): δ = 171.0 (C=O), 169.3 (C=O), 161.3 (C_q), 137.6 (C_q), 133.3 (C_q), 128.8 (2 C, Ar-C), 128.7 (Ar-C), 128.5 (2 C, Ar-C), 127.2 (Ar-C), 125.4 (2 C, Ar-C), 119.1 (2 C, Ar-C), 79.3 (*C*HOAc), 69.2 (C_q), 54.2 (*C*HAr), 33.1 (SCH_2), 24.5 (CH_2), 20.7 (CH_3), 9.0 (CH_2CH_3).

MS (EI, 70 eV): *m*/*z* (%) = 394.0 (3) $[M]^+$, 333.9 (12) $[M - HOAc]^+$, 77.2 (100) $[C_6H_5]^+$.

HRMS (ESI): *m*/*z* $[M + Na]^+$ calcd for $C_{22}H_{22}N_2O_3SNa$: 417.1243; found: 417.1242.

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Supporting Information

Supporting information for this article is available online at http://dx.doi.org/10.1055/s-0035-1562473.

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