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ORIGINAL PAPER

A new rearrangement of spiro[indane-1,3′-thiophene] and spiro[naphthalene-1,3′-thiophene] derivatives accompanied by opening of the cycloalkane ring

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Abstract The new thioamides 2-oxoindane-1-carbothioamides and 2-oxo-1,2,3,4-tetrahydronaphthalene-1-carbothioamides underwent conjugated addition to (*E*)-*β*-nitrostyrenes followed by cyclization to give products containing 5-hydroxyimino-2-aryliminothiophene rings spiro-annulated to the 2-indanone or 2-tetralone system. On treatment with hydrochloric acid in boiling methanol the compounds underwent a new rearrangement, involving transformation of the 2-aryliminothiophene ring to a pyrrole and an opening of the alicyclic ring in the proximity of the carbonyl group, affording 2-(1,3-diaryl-2-oxo-5-thioxopyrrol-4-yl)benzeneacetic or 2-(1,3-diaryl-2-oxo-5-thioxopyrrol-4-yl)benzenepropanoic acid methyl esters. The structures of two selected pyrrole derivatives were determined by X-ray crystal analyses. The thioamides derived from 2-indanone showed unexpected reactivity towards primary alcohols and underwent conversion to 2-hydroxy-1*H*-indene-3-thiocarboxylic acid *O*-esters.

Keywords Heterocycles · Michael addition · Thioamides · Nitrostyrenes · Spiro compounds · X-ray structure determination

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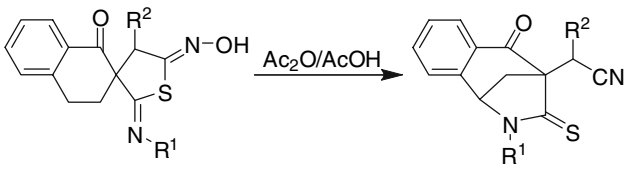
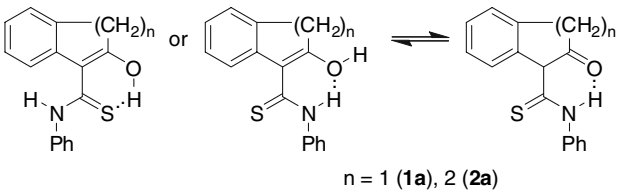
Introduction

The *β*-ketothioamides are valuable building blocks for the synthesis of various nitrogen and sulfur heterocyclic compounds [1]. The versatility of nucleophilic centers of the *β*-ketothioamides facilitates their reactivity towards electrophilic reagents [2]. Acylating agents, e.g. oxalyl chloride [3], and alkylating agents, e.g. dihaloalkanes [4, 5], attack, mainly, the nitrogen and sulfur atoms affording thiazole or thiazine derivatives. In reactions with electrophilic olefins, *β*-ketothioamides have CH-acidic properties, e.g. reactions with *α*,*β*-unsaturated aldehydes give 6-hydroxypiperidine-2-thiones [6]. We have recently found that conjugate addition of *β*-aminocycloalkenethioamides to maleimides and subsequent domino reaction provide easy access to polycyclic monothioimides [7]. However, *β*-ketothioamides also react with CH acids, e.g. malononitrile, yielding 6-aminopyridine-2-thiones [8]. In acidic medium some *γ*,*δ*-unsaturated *β*-ketothioamides undergo intramolecular cyclization to 2,3-dihydro-4*H*-thiopyran-4-ones [9]. *β*-Ketothioamides may react with some reagents which convert the thioamide group into five membered nitrogen heterocycles, e.g. the reaction with DMAD leads to pyrroles [10], and the reaction with TMS azide leads to 1,5-substituted tetrazoles [11].

Cyclic monothioimides have important biological properties. The effect of monothioimides on tumor necrosis factor alpha (TNF-*α*) production by genetically modified B78H1 melanoma cells has been investigated [12]. It was found that monothiophthalimide derivatives had significant activity as enhancers of TNF-*α* production. Monothioimides with spiro-annulated alicyclic rings have been successfully tested for anticonvulsant activity [13, 14]. Cyclic monothioimides have recently been used for



Scheme 1



Scheme 2

synthesis of protease-resistant and conformationally restricted peptidomimetics [15].

Results and discussion

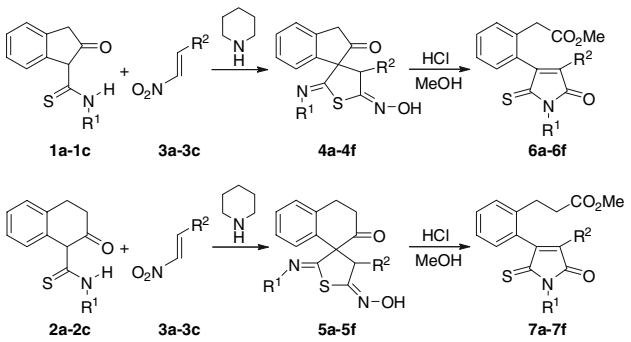
We have recently shown that *N*-aryl-*β*-ketothioamides react readily with *β*-nitrostyrenes affording thiophene derivatives with high diastereoselectivity [16–19]. Because the thiophene skeletons contain oxime and arylimino groups they are sensitive under acidic conditions. The thiophenes derived from α-unsubstituted *β*-ketothioamides treated with conc. HCl underwent a ring transformation to 5-thioxopyrrol-2-ones [16, 17, 19]. Thiophenes derived from 5 and 6-membered cyclic *β*-ketothioamides treated with conc. HCl underwent decomposition whereas they reacted smoothly under the acetylation conditions Ac_2O/AcOH yielding oxime esters [18]. We have found that thiophenes and their oxime esters spiro-annulated with a 1-tetralone skeleton underwent, under acidic conditions, an unique rearrangement giving polycyclic systems, e.g. 6-azabicyclo[3.2.1]octane [20] (Scheme 1).

Taking into account our results on rearrangement of compounds spiro-annulated with a 1-tetralone skeleton, in this work we studied the synthesis and the acidic rearrangements of thiophenes derived from some unreported thioamides containing 2-indanone and 2-tetralone ring systems.

The starting thioamides **1a**–**1c** and **2a**–**2c** were obtained, in moderate yields, by reaction of 2-indanone or 2-tetralone with sodium hydride and aryl isothiocyanates. The ^{1}H NMR spectra of thioamides **1a**–**1c** in $CDCl_3$ solutions contained singlets at $\delta = 14.15$–14.10 ppm, which indicated that the compounds exist almost exclusively in the enol form **A** in these solutions. The two alternative enol forms are shown in Scheme 2 [21]. Only traces of the keto form **B** were observed, e.g. the characteristic signals for the HC-1 protons at $\delta \approx 4.65$ ppm. The ratio of the **A** and **B** forms in $CDCl_3$ solutions, based on the integration in the ^{1}H NMR spectra, was **A**:**B** ≈ 40:1. The IR spectra of **1a**–**1c** in KBr pellets suggested the preference of the form **A** in the solid state also. In the ^{1}H NMR spectra of the thioamides **2a**–**2c** in $CDCl_3$ solutions two sets of signals for the **A** and **B** forms were clearly visible. The compounds existed predominantly in the enol form **A**. The ratio of forms **A** and **B** in $CDCl_3$ solutions, **A**:**B**, ranged from 4.3:1 for **2c** to 4.9:1 for **2b**. In the ^{1}H NMR spectra of **2a**–**2c** recorded in DMSO-d_6 solutions an inverse ratio **A**:**B** has been observed, from 1:1.2 for **2c** to 1:1.7 for **2b**. The increase of amount of the keto form in more polar solvents is typical of *β*-ketothioamides [21]. The presence of a strong band at 1,711 cm^{-1} in the IR spectrum of **2a** and a medium band at 1,712 cm^{-1} in the IR spectrum of **2b** show the amount of the **B** form in the solid state. In the IR spectrum of **2c** the analogous C=O absorption band was not observed.

The thioamides **1a**–**1c** and **2a**–**2c** treated with (*E*)-*β*-nitrostyrenes **3a**–**3c** in the presence of a catalytic amount of piperidine underwent a conjugated addition–cyclization to give the products **4a**–**4f** and **5a**–**5f** with thiophene rings spiro-annulated to the 2-indanone and 2-tetralone system (Scheme 3). The matched pairs of reagents had different aryl groups R^1 and R^2 (Table 1). The reactions of **1a**–**1c** with **3a**–**3c** were performed in acetonitrile, because we observed slow decomposition of the thioamides in the presence of primary alcohols (see below). However the desired products **4a**–**4f** were formed in moderate or poor yields (23–54%). The reactions of **2a**–**2c** with **3** were carried out in dry ethanol at boiling temperature, affording **5a**–**5f** in moderate to good yields (33–60%). The mechanism of the addition—cyclization has been reported in detail in our previous work [16–19].

The ^{1}H NMR spectra of **4** and **5** contained the characteristic singlet of the oxime proton; e.g. in the ^{1}H NMR spectrum of **4b** the oxime proton resonated at $\delta = 11.88$ ppm and the analogous proton in the ^{1}H NMR



Scheme 3

Table 1 Results from synthesis of the thiophene derivatives **4a–4f** and **5a–5f** and subsequent reactions with HCl in methanol (Scheme 3)

Thioamide	Nitroalkene	R^1	R^2	Yield (%)		Yield (%)	
1a	**3b**	C_6H_5	4-CH_3–C_6H_4	**4a**	36	**6a**	26
1a	**3c**	C_6H_5	4-Cl–C_6H_4	**4b**	54	**6b**	23
1b	**3a**	4-CH_3–C_6H_4	C_6H_5	**4c**	46	**6c**	11
1b	**3c**	4-CH_3–C_6H_4	4-Cl–C_6H_4	**4d**	56	**6d**	20
1c	**3a**	4-Cl–C_6H_4	C_6H_5	**4e**	24	**6e**	27
1c	**3b**	4-Cl–C_6H_4	4-CH_3–C_6H_4	**4f**	23	**6f**	29
2a	**3b**	C_6H_5	4-CH_3–C_6H_4	**5a**	46	**7a**	41
2a	**3c**	C_6H_5	4-Cl–C_6H_4	**5b**	48	**7b**	38
2b	**3a**	4-CH_3–C_6H_4	C_6H_5	**5c**	47	**7c**	32
2b	**3c**	4-CH_3–C_6H_4	4-Cl–C_6H_4	**5d**	33	**7d**	22
2c	**3a**	4-Cl–C_6H_4	C_6H_5	**5e**	49	**7e**	77
2c	**3b**	4-Cl–C_6H_4	4-CH_3–C_6H_4	**5f**	60	**7f**	54

spectrum of **5b** resonated at $\delta = 11.62$ ppm. The proton attached to C-4′ of the spiro[indane-1,3′-thiophene] system of **4b** resonated at $\delta = 5.00$ (s) ppm, and the protons attached to C-3 appeared as two doublets at $\delta = 3.77$ and 3.63 ppm. The proton attached to C-4′ of the spiro[naphthalene-1,3′-thiophene] system of **5b** resonated at $\delta = 4.95$ (s) ppm, and the protons attached to C-3 and C-4 appeared as four signals coupled together (d × d × d) at $\delta = 2.77$, 2.62, 2.11, and 1.92 ppm.

The reactivity of the thiophene derivatives **4a–4f** and **5a–5f**, which contain two exocyclic C=N bonds, towards acidic reagents has been investigated. The compounds were stable in acetic acid and acetic anhydride. When treated with hydrochloric acid in methanol solutions, however, **4a–4f** and **5a–5f** underwent a rearrangement involving transformation of the thiophene ring and breaking of the alicyclic ring in the proximity of the carbonyl group. The reaction mixture after work up afforded the products **6a–6f** in moderate to poor yields (11–29%) and **7a–7f** in moderate to good yields (22–77%). The IR spectra of the products contained the characteristic bands indicating ester functionality, e.g. broad bands at 1,733 cm^{-1} (C=O) and at 1,150 cm^{-1} (C–O) in the IR spectrum of **6b**. In the ^1H NMR spectrum of **6b** the ester methyl group appeared as singlet at $\delta = 3.45$ ppm, overlapping the two doublets of the *AB* system of the methylene fragment adjacent to the ester group. The HSQC spectrum revealed correlations of the protons with two carbon atoms: the methyl carbon at $\delta = 52.0$ and the methylene carbon at $\delta = 39.6$ ppm. The ^{13}C NMR spectrum of **6b** also revealed the thiocarbonyl group at $\delta = 199.3$ ppm. Other signals, especially those of the aromatic and alkene fragments appear very close to each other and cannot be assigned. Therefore, the structure of compounds **6** and **7** was unequivocally determined on the basis of crystallographic measurements.

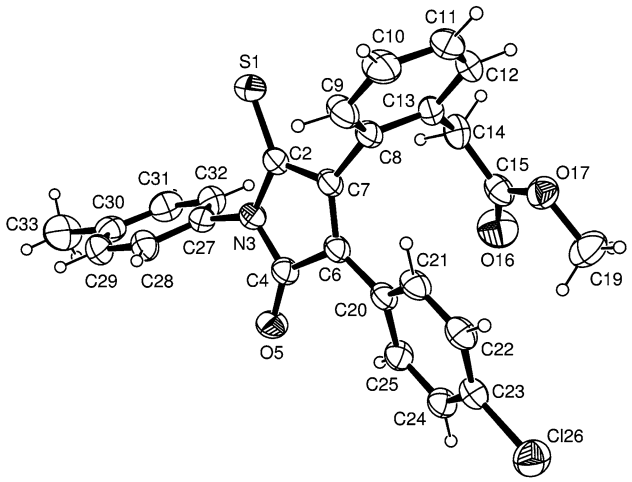


Fig. 1 A perspective view of the molecule of **6d** with the crystallographic atom numbering scheme

Two crystalline compounds **6d** and **7a** were chosen and submitted to X-ray crystal analysis. Perspective views of the molecules of **6d** and **7a** with the crystallographic atom numbering are shown in Figs. 1 and 2, respectively. Despite the similar structures, there is one rather significant difference. The terminal $COOCH_3$ group has one more single bond separating it from the phenyl ring and thus more rotational freedom. This manifests itself in the disorder of this substituent in **7a**, whereas the same moiety does not show any disorder in **6d**. This could be modeled in part by splitting the atom O17 in **7a**, with both positions rotated by about 37 degrees. Also, the atomic displacement parameters of the remaining atoms in this moiety are somewhat high. As a result there is a residual electron density peak of 0.63 $eÅ^{-3}$ in the final Fourier map of **7a**. The conformations of the molecules of both **6d** and **7a** are stabilized by an intramolecular close contact C25-

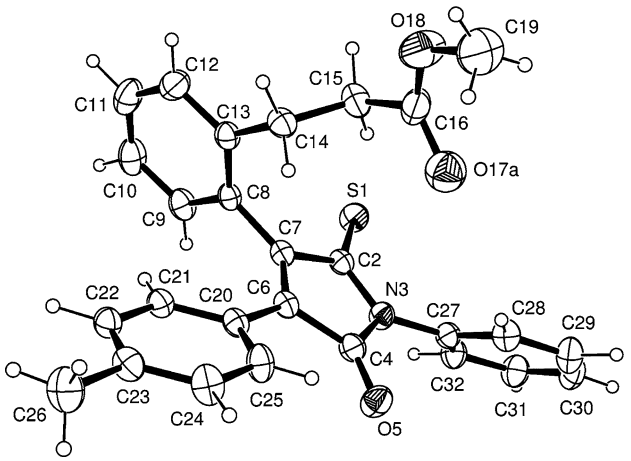
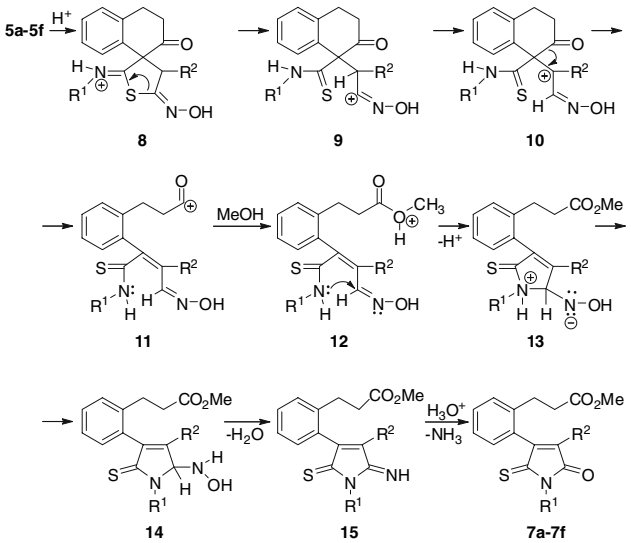


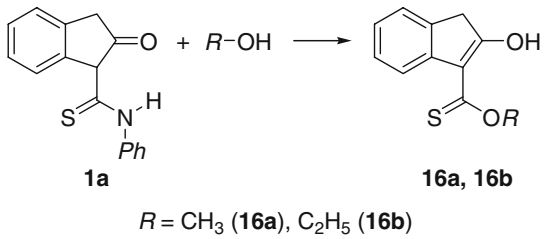
Fig. 2 A perspective view of the molecule of **7a** with the crystallographic atom numbering scheme. The oxygen atom O17 has two disordered positions, of which only one is presented in the figure for clarity



Scheme 4

H25…O5 (in both cases). Neither crystal structure shows typical intermolecular hydrogen bonds.

The reaction of **4a–4f** and **5a–5f** with HCl and MeOH leading to the formation of **6a–6f** and **7a–7f** might be explained by a mechanism shown in Scheme 4 for **5a–5f**. Initial protonation of the arylimino group leads to opening of the thiophene ring and formation of hydroxyiminium ion **9**. The key step of rearrangement is the conversion of the ion **9** to the carbocation **10** by a 1,2-hydrogen shift. The tertiary carbocation **10**, which is also stabilized by the aryl group R^2, undergoes subsequent rearrangement involving the formation of a C=C double bond and the opening of the tetralone ring at a position adjacent to the carbonyl group. The newly formed acylium ion **11** reacts with the solvent



Scheme 5

MeOH affording the methyl ester. Nucleophilic attack of the thioamide nitrogen on the carbon of the aldoxime group leads to the closure of a pyrrole ring. Subsequent elimination of a water molecule from **14** followed by a spontaneous hydrolysis of the imine **15** provides the products **7a–7f**.

We observed unusual reactivity of the thioamides derived from 2-indanone **1a–1c** towards primary alcohols. For example, the thioamide **1a** reacted with boiling methanol or ethanol affording appropriate thiocarboxylic acid *O*-esters **16a** or **16b** in good yields of 43 and 61% (Scheme 5). The direction of these reactions is opposite to the typically observed synthesis of amides from esters [22, 23]. The new reactions seem to be the only method of transformation of thioamides into *O*-thioesters, because the reactions of thioamides with alkylating agents, e.g. alkyl iodides or dimethyl sulfate, give *S*-thioesters [24, 25]. In the ^{13}C NMR spectrum of **16b** in $CDCl_3$ solution the thiocarbonyl carbon atom appeared at $\delta = 204.6$ ppm. The ^1H NMR spectrum of **16b** contained a triplet at $\delta = 1.64$ ppm (CH_3) and quartet at $\delta = 4.74$ ppm (CH_2) for the ethyl group, which clearly indicate the presence of the *O*-ester group. The singlet at $\delta = 13.84$ ppm assigned to the OH proton shows that the product **16b** exists almost exclusively in enol form in $CDCl_3$ solution.

In conclusion, we have developed new applications of tandem conjugate addition–cyclization reactions for synthesis of functionalized thiophenes and pyrroles. This study revealed a unique rearrangement of spiro-annulated thiophene derivatives under acidic conditions involving breakage of a C-C single bond and ring transformations of iminothiophenes to pyrroles. The results presented provide easy access to new heterocycles with potential biological properties.

Experimental

Melting points were determined on a Boetius hot-stage apparatus and are corrected. IR spectra were run in KBr pellets on a Bruker IFS 48 spectrometer. Mass spectra were obtained on a Finnigan Mat 95 (EI) or a Bruker Esquire 3000 (ESI) mass spectrometer. NMR spectra were recorded

on a Bruker AMX 500 spectrometer (^{1}H, 500.14 MHz; ^{13}C, 125.76 MHz) or Bruker Avance II 300 MHz in $CDCl_3$ or DMSO-d_6 using TMS as internal standard. Microanalyses (C, H, N) of the crystalline compounds were performed with a Euro EA 3000 Elemental Analyzer; the results agreed satisfactorily (±0.3%) with calculated values. Diffraction data were collected using a Nonius Kappa CCD diffractometer with graphite monochromated Mo–K_α radiation.

General procedure for synthesis of thioamides ***1a–1c, 2a–2c***

To a vigorously stirred suspension of sodium hydride (50 mmol) in 90 cm^3 dry DMF at −10 °C, 2-indanone (for **1a**–**1c**; 6.60 g, 50 mmol) or 2-tetralone (for **2a**–**2c**; 7.30 g, 50 mmol) was added slowly, over a period of 1 h, so the temperature did not exceed 0 °C. After the gas was evolved, a solution of the appropriate aryl isothiocyanate (50 mmol) in 10 cm^3 dry DMF was added dropwise. The mixture was stirred for 3 h at −10 °C, left in a fridge overnight, then added slowly to 50 cm^3 1 M HCl, and acidified with 2 M HCl. After 3 h most of the water–DMF solution was decanted. The oily residue was dissolved in CH_2Cl_2, washed twice with 1 M HCl and water, then evaporated and purified by flash chromatography on silica gel using CH_2Cl_2 as eluent. The crude **2a**–**2c** was treated with Et_2O, cooled in a fridge, and collected by filtration. The crude **1a**–**1c** was dissolved in MeCN at 50 °C and treated with 50 cm^3 2 M HCl for hydrolysis of imine side-products. After evaporation of the solvent the product was purified again by flash chromatography on silica gel, using CH_2Cl_2 as eluent, and crystallized from Et_2O.

2,3-Dihydro-2-oxo-N-phenyl-1H-indene-1-carbothioamide (**1a**, $C_{16}H_{13}NOS$)
Orange crystals (7.41 g, 56%); $R_f = 0.41$ ($CHCl_3$); m.p.: 127–128 °C; ^{1}H NMR (300 MHz, $CDCl_3$): 97% of enol **A** + 3% of ketone **B**, $\delta = 14.15$ (s, 1H, OH **A**), 9.29 (bs, 1H, NH **B**), 8.87 (bs, 1H, NH **A**), 7.53 (d, 2H, $^3J = 8.0$ Hz, CH arom **B**), 7.57 (d, 2H, $^3J = 8.0$ Hz, CH arom **A**), 7.50-7.27 (m, 6CH arom **A** + 6CH arom **B**), 7.17 (ddd, $^3J \approx 7.4$, 7.4, $^4J = 1.0$ Hz, 1CH arom **A** + 1CH arom **B**), 4.66 (s, 1H, HC-1 **B**), 3.67 (s, 2H **A** + 2H **B**, H_2C-3 **A** + **B**) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 188.8$, 182.1, 140.2, 137.2, 132.7, 129.1, 127.30, 127.27, 125.1, 124.8, 124.2, 117.7, 111.4, 39.2 ppm; IR (KBr): $\bar{\nu} = 3{,}333$, 3,041, 3,003, 2,923, 1,549, 1,515, 1,494, 1,472, 1,457, 1,417, 1,359, 1,314, 1,291, 1,227, 1,139, 913 cm^{-1}; MS (70 eV): *m/z* (%) = 267.1 (51) $[M]^+$, 233.1 (18), 204.1 (20), 174.0 (25), 146.0 (35), 132.1 (17), 131.1 (18), 102.0 (20), 93.0 (100), 77.0 (17).

2,3-Dihydro-N-(4-methylphenyl)-2-oxo-1H-indene-1-carbothioamide (**1b**, $C_{17}H_{15}NOS$)
Dark orange crystals (9.89 g, 70%); m.p.: 121–122 °C; $R_f = 0.42$ ($CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$): 97% of enol **A** + 3% of ketone **B**, $\delta = 14.15$ (s, 1H, OH **A**), 9.21 (bs, 1H, NH **B**), 8.87 (bs, 1H, NH **A**), 7.53 (d, 2H, $^3J = 8.4$ Hz, CH arom **B**), 7.46-7.36 (m, 4CH arom **A** + 2CH arom **B**), 7.34-7.22 (m, 3CH arom **A** + 3CH arom **B**), 7.16 (ddd, $^3J \approx 7.5$, 7.5, $^4J = 0.9$ Hz, 1CH arom **A** + 1CH arom **B**), 4.65 (s, 1H, HC-1 **B**), 3.66 (s, 2H **A** + 2H **B**, H_2C-3 **A** + **B**), 2.39 (s, 3H, CH_3 **A**), 2.34 (s, 3H, CH_3 **B**) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 188.8$, 181.8, 140.2, 137.3, 134.6, 132.7, 129.7, 127.3, 125.1, 124.7, 124.1, 117.6, 111.3, 39.1, 21.2 ppm; IR (KBr): $\bar{\nu} = 3{,}365$, 3,314, 3,079–3,018, 2,951, 1,562, 1,512, 1,488, 1,457, 1,401, 1,377, 1,299, 1,212, 1,142, 906 cm^{-1}; MS (70 eV): *m/z* (%) = 281.1 (31) $[M]^+$, 247.1 (18), 174.0 (29), 146.0 (36), 145.0 (19), 132.1 (10), 107.1 (100), 106.1 (64), 102.1 (22), 77.0 (12).

N-(4-Chlorophenyl)-2,3-dihydro-2-oxo-1H-indene-1-carbothioamide (**1c**, $C_{16}H_{12}ClNOS$)
Orange crystals (9.516 g, 63%); m.p.: 151–153 °C; $R_f = 0.44$ ($CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$): 97% of enol **A** + 3% of ketone **B**, $\delta = 14.10$ (s, 1H, OH **A**), 9.31 (bs, 1H, NH **B**), 8.83 (bs, 1H, NH **A**), 7.66 (d, 2H, $^3J = 8.7$ Hz, CH arom **B**), 7.51 (d, 2H, $^3J = 8.7$ Hz, CH arom **A**), 7.44–7.37 (m, 4CH arom **A** + 4CH arom **B**), 7.36-7.28 (dd, $^3J \approx 7.4$, 7.4 Hz, 1CH arom **A** + 1CH arom **B**), 7.18 (ddd, $^3J \approx 7.4$, 7.4, $^4J = 1.1$ Hz, 1CH arom **A** + 1CH arom **B**), 4.64 (s, 1H, HC-1 **B**), 3.67 (s, 2H, H_2C-3 **A** + **B**) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 188.9$, 182.5, 140.0, 135.7, 132.7, 132.6, 129.3, 127.3, 126.4, 124.8, 124.3, 117.6, 111.4, 39.2 ppm; IR (KBr): $\bar{\nu} = 3{,}369$, 3,090–3,021, 2,925–2,851, 1,548, 1,502, 1,465, 1,430, 1,392, 1,378, 1,273, 1,138, 1,103, 1,090, 901 cm^{-1}; MS (70 eV): *m/z* (%) = 303.0 (8) $[M + 2]^+$, 301.1 (51) $[M]^+$, 204.1 (12), 174.0 (41), 146.0 (51), 145.0 (24), 132.1 (10), 129.0 (31), 127.0 (100), 102.1 (26), 65.1 (11).

1,2,3,4-Tetrahydro-2-oxo-N-phenylnaphthalene-1-carbothioamide (**2a**, $C_{17}H_{15}$ NOS)
Yellow crystals (12.65 g, 90%); m.p.: 129–131 °C; $R_f = 0.39$ ($CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$): 83% of enol **A** + 17% of ketone **B**, $\delta = 14.01$ (bs, 1H, OH **A**), 9.29 (bs, 1H, NH **B**), 8.87 (bs, 1H, NH **A**), 7.67 (d, 2H, $^3J = 7.7$ Hz, CH arom **B**), 7.56–7.08 (m, 9CH arom **A** + 7CH arom **B**), 4.79 (s, 1H, C-1 **B**), 3.34 (ddd, 1H, $^2J = 15.7$ Hz, $^3J = 9.7$, 5.8 Hz, HC-3 **B**), 3.01 (ddd, 1H, $^2J = 15.7$ Hz, $^3J \approx 6$, 5.5 Hz, HC-3 **B**), 2.91 (dt, 1H, $^2J = 17.5$ Hz, $^3J \approx 5.5$ Hz, HC-4 **B**), 2.82 (t, 2H, $^3J \approx 7$ Hz, H_2C-3 **A**), 2.63–2.52 (m, $^3J \approx 7$ Hz, H_2C-4

A, HC-4 **B**) ppm; ^{13}C NMR (125 MHz, $CDCl_3$): $\delta = 206.7$, 190.9, 174.0, 165.7, 138.4, 137.6, 135.7, 133.7, 132.8, 129.4, 129.0, 128.9, 128.5, 128.2, 127.4, 127.11, 127.07, 126.98, 125.7, 124.9, 124.8, 123.4, 109.7, 69.5, 37.2, 31.1, 27.9, 27.7 ppm; IR (KBr): $\bar{\nu} = 3{,}291$ (N–H), 3,129, 3,060, 3,034, 2,968–2,850, 1,711 (C=O), 1,596, 1,541, 1,493, 1,412, 1,231, 1,205, 1,158, 1,117 cm^{-1}; MS (70 eV): *m/z* (%) = 281.1 (96) $[M]^+$, 248.1 (27), 188 (49), 160.0 (23), 115.0 (41), 93 (100), 77.0 (25).

1,2,3,4-Tetrahydro-N-(4-methylphenyl)-2-oxonaphthalene-1-carbothioamide (**2b**, $C_{18}H_{17}NOS$)

Yellow crystals (11.59 g, 79%); m.p.: 113–115 °C; $R_f = 0.40$ ($CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$): 82% of enol **A** + 18% of ketone **B**, $\delta = 13.99$ (bs, 1H, OH **A**), 9.22 (bs, 1H, NH **B**), 8.83 (bs, 1H, NH **A**), 7.50 (d, 2H, $^3J = 8.4$ Hz, CH arom **B**), 7.44–7.06 (m, 8CH arom **A** + 6CH arom **B**), 4.77 (s, 1H, C-1 **B**), 3.34 (ddd, 1H, $^2J = 15.5$ Hz, $^3J = 9.4$, 5.8 Hz, HC-3 **B**), 3.04–2.86 (m, 2H, HC-3 **B,** HC-4 **B**), 2.81 (t, 2H, $^3J \approx 7$ Hz, H_2C-3 **A**), 2.64–2.50 (m, 2H **A** + 1H **B**, $^3J \approx 7$ Hz, H_2C-4 **A**, HC-4 **B**), 2.36 (s, 3H, CH_3 **A**), 2.33 (s, 3H, CH_3 **B**) ppm; ^{1}H NMR (300 MHz, DMSO-d_6): 37% of enol **A** + 63% of ketone **B**, $\delta = 12.01$ (bs, 1H, NH **B**), 11.43 (bs, 1H, OH **A**), 10.32 (bs, 1H, NH **A**), 7.73 (bd, 2H, $^3J \approx 7.4$ Hz, CH arom **A**), 7.65 (d, 2H, $^3J = 8.5$ Hz, CH arom **B**), 7.33–6.90 (m, 6CH arom **A** + 6CH arom **B**), 5.02 (s, 1H, HC-1 **B**), 3.47 (ddd, 1H, $^2J = 15.6$ Hz, $^3J = 9.4$, 5.6 Hz, HC-3 **B**), 2.99 (dt, 1H, $^2J = 15.6$ Hz, $^3J \approx 6$ Hz, HC-3 **B**), 2.88–2.72 (m, $^2J = 16.3$ Hz, $^3J \approx 6$ Hz, HC-4 **B,** H_2C-3 **A**), 2.61 (ddd, 1H, $^2J = 16.3$ Hz, $^3J = 9.4$, 5.8 Hz, HC-4 **B**), 2.48-2.40 (m, 2H, H_2C-4 **A**), 2.31 (s, 3H **A** + 3H **B**, CH_3 **A** + **B**) ppm; ^{13}C NMR (75 MHz, DMSO-d_6): $\delta = 206.2$, 198.1, 194.0, 155.8, 137.0, 136.7, 136.4, 135.8, 135.7, 134.8, 131.9, 128.9, 128.7, 128.1, 127.7, 126.9, 126.8, 126.5, 126.2, 124.0, 123.4, 123.2, 123.0, 114.4, 66.7, 38.1, 28.2, 27.4, 27.3, 20.6 ppm; IR (KBr): $\bar{\nu} = 3{,}322$, 3,211, 3,059, 3,032, 2,956–2,832, 1,712 (C=O), 1,597, 1,560, 1,513, 1,483, 1,431, 1,412, 1,312, 1,292, 1,202, 1,188, 1,142, 921 cm^{-1}; ESI–MS: *m/z* (%) = 318.0 (31) $[M + Na]^+$, 296.1 (100) $[M + H]^+$.

N-(4-Chlorophenyl)-1,2,3,4-tetrahydro-2-oxonaphthalene-1-carbothioamide (**2c**, $C_{17}H_{14}ClNOS$)

Yellow crystals (13.87 g, 88%); m.p.: 99–102 °C; $R_f = 0.42$ ($CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$): 81% of enol **A** + 19% of ketone **B**, $\delta = 13.98$ (bs, 1H, OH **A**), 9.34 (bs, 1H, NH **B**), 8.81 (bs, 1H, NH **A**), 7.65 (d, 2H, $^3J = 8.8$ Hz, CH arom **B**), 7.47 (d, 2H, $^3J = 8.8$ Hz, CH arom **A**), 7.40–7.08 (m, 6CH arom **A** + 6CH arom **B**), 4.78 (s, 1H, HC-1 **B**), 3.32 (ddd, 1H, $^2J = 15.6$ Hz, $^3J = 9.7$, 6.0 Hz, HC-3 **B**), 3.01 (ddd, 1H, $^2J = 15.6$ Hz, $^3J \approx 6.0$, 5.2 Hz, HC-3 **B**), 2.91–2.75 (t, 2H **A**, $^3J \approx 7$ Hz, H_2C-3 **A** + m, 1H **B**, HC-4 **B**), 2.63–2.52 (m, 2H **A**, $^3J \approx 7$ Hz, H_2C-4 **A**, + 1H **B**, HC-4 **B**) ppm; ^{1}H NMR (300 MHz, DMSO-d_6): 45% of enol **A** + 55% of ketone **B**, $\delta = 12.15$ (bs, 1H, NH **B**), 11.62 (bs, 1H, OH **A**), 10.18 (bs, 1H, NH **A**), 7.94 (bd, 2H, CH arom **A**), 7.85 (d, 2H, $^3J = 8.8$ Hz, CH arom **B**), 7.48 (m, $^3J = 8.8$ Hz, 2CH arom **B** + 2CH arom **A**), 7.32–7.20 (m, 4CH arom **B**), 7.15–6.94 (m, 4CH arom **A**), 5.04 (s, 1H, HC-1 **B**), 3.44 (ddd, 1H, $^2J = 15.5$ Hz, $^3J = 9.3$, 5.4 Hz, HC-3 **B**), 3.00 (dt, 1H, $^2J = 15.5$ Hz, $^3J \approx 6$ Hz, HC-3 **B**), 2.89-2.71 (m, 2H **A**, H_2C-3 **A** + 1H **B**, $^2J = 16.3$ Hz, $^3J \approx 6$ Hz, HC-4 **B,**), 2.62 (ddd, 1H, $^2J = 16.3$ Hz, $^3J = 9.3$, 5.9 Hz, HC-4 **B**), 2.48–2.40 (m, 2H, H_2C-4 **A**) ppm; ^{13}C NMR (75 MHz, DMSO-d_6): $\delta = 207.2$, 200.1, 156.3, 139.7, 139.0, 137.9, 136.9, 135.9, 132.9, 131.3, 130.7, 129.7, 129.5, 129.3, 129.0, 128.2, 128.1, 127.8, 127.4, 126.1, 125.2, 124.1, 68.2, 39.3, 29.3, 28.6, 28.5 ppm; IR (KBr): $\bar{\nu} = 3{,}309$, 3,089–3,026, 2,942–2,817, 1,584, 1,561, 1,508, 1,483, 1,413, 1,393, 1,311, 1,285, 1,210, 1,194, 1,139, 1,091 cm^{-1}; ESI–MS: *m/z* (%) = 318.2 (44), 316.3 (100) $[M + H]^+$.

General procedure for synthesis of spiro[indane-1, 3′-thiophenes] ***4a–4f***

To a solution of the appropriate thioanilide **1a–1c** (5 mmol) in 20 cm^3 MeCN (for **1c** 60 cm^3) two drops of piperidine were added at 50 °C. The appropriate (*E*)-*β*-nitrostyrene **3a–3c** (5.5 mmol) was then added slowly over a period of 0.5 h. The mixture was stirred for 0.5 h at 50 °C, then concentrated in vacuo to half of the initial volume, and cooled in a fridge. The product was isolated by filtration and recrystallized from EtOAc.

2,3,4′,5′-Tetrahydro-5′-(hydroxyimino)-4′-(4-methylphenyl)-2′-(phenylimino)spiro[1H-indene-1,3′(2′H)-thiophene]-2-one (**4a**, $C_{25}H_{20}N_2O_2S$)

Pale yellow crystals (734 mg, 36%); m.p.: 226–228 °C; ^{1}H NMR (300 MHz, DMSO-d_6): $\delta = 11.66$ (s, 1H, NOH), 7.81 (d, 1H, $^3J = 7.5$ Hz, CH arom), 7.49–7.29 (m, 4H, CH arom), 7.22-7.13 (m, 2H, CH arom), 6.97 (d, 2H, $^3J = 8.0$ Hz, CH arom), 6.88–6.77 (m, 4H, CH arom), 5.02 (s, 1H, HC-4′), 3.56 (d, 1H, $^2J = 23.1$ Hz, HC-3), 2.67 (d, 1H, $^2J = 23.1$ Hz, HC-3), 2.19 (s, 3H, CH_3) ppm; ^{13}C NMR (75 MHz, DMSO-d_6): $\delta = 210.8$, 167.1, 151.7, 150.3, 139.6, 137.3, 136.8, 130.0, 129.8, 129.3, 128.5, 128.3, 127.7, 125.9, 125.0, 124.1, 119.0, 73.8, 56.9, 42.4, 20.5 ppm; IR (KBr): $\bar{\nu} = 3{,}250$, 3,094–3,011, 2,920–2,858, 1,751, 1,655, 1,633, 1,592, 1,485, 1,428, 1,134, 1,118, 1,071, 964 cm^{-1}; MS (70 eV): *m/z* (%) = 411.8 (100) $[M]^+$, 277.1 (13), 248.1 (14), 234.1 (22), 233.0 (38), 232.0 (16), 205.1 (16), 204.1 (32), 77.2 (11).

4′-(4-Chlorophenyl)-2,3,4′,5′-tetrahydro-5′-(hydroxyimino)-2′-(phenylimino)spiro[1H-indene-1,3′(2′H)-thiophene]-2-one (**4b**, $C_{24}H_{17}ClN_2O_2S$)
Pale yellow crystals (1.164 g, 54%); m.p.: 185–187 °C; ^{1}H NMR (300 MHz, DMSO-d_6): $\delta = 11.88$ (s, 1H, NOH), 7.44–7.15 (m, 8H, CH arom), 7.07 (d, 2H, $^3J = 8.5$ Hz, CH arom), 6.88 (d, 1H, $^3J = 7.6$ Hz, CH arom), 6.79 (d, 2H, $^3J = 7.3$ Hz, CH arom), 5.00 (s, 1H, HC-4′), 3.77 (d, 1H, $^2J = 23.1$ Hz, HC-3), 3.63 (d, 1H, $^2J = 23.1$ Hz, HC-3) ppm; ^{13}C NMR (75 MHz, DMSO-d_6): $\delta = 210.7$, 167.3, 151.4, 149.9, 137.9, 137.0, 134.0, 132.3, 131.0, 129.4, 128.7, 128.0, 127.0, 125.5, 125.3, 124.9, 119.2, 72.8, 53.6, 42.1 ppm; IR (KBr): $\bar{\nu} = 3{,}271$, 3,054, 2,956–2,853, 1,754, 1,593, 1,556, 1,513, 1,494, 1,440, 1,418, 1,375, 1,183, 1,130, 1,094, 1,061, 955 cm^{-1}; MS (70 eV): *m/z* (%) = 432.0 (6) $[M]^+$, 429.3 (36), 428.3 (100), 427.2 (28), 413.1 (46), 406.2 (28), 405.2 (30), 404.2 (79), 335.0 (21), 267.1 (46), 234.1 (76), 233.1 (56), 205.1 (39), 204.1 (61), 169.0 (27), 146.0 (24), 136.0 (35), 102.0 (33), 93.0 (41), 77.0 (23).

2,3,4′,5′-Tetrahydro-5′-(hydroxyimino)-2′-[(4-methylphenyl)imino]-4′-phenylspiro[1H-indene-1,3′(2′H)-thiophene]-2-one (**4c**, $C_{25}H_{20}N_2O_2S$)
Pale yellow crystals (941 mg, 46%); m.p.: 199–201 °C; ^{1}H NMR (300 MHz, DMSO-d_6): $\delta = 11.76$ (s, 1H, NOH), 7.34–7.12 (m, 8H, CH arom), 7.09–7.02 (m, 2H, CH arom), 6.82 (d, 1H, $^3J = 7.6$ Hz, CH arom), 6.70 (d, 2H, $^3J = 8.3$ Hz, CH arom), 4.90 (s, 1H, HC-4′), 3.75 (d, 1H, $^2J = 23.0$ Hz, HC-3), 3.59 (d, 1H, $^2J = 23.0$ Hz, HC-3), 2.29 (s, 3H, CH_3) ppm; ^{13}C NMR (75 MHz, DMSO-d_6): $\delta = 210.8$, 167.0, 152.0, 147.5, 138.2, 137.0, 135.0, 134.5, 129.8, 129.2, 128.4, 127.9, 127.6, 126.8, 125.6, 124.7, 119.2, 72.9, 54.4, 42.1, 20.4 ppm; IR (KBr): $\bar{\nu} = 3{,}284$, 3,065–3,002, 2,951, 2,951, 1,757, 1,554, 1,514, 1,416, 1,380, 1,308, 1,286, 1,185, 1,133, 1,061 cm^{-1}; MS (70 eV): *m/z* (%) = 412.1 (100) $[M]^+$, 281.1 (10), 263.1 (14), 247.1 (35), 246.1 (16), 234.1 (12), 233.1 (14), 220.1 (17), 218.1 (27), 205.1 (15), 204.1 (16), 191.1 (18), 174.0 (11), 146.1 (16), 107.1 (48), 106.1 (28), 102.0 (18), 91.0 (19), 77.0 (13).

4′-(4-Chlorophenyl)-2,3,4′,5′-tetrahydro-5′-(hydroxyimino)-2′-[(4-methylphenyl)imino]spiro[1H-indene-1,3′(2′H)-thiophene]-2-one (**4d**, $C_{25}H_{19}ClN_2O_2S$)
Pale yellow crystals (1.256 g, 56%); m.p.: 184–186 °C; ^{1}H NMR (300 MHz, DMSO-d_6): $\delta = 11.84$ (s, 1H, NOH), 7.34–7.16 (m, 7H, CH arom), 7.07 (d, 2H, $^3J = 8.5$ Hz, CH arom), 6.90 (d, 1H, $^3J = 7.5$ Hz, CH arom), 6.70 (d, 2H, $^3J = 8.2$ Hz, CH arom), 4.97 (s, 1H, HC-4′), 3.76 (d, 1H, $^2J = 23.1$ Hz, HC-3), 3.61 (d, 1H, $^2J = 23.1$ Hz, HC-3), 2.28 (s, 3H, CH_3) ppm; ^{13}C NMR (75 MHz, DMSO-d_6): $\delta = 210.8$, 167.1, 151.7, 150.3, 139.6, 137.3, 136.8, 130.0, 129.8, 129.3, 128.5, 128.3, 127.7, 125.9, 125.0, 124.1, 119.0, 73.8, 56.9, 42.4, 20.5 ppm; IR (KBr): $\bar{\nu} = 3{,}260$, 3,100–3,036, 2,961, 2,916, 1,753, 1,592, 1,557, 1,517, 1,491, 1,418, 1,377, 1,183, 1,131, 1,091, 1,063 cm^{-1}; MS (70 eV): *m/z* (%) = 446.1 (2) $[M]^+$, 420.1 (36), 419.1 (37), 418.1 (93), 417.1 (32), 281.1 (36), 280.1 (22), 269.1 (28), 268.1 (22), 265.1 (27), 254.1 (13), 250.1 (13), 249.1 (19), 248.1 (100), 247.1 (37), 236.1 (17), 219.1 (22), 218.1 (22), 205.1 (19), 204.1 (32), 203.1 (14), 150.0 (28), 146.0 (17), 138.0 (22), 132.1 (14), 125.0 (24), 107.1 (31), 65.1 (26), 63.0 (21).

2′-[(4-Chlorophenyl)imino]-2,3,4′,5′-tetrahydro-5′-(hydroxyimino)-4′-phenylspiro[1H-indene-1,3′(2′H)-thiophene]-2-one (**4e**, $C_{24}H_{17}ClN_2O_2S$)
Pale yellow crystals (522 mg, 24%); m.p.: 211–214 °C; ^{1}H NMR (300 MHz, DMSO-d_6): $\delta = 11.84$ (s, 1H, NOH), 7.44 (d, 2H, $^3J = 8.7$ Hz, CH arom), 7.32–7.10 (m, 6H, CH arom), 7.09–7.02 (m, 2H, CH arom), 6.83 (d, 2H, $^3J = 8.7$ Hz, CH arom), 6.76 (d, 1H, $^3J = 7.7$ Hz, CH arom), 4.93 (s, 1H, HC-4′), 3.80–3.59 (m, 2H, $^2J = 23.0$ Hz, H_2C-3) ppm; ^{13}C NMR (75 MHz, DMSO-d_6): $\delta = 210.5$, 168.8, 151.6, 148.8, 138.0, 137.0, 135.1, 129.41, 129.37, 129.1, 128.5, 128.0, 127.7, 126.8, 125.7, 124.7, 121.1, 73.0, 54.5, 42.0 ppm; IR (KBr): $\bar{\nu} = 3{,}205$, 3,067, 3,037, 2,921–2,830, 1,756, 1,647, 1,616, 1,484, 1,457, 1,422, 1,390, 1,209, 1,146, 1,123, 965 cm^{-1}; MS (70 eV): *m/z* (%) = 434.1 (40) $[M + 2]^+$, 432.1 (100) $[M]^+$, 387.1 (11), 267.1 (14), 263.1 (16), 246.1 (11), 234.1 (11), 233.1 (15), 220.1 (19), 219.1 (12), 218.1 (15), 217.1 (12), 215.1 (13), 205.1 (16), 204.1 (24), 191.1 (20).

2′-[(4-Chlorophenyl)imino]-2,3,4′,5′-tetrahydro-5′-(hydroxyimino)-4′-(4-methylphenyl)spiro[1H-indene-1,3′(2′H)-thiophene]-2-one (**4f**, $C_{25}H_{19}ClN_2O_2S$)
Pale yellow crystals (527 mg, 23%); m.p.: 191–193 °C; ^{1}H NMR (300 MHz, DMSO-d_6): $\delta = 11.81$ (s, 1H, NOH), 7.43 (d, 2H, $^3J = 8.7$ Hz, CH arom), 7.33–7.24 (m, 2H, CH arom), 7.17 (dd, $^3J \approx 7.4$, $^4J = 1.9$ Hz, CH arom), 6.99 (d, 2H, $^3J = 8.2$ Hz, CH arom), 6.92 (d, 2H, $^3J = 8.2$ Hz, CH arom), 6.87–6.78 (m, 3H, CH arom), 4.88 (s, 1H, HC-4′), 3.79–3.55 (m, 2H, $^2J = 23.1$ Hz, H_2C-3), 2.20 (s, 3H, CH_3) ppm; ^{13}C NMR (75 MHz, DMSO-d_6): $\delta = 210.6$, 168.9, 151.6, 148.7, 138.1, 137.0, 136.8, 131.8, 129.40, 129.36, 129.0, 128.5, 126.9, 125.6, 124.8, 121.1, 73.1, 54.3, 42.1, 20.5 ppm; IR (KBr): $\bar{\nu} = 3{,}267$, 3,095–3,021, 2,961, 2,920, 1,754, 1,555, 1,513, 1,417, 1,379, 1,283, 1,186, 1,131, 1,091, 1,065, 1,015 cm^{-1}; MS (70 eV): *m/z* (%) = 446.1 (3) $[M]^+$, 420.1 (35), 419.1 (35), 418.1 (84), 417.1 (34), 301.0 (17), 270.1 (38), 269.1 (27), 268.1 (100), 267.1 (30), 265.1 (56), 248.1 (28), 236.1 (23), 205.1 (26), 204.1 (37), 174.0 (35), 169.0 (22), 146.0 (42), 129.0 (26), 127.0 (65), 118.1 (41), 117.1 (22), 115.1 (36), 105.1 (36), 102.1 (32), 91.0 (24).

General procedure for synthesis of spiro[naphthalene-1,3′-thiophenes] ***5a–5f***

To a solution of the appropriate thioanilide **2a–2c** (5 mmol) and (*E*)-*β*-nitrostyrene **3a–3c** (5 mmol) in 50 cm^3 dry EtOH, two drops of piperidine were added. The mixture was gently heated under reflux for 3 h then the solvent was removed by evaporation. The residue was chromatographed on silica gel using $CHCl_3$ or $CHCl_3$–acetone 100:1 as eluent, and crystallized from MeOH.

3,4,4′,5′-Tetrahydro-5′-(hydroxyimino)-4′-(4-methylphenyl)-2′-(phenylimino)spiro[naphthalene-1(2H),-3′(2′H)-thiophene]-2-one (**5a**, $C_{26}H_{22}N_2O_2S$)
Pale yellow crystals (979 mg, 46%); m.p.: 242–243 °C; ^{1}H NMR (500 MHz, DMSO-d_6): $\delta = 11.53$ (s, 1H, NOH), 7.67 (d, 1H, $^3J = 7.8$ Hz, CH arom), 7.44–7.37 (m, 3H, CH arom), 7.29 (t, 1H, $^3J = 7.3$ Hz, CH arom), 7.19–7.12 (m, 2H, CH arom), 7.00 (d, 2H, $^3J = 8.0$ Hz, CH arom), 6.82 (d, 2H, $^3J = 7.3$ Hz, CH arom), 6.73 (d, 2H, $^3J = 8.0$ Hz, CH arom), 4.84 (s, 1H, HC-4′), 2.71 (dt, 1H, $^2J = 15.7$, $^3J \approx 5.5$ Hz, CH_2), 2.54 (ddd, 1H, $^2J = 15.0$, $^3J = 11.0$, 5.8 Hz, CH_2), 2.23 (s, 3H, CH_3), 2.02 (dt, 1H, $^2J = 15.0$, $^3J \approx 5$ Hz, CH_2), 1.88 (ddd, 1H, $^2J = 15.7$, $^3J = 11.0$, 4.6 Hz, CH_2) ppm; ^{13}C NMR (125 MHz, DMSO-d_6): $\delta = 206.6$ (C=O), 170.1, 152.1, 150.5, 137.7, 137.4, 137.0, 130.0, 129.9, 129.6, 129.3, 128.2, 127.4, 127.2, 127.0, 124.9, 118.8, 71.0, 60.9, 38.8, 25.9, 20.5 ppm; IR (KBr): $\bar{\nu} = 3{,}183$ (OH), 3,064, 3,023, 2,960–2,856 (C–H), 1,712 (C=O), 1,610, 1,591, 1,512, 1,488, 1,447, 1,380, 1,210, 1,121, 959 cm^{-1}; MS (70 eV): *m/z* (%) = 426 (100) $[M]^+$, 276.7 (56), 260.7 (42), 259.8 (37), 231.9 (34), 115.2 (36), 91 (32).

4′-(4-Chlorophenyl)-3,4,4′,5′-tetrahydro-5′-(hydroxyimino)-2′-(phenylimino)spiro[naphthalene-1(2H),3′(2′H)-thiophene]-2-one (**5b**, $C_{25}H_{19}ClN_2O_2S$)
Pale yellow crystals (1.071 g, 48%); m.p.: 241–243 °C; ^{1}H NMR (500 MHz, DMSO-d_6): $\delta = 11.62$ (s, 1H, NOH), 7.69 (d, 1H, $^3J = 8.0$ Hz, CH arom), 7.45–7.37 (m, 3H, CH arom), 7.33–7.27 (m, 3H, CH arom), 7.17 (dd, 2H, $^3J \approx 7$, 7 Hz, CH arom), 6.87–6.81 (m, 4H, CH arom), 4.95 (s, 1H, HC-4′), 2.77 (dt, 1H, $^2J = 15.8$, $^3J \approx 5.5$ Hz, CH_2), 2.62 (ddd, 1H, $^2J = 14.9$, $^3J = 11.3$, 5 Hz, CH_2), 2.11 (dt, 1H, $^2J = 14.9$, $^3J \approx 5$ Hz, CH_2), 1.92 (ddd, 1H, $^2J = 15.8$, $^3J = 11.3, 4.4$ Hz, CH_2) ppm; ^{13}C NMR (125 MHz, DMSO-d_6): $\delta = 206.3$, 169.4, 151.7, 150.4, 137.7, 137.0, 132.5, 132.1, 132.0, 129.7, 129.3, 127.7, 127.5, 127.3, 127.1, 125.0, 118.8, 71.0, 59.9, 38.7, 26.0 ppm; IR (KBr): $\bar{\nu} = 3{,}201$ (OH), 3,026, 2,959–2,854 (C–H), 1,711 (C=O), 1,609, 1,592, 1,490, 1,383, 1,127, 1,088, 960 cm^{-1}; MS (70 eV): *m/z* (%) = 448 (38) $[M + 2]^+$, 446 (100) $[M]^+$, 313 (17), 311 (56), 282 (13), 266 (15), 247 (42), 246 (28), 218 (12), 116.1 (12), 115.1 (17).

3,4,4′,5′-Tetrahydro-5′-(hydroxyimino)-2′-[(4-methylphenyl)imino]-4′-phenylspiro[naphthalene-1(2H),-3′(2′H)-thiophene]-2-one (**5c**, $C_{26}H_{22}N_2O_2S$)
Colorless crystals (1.003 g, 47%); m.p.: 238-240 °C; ^{1}H NMR (500 MHz, DMSO-d_6): $\delta = 11.55$ (s, 1H, NOH), 7.66 (d, 1H, $^3J = 7.9$ Hz, CH arom), 7.42 (t, 1H, $^3J = 7.4$ Hz, CH arom), 7.31–7.16 (m, 6H, CH arom), 7.12 (d, 1H, $^3J = 7.4$ Hz, CH arom), 6.83 (d, 2H, $^3J = 7.3$ Hz, CH arom), 6.73 (d, 2H, $^3J = 8.2$ Hz, CH arom), 4.86 (s, 1H, HC-4′), 2.69 (dt, 1H, $^2J = 15.7$, $^3J \approx 5.5$ Hz, CH_2), 2.54 (ddd, 1H, $^2J = 15.0$, $^3J = 11.2$, 5.8 Hz, CH_2), 2.29 (s, 3H, CH_3), 2.01 (dt, 1H, $^2J = 15.0$, $^3J \approx 5$ Hz, CH_2), 1.82 (ddd, 1H, $^2J = 15.7$, $^3J = 11.2$, 4.6 Hz, CH_2) ppm; ^{13}C NMR (125 MHz, DMSO-d_6): $\delta = 206.6$ (C=O), 169.5, 152.1, 148.0, 137.7, 137.4, 134.2, 133.0, 130.2, 129.7, 129.6, 127.7, 127.6, 127.4, 127.2, 127.0, 118.8, 71.0, 61.1, 38.8, 25.9, 20.4 ppm; IR (KBr): $\bar{\nu} = 3{,}205$ (OH), 3,064, 3,027, 2,960–2,843 (C–H), 1,716 (C=O), 1,598, 1,504, 1,449, 1,391, 1,229, 1,209, 1,124, 1,069, 957 cm^{-1}; MS (70 eV): *m/z* (%) = 426 (100) $[M]^+$, 277 (62), 261 (44), 260 (39), 248 (15), 232 (36), 218 (13), 217 (13), 116 (30), 115 (35), 91 (32).

4′-(4-Chlorophenyl)-3,4,4′,5′-tetrahydro-5′-(hydroxyimino)-2′-[(4-methylphenyl)imino]spiro-[naphthalene-1(2H),3′(2′H)-thiophene]-2-one
(**5d**, $C_{26}H_{21}ClN_2O_2S$)
Crystallized from $CHCl_3$. Colorless crystals of **5d**·$CHCl_3$ (949 mg, 33%); m.p.: 222–224 °C; ^{1}H NMR (300 MHz, DMSO-d_6): $\delta = 11.59$ (s, 1H, NOH), 8.31 (s, $CHCl_3$) 7.66 (d, 1H, $^3J = 7.8$ Hz, CH arom), 7.42 (dt, 1H, $^3J = 7.3$, $^4J = 1.3$ Hz, CH arom), 7.33–7.25 (m, 3H, CH arom), 7.22–7.13 (m, 3H, CH arom), 6.85 (d, 2H, $^3J = 8.6$ Hz, CH arom), 6.73 (d, 2H, $^3J = 8.2$ Hz, CH arom), 4.93 (s, 1H, HC-4′), 2.76 (ddd, 1H, $^2J = 15.7$, $^3J \approx 5.7$, 5.0 Hz, CH_2), 2.61 (ddd, 1H, $^2J = 14.9$, $^3J = 11.4$, 5.7 Hz, CH_2), 2.29 (s, 3H, CH_3), 2.10 (dt, 1H, $^2J = 14.9$, $^3J \approx 5$ Hz, CH_2), 1.91 (ddd, 1H, $^2J = 15.7$, $^3J = 11.4$, 4.6 Hz, CH_2) ppm; ^{13}C NMR (75 MHz, DMSO-d_6): $\delta = 206.3$, 168.9, 151.8, 147.9, 137.7, 137.1, 134.2, 132.5, 132.1, 132.0, 129.7, 127.7, 127.5, 127.3, 127.1, 118.8, 79.1 ($CHCl_3$), 71.0, 59.9, 38.7, 26.0, 20.4 ppm; IR (KBr): $\bar{\nu} = 3{,}192$, 3,062, 3,021, 2,917, 2,854, 1,713, 1,605, 1,493, 1,414, 1,398, 1,228, 1,216, 1,129, 1,091, 1,017, 997, 960 cm^{-1}; ESI–MS: *m/z* (%) = 462.9 (39), 461.2 (100) $[M + H]^+$, 376.5 (20).

2′-[(4-Chlorophenyl)imino]-3,4,4′,5′-tetrahydro-5′-(hydroxyimino)-4′-phenylspiro[naphthalene-1(2H),-3′(2′H)-thiophene]-2-one (**5e**, $C_{25}H_{19}ClN_2O_2S$)
Pale yellow crystals (1.092 g, 49%); m.p.: 240–242 °C; ^{1}H NMR (500 MHz, DMSO-d_6): $\delta = 11.62$ (s, 1H, NOH), 7.69 (d, 1H, $^3J = 8.0$ Hz, CH arom), 7.47–7.39 (m, 3H, CH arom), 7.30 (ddd, 1H, $^3J = 7.5$, 7.5, $^4J = 1.1$ Hz, CH

arom), 7.25 (t, 1H, $^3J = 7.4$ Hz, CH arom), 7.19 (dd, 2H, $^3J \approx 7.4$, 7.4 Hz, CH arom), 7.12 (d, 1H, $^3J = 7.5$ Hz, CH arom), 6.88–6.81 (m, 4H, CH arom), 4.90 (s, 1H, HC-4′), 2.70 (dt, 1H, $^2J = 15.6$, $^3J \approx 5.5$ Hz, CH_2), 2.55 (ddd, 1H, $^2J = 15.2$, $^3J = 11.1$, 5.5 Hz, CH_2), 2.00 (dt, 1H, $^2J = 15.2$, $^3J \approx 5$ Hz, CH_2), 1.83 (ddd, 1H, $^2J = 15.6$, $^3J = 11.1$, 4.6 Hz, CH_2) ppm; ^{13}C NMR (125 MHz, DMSO-d_6): $\delta = 206.4$ (C=O), 171.2, 151.6, 149.3, 137.7, 137.0, 132.9, 130.1, 129.6, 129.3, 129.1, 127.7, 127.6, 127.4, 127.3, 127.0, 120.7, 71.1, 61.1, 38.8, 25.9 ppm; IR (KBr): $\bar{\nu} = 3{,}233$ (OH), 3,065, 3,031, 2,963–2,844 (C–H), 1,718 (C=O), 1,607, 1,484, 1,451, 1,398, 1,230, 1,211, 1,125, 1,008, 959 cm^{-1}; MS (70 eV): *m/z* (%) = 448 (38) $[M + 2]^+$, 446 (100) $[M]^+$, 282 (13), 281 (33), 280 (15), 277 (66), 260 (13), 248 (15), 246 (12), 232 (28), 218 (17), 217 (17), 116 (23), 115 (29).

2′-[(4-Chlorophenyl)imino]-3,4,4′,5′-tetrahydro-5′-(hydroxyimino)-4′-(4-methylphenyl)spiro[naphthalene-1(2H),3′(2′H)-thiophene]-2-one (**5f**, $C_{26}H_{21}ClN_2O_2S$)
Colorless crystals (1.377 g, 60%); m.p.: 216–218 °C; ^{1}H NMR (300 MHz, DMSO-d_6): $\delta = 11.60$ (s, 1H, NOH), 7.67 (d, 1H, $^3J = 7.9$ Hz, CH arom), 7.48–7.38 (m, 3H, CH arom), 7.29 (dd, 1H, $^3J \approx 7.4$, 7.4 Hz, CH arom), 7.13 (d, 1H, $^3J = 7.4$ Hz, CH arom), 6.99 (d, 2H, $^3J = 8.0$ Hz, CH arom), 6.86 (d, 2H, $^3J = 8.6$ Hz, CH arom), 6.72 (d, 2H, $^3J = 8.0$ Hz, CH arom), 4.85 (s, 1H, HC-4′), 2.69 (ddd, 1H, $^2J = 15.5$, $^3J \approx 5.7$, 5.3 Hz, CH_2), 2.55 (ddd, 1H, $^2J = 14.9$, $^3J = 10.8$, 5.7 Hz, CH_2), 2.23 (s, 3H, CH_3), 2.01 (dt, 1H, $^2J = 14.9$, $^3J \approx 5$ Hz, CH_2), 1.88 (ddd, 1H, $^2J = 15.5$, $^3J = 10.8$, 4.7 Hz, CH_2) ppm; ^{13}C NMR (75 MHz, DMSO-d_6): $\delta = 207.1$, 171.9, 152.4, 149.9, 138.3, 137.8, 137.6, 130.6, 130.4, 130.2, 129.9, 129.7, 128.9, 128.1, 127.9, 127.7, 121.4, 71.7, 61.5, 26.6, 21.1 ppm; IR (KBr): $\bar{\nu} = 3{,}200$, 3,054, 3,027, 2,912, 2,848, 1,719, 1,608, 1,513, 1,483, 1,444, 1,229, 1,161, 1,136, 1,091, 999, 965 cm^{-1}; ESI–MS: *m/z* (%) = 483.1 (11) $[M + Na]^+$, 463.1 (39), 461.4 (100) $[M + H]^+$.

*General procedure for synthesis of **6a–6f** and **7a–7f***

To a solution of the appropriate iminothiophene **4a–4f** or **5a–5f** (0.5 mmol) in MeOH (for **4a–4f**: 80 cm^3; for **5a–5f**: 120–160 cm^3) at reflux temperature 1 cm^3 conc. HCl was added in one portion. For **5a–5f**, the mixture was gently heated under reflux for 0.5 h, then 1 cm^3 conc. HCl was added again. All the mixtures were stirred at reflux temperature for 3 h then concentrated to a volume of ca. 40 cm^3. Then 40 cm^3 water was added, the mixture was left overnight, then most of the solution was decanted. The oily residue was dissolved in $CHCl_3$, washed with plenty of water, and the organic layer was dried with $MgSO_4$, concentrated, and purified by column chromatography on silica gel using $CHCl_3$ as eluent. The products **6d**, **6f**, **7a**, **7d**, and **7f** crystallized from MeOH solution in a fridge.

2-[2,5-Dihydro-4-(4-methylphenyl)-5-oxo-1-phenyl-2-thioxo-1H-pyrrol-3-yl]benzeneacetic acid methyl ester (**6a**, $C_{26}H_{21}NO_3S$)
Brown thick oil (55 mg, 26%); ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 7.56$–7.33 (m, 10H, CH arom), 7.28–7.24 (m, 1H, CH arom), 7.09 (d, 2H, $^3J = 8.1$ Hz, CH arom), 3.54–3.37 (2 × d, *AB* system, 2H, $^2J = 16.1$ Hz, CH_2, + s, 3H, OCH_3), 2.30 (s, 3H, CH_3) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 199.8$, 172.2, 171.0, 140.6, 140.0, 133.9, 133.0, 131.6, 131.55, 131.0, 130.9, 130.0, 129.55, 129.4, 129.1, 128.7, 128.4, 127.3, 125.8, 51.9, 39.6, 21.5 ppm; IR (KBr): $\bar{\nu} = 3{,}439$, 3,030, 2,948, 2,923, 2,854, 1,732, 1,710, 1,597, 1,499, 1,434, 1,380, 1,294, 1,222, 1,148, 1,016 cm^{-1}; ESI–MS: *m/z* (%) = 450.1 (42) $[M + Na]^+$, 428.5 (70) $[M + H]^+$, 412.5 (71), 396.6 (27).

2-[4-(4-Chlorophenyl)-2,5-dihydro-5-oxo-1-phenyl-2-thioxo-1H-pyrrol-3-yl]benzeneacetic acid methyl ester (**6b**, $C_{25}H_{18}ClNO_3S$)
Dark green, thick oil (51 mg, 23%); ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 7.57$–7.43 (m, 6H, CH arom), 7.42–7.35 (m, 4H, CH arom), 7.30–7.21 (m, 3H, CH arom), 3.51–3.37 (2 × d, *AB* system, 2H, $^2J = 15.6$ Hz, CH_2, + s, 3H, OCH_3) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 199.3$, 171.9, 170.9, 140.9, 136.5, 133.8, 133.0, 131.3, 131.2, 131.0, 130.7, 130.5, 129.9, 129.2, 129.0, 128.9, 128.4, 127.5, 127.1, 52.0 (OCH_3), 39.6 (CH_2) ppm; IR (KBr): $\bar{\nu} = 3{,}441$, 3,063, 2,948, 2,852, 1,733, 1,592, 1,496, 1,379, 1,293, 1,223, 1,150, 1,092, 1,013 cm^{-1}; MS (70 eV): *m/z* (%) = 449.1 (40) $[M + 2]^+$, 447.1 (100) $[M]^+$, 418.1 (19), 416.1 (14), 414.1 (21), 390.1 (24), 389.1 (23), 388.1 (65), 376.1 (22), 374.0 (56), 346.1 (15), 221.0 (17), 189.2 (25).

2-[2,5-Dihydro-1-(4-methylphenyl)-5-oxo-4-phenyl-2-thioxo-1H-pyrrol-3-yl]benzeneacetic acid methyl ester (**6c**, $C_{26}H_{21}NO_3S$)
Brown thick oil (23 mg, 11%); ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 7.56$ (dd, 2H, $^3J = 8.3$, $^4J = 1.7$ Hz, CH arom), 7.48–7.25 (m, 11H, CH arom), 3.54–3.36 (2 × d, *AB* system, 2H, $^2J \approx 16$ Hz, CH_2, + s, 3H, OCH_3), 2.42 (s, 3H, CH_3) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 199.8$, 172.1, 170.9, 140.7, 138.9, 133.0, 131.53, 131.37, 131.25, 131.0, 130.9, 130.0, 129.9, 129.6, 128.7, 128.6, 128.1, 127.3, 51.9, 39.6, 21.3 ppm; IR (KBr): $\bar{\nu} = 3{,}453$, 3,059, 2,948, 2,922, 2,853, 1,731, 1,710, 1,514, 1,444, 1,434, 1,382, 1,293, 1,148, 1,019 cm^{-1}; MS (70 eV): *m/z* (%) = 427.1 (100) $[M]^+$, 398.1 (19), 394.1 (19), 369.1 (18), 368.1 (62), 367.1 (25), 355.1 (16), 354.1 (57), 326.1 (15), 221.0 (14), 191.1 (12), 189.1 (21).

2-[4-(4-Chlorophenyl)-2,5-dihydro-1-(4-methylphenyl)-5-oxo-2-thioxo-1H-pyrrol-3-yl]benzeneacetic acid methyl ester (**6d**, $C_{26}H_{20}ClNO_3S$)
Dark green crystals (46 mg, 20%); m.p.: 135 °C; ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 7.53$ (d, 2H, $^3J = 8.9$ Hz, CH arom), 7.49–7.20 (m, 10H, CH arom), 3.50–3.37 (2 × d, *AB* system, 2H, $^2J = 15.5$ Hz, CH_2, + s, 3H, OCH_3), 2.42 (s, 3H, CH_3) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 199.4$, 172.0, 170.9, 140.8, 139.0, 136.4, 133.0, 131.32, 131.17, 131.10, 130.7, 130.5, 129.9, 129.8, 128.9, 128.1, 127.4, 127.2, 51.9, 39.6, 21.3 ppm; IR (KBr): $\bar{\nu} = 3{,}433$, 3,067, 2,950, 2,921, 2,853, 1,725, 1,587, 1,513, 1,481, 1,382, 1,308, 1,291, 1,263, 1,223, 1,148, 1,090, 1,013 cm^{-1}; ESI–MS: *m/z* (%) = 484.3 (81) $[M + Na]^+$, 464.3 (40), 462.4 (100) $[M + H]^+$.

2-[1-(4-Chlorophenyl)-2,5-dihydro-5-oxo-4-phenyl-2-thioxo-1H-pyrrol-3-yl]benzeneacetic acid methyl ester (**6e**, $C_{25}H_{18}ClNO_3S$)
Dark green solid (61 mg, 27%); m.p.: 77–79 °C; ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 7.57$–7.23 (m, 13H, CH arom), 3.47–3.35 (2 × d, *AB* system, 2H, $^2J = 15.5$ Hz, CH_2, + s, 3H, OCH_3) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 199.4$, 171.9, 170.9, 141.0, 134.8, 133.0, 132.3, 131.7, 131.2, 130.9, 130.3, 130.1, 129.81, 129.77, 129.5, 128.7, 128.5, 127.4, 52.0, 39.6 ppm; IR (KBr): $\bar{\nu} = 3{,}448$, 3,063–2,996, 2,948, 2,945, 1,736, 1,493, 1,434, 1,383, 1,305, 1,289, 1,270, 1,211, 1,159, 1,089, 1,018 cm^{-1}; MS (70 eV): *m/z* (%) = 449.1 (41) $[M + 2]^+$, 447.1 (100) $[M]^+$, 418.1 (23), 416.1 (14), 414.1 (22), 390.1 (31), 389.0 (31), 388.1 (86), 387.1 (29), 376.1 (24), 374.0 (63), 355.1 (12), 311.1 (13), 310.1 (18), 221.1 (20), 191.1 (15), 189.1 (28), 165.1 (13).

2-[1-(4-Chlorophenyl)-2,5-dihydro-4-(4-methylphenyl)-5-oxo-2-thioxo-1H-pyrrol-3-yl]benzeneacetic acid methyl ester (**6f**, $C_{26}H_{20}ClNO_3S$)
Brown crystals (68 mg, 29%); m.p.: 109–110 °C; ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 7.52$–7.33 (m, 9H, CH arom), 7.27–7.22 (m, 1H, CH arom), 7.10 (d, 2H, $J = 8.1$ Hz, CH arom), 3.48–3.35 (2 × d, *AB* system, 2H, $^2J = 15.5$ Hz, CH_2, + s, 3H, OCH_3), 2.31 (s, 3H, CH_3) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 199.5$, 171.9, 170.9, 140.8, 140.2, 134.6, 133.0, 132.3, 131.6, 131.4, 131.1, 130.9, 130.0, 129.74, 129.65, 129.45, 129.37, 127.3, 125.7, 51.9, 39.6, 21.5 ppm; IR (KBr): $\bar{\nu} = 3{,}445$, 3,095-2,994, 2,948, 2,923, 1,734, 1,612, 1,493, 1,386, 1,305, 1,289, 1,270, 1,211, 1,160, 1,089, 1,016 cm^{-1}; MS (70 eV): *m/z* (%) = 463.1 (43) $[M + 2]^+$, 461.1 (100) $[M]^+$, 432.1 (17), 430.0 (16), 428.1 (28), 404.1 (23), 403.0 (25), 402.1 (59), 401.0 (27), 390.0 (18), 388.0 (44), 291.1 (21).

2-[2,5-Dihydro-4-(4-methylphenyl)-5-oxo-1-phenyl-2-thioxo-1H-pyrrol-3-yl]benzenepropanoic acid methyl ester (**7a**, $C_{27}H_{23}NO_3S$)
Brown crystals (91 mg, 41%); m.p.: 136–137 °C; ^{1}H NMR (500 MHz, $CDCl_3$): $\delta = 7.52$ (dd, 2H, $^3J = 7.6$, 7.6 Hz, CH arom), 7.48–7.39 (m, 6H, CH arom), 7.34–7.28 (m, 2H, CH arom), 7.22 (d, 1H, $^3J = 7.5$ Hz, CH arom), 7.09 (d, 2H, $^3J = 8.5$ Hz, CH arom), 3.60 (s, 3H, OCH_3), 2.80–2.66 (2 × ddd, 2H, $^2J = 14.6$, $^3J = 9.7$, 9.5, 6.3 Hz, CH_2), 2.42 (ddd, 1H, $^2J = 16.0$, $^3J = 9.5$, 6.3 Hz, CH_2), 2.36–2.27 (m, 4H, $^3J = 9.7$, 6.5 Hz, H–CH + s, CH_3) ppm; ^{13}C NMR (125 MHz, $CDCl_3$): $\delta = 200.3$ (C=S), 173.0, 172.2, 140.6, 140.5, 139.0, 134.0, 131.3, 131.1, 130.8, 129.8, 129.5, 129.4, 129.1, 129.0, 128.7, 128.4, 126.4, 126.0, 51.6 (OCH_3), 34.4 (C-3), 28.5 (C-2), 21.5 (CH_3) ppm; IR (nujol): $\bar{\nu} = 1{,}727$ (C=O), 1,591, 1,278, 1,143 cm^{-1}; MS (70 eV): *m/z* (%) = 441.0 (100) $[M]^+$, 412.0 (13), 408.1 (52), 368 (32), 367.0 (30), 354.0 (51), 348.1 (41), 326.0 (18), 320.1 (18), 203.0 (15), 202.0 (20).

2-[4-(4-Chlorophenyl)-2,5-dihydro-5-oxo-1-phenyl-2-thioxo-1H-pyrrol-3-yl]benzenepropanoic acid methyl ester (**7b**, $C_{26}H_{20}ClNO_3S$)
Brown thick oil (87 mg, 38%); ^{1}H NMR (500 MHz, $CDCl_3$): $\delta = 7.56$–7.40 (m, 8H, CH arom), 7.35–7.29 (m, 2H, CH arom), 7.26 (d, 2H, $^3J = 8.7$ Hz, CH arom), 7.21 (d, 1H, $^3J = 7.4$ Hz, CH arom), 3.60 (s, 3H, OCH_3), 2.79–2.64 (2 × ddd, 2H, $^2J = 14.7$, $^3J = 9.5$, 9.1, 6.6 Hz, CH_2), 2.46 (ddd, 1H, $^2J = 16.3$, $^3J = 9.1$, 6.4 Hz, CH_2), 2.36 (ddd, 1H, $^2J = 16.3$, $^3J = 9.5$, 6.6 Hz, CH_2) ppm; ^{13}C NMR (125 MHz, $CDCl_3$): $\delta = 199.8$ (C=S), 172.9, 171.9, 141.5, 138.9, 136.4, 133.8, 131.1, 130.6, 130.1, 129.7, 129.1, 129.05, 128.9, 128.8, 128.4, 127.3, 126.5, 51.6 (OCH_3), 34.4 (C-3), 28.4 (C-2) ppm; IR (nujol): $\bar{\nu} = 1{,}733$ (C=O), 1,558, 1,492, 1,296, 1,166, 1,150, 1,090 cm^{-1}; MS (70 eV): *m/z* (%) = 463.1 (40) $[M + 2]^+$, 461 (100) $[M]^+$, 430.1 (21), 428.1 (35), 388.0 (31), 376.0 (23), 374.0 (59), 372.1 (21), 368.1 (30), 340.1 (15), 202.1 (29), 93.0 (16), 77.0 (17).

2-[2,5-Dihydro-1-(4-methylphenyl)-5-oxo-4-phenyl-2-thioxo-1H-pyrrol-3-yl]benzenepropanoic acid methyl ester (**7c**, $C_{27}H_{23}NO_3S$)
Brown thick oil (70 mg, 32%); ^{1}H NMR (500 MHz, $CDCl_3$): $\delta = 7.53$ (d, 2H, $^3J = 8.6$ Hz, CH arom), 7.42 (dt, 1H, $^3J = 7.6$, $^4J = 1.4$ Hz, CH arom), 7.35–7.25 (m, 9H, CH arom), 7.22 (d, 1H, $^3J = 7.5$ Hz, CH arom), 3.59 (s, 3H, OCH_3), 2.75 (ddd, 1H, $^2J = 14.6$, $^3J = 9.8$, 6.2 Hz, CH_2), 2.67 (ddd, 1H, $^2J = 14.6$, $^3J = 9.5$, 6.4 Hz, CH_2), 2.46–2.39 (m, 4H, $^2J = 16.1$, $^3J = 9.5$, 6.2 Hz, H–CH + s, CH_3), 2.27 (ddd, 1H, $^2J = 16.1$, $^3J = 9.8$, 6.4 Hz, CH_2) ppm; ^{13}C NMR (125 MHz, $CDCl_3$):

δ = 200.3 (C=S), 173.0, 172.1, 141.3, 138.9, 138.8, 131.2, 130.86, 130.82, 129.94, 129.86, 129.8, 129.5, 128.95, 128.88, 128.5, 128.1, 126.3, 51.6 (OCH_3), 34.4 (C-3), 28.4 (C-2), 21.3 (CH_3) ppm; IR (nujol): $\bar{\nu}$ = 1,733 (C=O), 1,558, 1,492, 1,296, 1,166,1,150, 1,090 cm^{-1}; MS (70 eV): *m/z* (%) = 441 (100) $[M]^+$, 412.1 (14), 408.1 (42), 368.1 (33), 367.0 (23), 354.1 (55), 348.1 (39), 320.1 (16), 355.0 (32), 203.1 (17), 202.1 (16), 159.8 (34), 127.9 (49), 63.9 (49).

2-[4-(4-Chlorophenyl)-2,5-dihydro-1-(4-methylphenyl)-5-oxo-2-thioxo-1H-pyrrol-3-yl]benzenepropanoic acid methyl ester (**7d**, $C_{27}H_{22}ClNO_3S$)

Green crystals (52 mg, 22%); m.p.: 80–86 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.50 (d, 2H, ^3J = 8.8 Hz, CH arom), 7.42 (ddd, 1H, $^3J \approx 7.5$, 7.5, ^4J = 1.5 Hz, CH arom), 7.36–7.17 (m, 9H, CH arom), 3.60 (s, 3H, OCH_3), 2.81–2.62 (m, 2H, CH_2), 2.52–2.29 (m, 5H, CH_2, CH_3) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ = 200.0, 173.0, 172.0, 141.4, 139.0, 138.9, 136.3, 131.13, 131.07, 130.65, 130.61, 130.1, 129.9, 129.8, 129.1, 128.9, 128.1, 127.4, 126.5, 51.7, 34.4, 28.4, 21.3 ppm; IR (KBr): $\bar{\nu}$ = 3,434, 3,062, 2,921, 2,852, 1,726, 1,588, 1,514, 1,387, 1,293, 1,149, 1,092, 1,011 cm^{-1}; ESI–MS: *m/z* (%) = 492.2 (100), 476.4 (25) $[M + H]^+$, 460.4 (42), 444.5 (72), 442.5 (48).

2-[1-(4-Chlorophenyl)-2,5-dihydro-5-oxo-4-phenyl-2-thioxo-1H-pyrrol-3-yl]benzenepropanoic acid methyl ester (**7e**, $C_{26}H_{20}ClNO_3S$)

Brown thick oil (177 mg, 77%); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.55–7.46 (m, 4H, CH arom), 7.44–7.25 (m, 8H, CH arom), 7.21 (dd, 1H, ^3J = 7.6 Hz, ^4J = 1.4 Hz, CH arom), 3.59 (s, 3H, OCH_3), 2.80–2.60 (2 × ddd, 2H, ^2J = 14.5, ^3J = 9.7, 9.2, 6.5 Hz, CH_2), 2.42 (ddd, 1H, ^2J = 16.1, ^3J = 9.2, 6.5 Hz, CH_2), 2.26 (ddd, 1H, ^2J = 16.1, ^3J = 9.7, 6.5 Hz, CH_2) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ = 199.8, 173.0, 171.8, 141.6, 138.9, 134.7, 132.3, 131.4, 130.8, 130.6, 130.2, 129.9, 129.73, 129.68, 129.4, 129.0, 128.69, 128.63, 126.4, 51.7, 34.4, 28.4 ppm; IR (KBr): $\bar{\nu}$ = 3,441, 3,059–2,994, 2,948, 2,850, 1,733, 1,493, 1,441, 1,377, 1,304, 1,285, 1,149, 1,089, 1,017 cm^{-1}; ESI–MS: *m/z* (%) = 478.2 (100), 462.3 (40) $[M + H]^+$, 446.3 (51), 430.4 (63), 428.4 (63).

2-[1-(4-Chlorophenyl)-2,5-dihydro-4-(4-methylphenyl)-5-oxo-2-thioxo-1H-pyrrol-3-yl]benzenepropanoic acid methyl ester (**7f**, $C_{27}H_{22}ClNO_3S$)

Brown crystals (128 mg, 54%); m.p.: 88–91 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.51–7.25 (m, 9H, CH arom), 7.20 (dd, 1H, ^3J = 7.7 Hz, ^4J = 1.4 Hz, CH arom), 7.09 (d, 2H, ^3J = 8.0 Hz, CH arom), 3.58 (s, 3H, OCH_3), 2.80–2.62 (m, 2H, CH_2), 2.51–2.24 (m, 5H, CH_2, CH_3) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ = 200.0, 173.1, 172.0, 140.81, 140.78, 139.0, 134.6, 132.4, 131.4, 131.0, 130.8, 129.9, 129.8, 129.6, 129.5, 129.3, 129.1, 126.4, 125.9, 51.7, 34.4, 28.4, 21.5 ppm; IR (KBr): $\bar{\nu}$ = 3,441, 3,090–2,985, 2,946, 2,917, 1,728, 1,608, 1,494, 1,385, 1,304, 1,290, 1,192, 1,150, 1,090, 1,017 cm^{-1}; ESI–MS: *m/z* (%) = 514.2 (100), 498.2 (38) $[M + Na]^+$, 476.4 (76) $[M + H]^+$, 460.4 (63), 444.5 (63), 442.5 (83).

*General procedure for synthesis of 2-hydroxy-1H-indene-3-thiocarboxylic acid O-esters **16a**, **16b***

A solution of **1a** (1 mmol) in 30 cm^3 dry MeOH (for **16a**) or EtOH (for **16b**) was heated under reflux until the starting material was consumed (TLC; 9 h for **16a**, 36 h for **16b**). The solvent was evaporated, and the residue was chromatographed on silica gel using $CHCl_3$ as eluent then crystallized from Et_2O.

2-Hydroxy-1H-indene-3-thiocarboxylic acid O-methyl ester (**16a**, $C_{11}H_{10}O_2S$)

Reddish brown crystals (89 mg, 43%); m.p.: 108–109 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 13.75 (s, 1H, OH), 7.78 (d, 1H, ^3J = 7.8 Hz, CH arom), 7.32–7.23 (m, 2H, CH arom), 7.13 (ddd, $^3J \approx 7.5$, 7.5, ^4J = 1.2 Hz, CH arom), 4.26 (s, 3H, OCH_3), 3.68 (s, 2H, H_2C-3) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ = 205.4, 185.4, 140.3, 131.4, 127.1, 124.4, 123.5, 121.8, 114.6, 56.5, 39.3 ppm; IR (KBr): $\bar{\nu}$ = 3,043, 3,001, 2,941, 2,919, 1,544, 1,483, 1,460, 1,440, 1,385, 1,304, 249, 1,234, 1,214, 1,183, 1,038, 944 cm^{-1}; MS (70 eV): *m/z* (%) = 206.0 (37) $[M]^+$, 174.0 (57), 146.0 (100), 145.0 (23), 134.0 (20), 102.0 (41).

2-Hydroxy-1H-indene-3-thiocarboxylic acid O-ethyl ester (**16b**, $C_{12}H_{12}O_2S$)

Yellow crystals (135 mg, 61%); m.p.: 90–92 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 13.84 (s, 1H, OH), 7.80 (d, 1H, ^3J = 7.8 Hz, CH arom), 7.33–7.23 (m, 2H, CH arom), 7.13 (ddd, $^3J \approx 7.4$, 7.4, ^4J = 1.1 Hz, CH arom), 4.74 (q, 2H, ^3J = 7.1 Hz, OCH_2), 3.72 (s, 2H, H_2C-3), 1.64 (t, 3H, ^3J = 7.1 Hz, CH_3) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ = 204.6, 185.4, 140.4, 131.4, 127.1, 124.3, 123.5, 121.7, 114.4, 66.1, 39.2, 13.9 ppm; IR (KBr): $\bar{\nu}$ = 3,041, 2,988, 2,975, 2,892, 2,672, 2,629, 1,533, 1,483, 1,458, 1,366, 1,324, 1,300, 1,253, 1,211, 1,172, 1,150, 1,036, 1,022, 918 cm^{-1}; MS (70 eV): *m/z* (%) = 220.1 (71) $[M]^+$, 174.0 (100), 146.0 (80), 102.0 (25).

X-ray structure analysis

Compound **6d**, formula $C_{26}H_{20}ClNO_3S$, crystallizes in the triclinic system, space group P-1, with unit cell parameters a = 8.3419(2), b = 11.3337(2), c = 13.8126(4) Å, α = 66.627(1), β = 74.298(1), γ = 88.138(1) °, V = 1,149.86

(3) $Å^3$, $Z = 2$. A total of 4,478 independent reflections ($R_{int} = 0.0204$) were collected from a sample (size 0.35 × 0.2 × 0.15 mm) using a Kappa CCD diffractometer and Mo–K_α radiation. The structure was solved by direct methods with SHELXS97 [26] and refined by the full-matrix least-squares method on F^2 using SHELXL97 [27] software. Final discrepancy indices for $I > 2\sigma(I)$ were: $R1 = 0.0476$, $wR2 = 0.1048$, and $R1 = 0.0656$, $wR2 = 0.1411$ for all data. The final difference Fourier map of electron density was featureless with the largest peak and hole of 0.18 and -0.23 $eÅ^{-3}$, respectively. All calculations and molecular graphics were done using the WinGX package [28].

Compound **7a**, formula $C_{27}H_{23}NO_3S$, crystallizes in the monoclinic system, space group $P2_1/c$, with unit cell parameters $a = 9.7300(1)$, $b = 10.3974(2)$, $c = 23.0241(4)$ Å, $\beta = 95.731(1)^\circ$, $V = 2317.63(6)$ $Å^3$, $Z = 4$. A total of 4,046 independent reflections ($R_{int} = 0.0246$) were collected from a sample (size 0.35 × 0.25 × 0.15 mm) using a Kappa CCD diffractometer and Mo–K_α radiation. The structure was solved by direct methods using SHELXS97 [26] and refined by the full-matrix least-squares method on F^2 using SHELXL97 [27] software. Final discrepancy indices for $I > 2\sigma(I)$ were: $R1 = 0.0526$, $wR2 = 0.1413$, and $R1 = 0.0616$, $wR2 = 0.1500$ for all data. The final difference Fourier map of electron density had the largest peak and hole of 0.63 and -0.408 $eÅ^{-3}$, respectively. All calculations and molecular graphics were done using the WinGX package [28].

The structural data for compounds **6d** and **7a** have been deposited with Cambridge Crystallographic Data Centre as Supplementary Publications CCDC-720640 (**6d**) and CCDC-720639 (**7a**). Copies of these data can be obtained free of charge via www.ccdc.cam.ac.uk/conts/retrieving.html or from the CCDC, 12 Union Road, Cambridge CB2 1EZ, UK; Fax: (internat.) +44-1223-336033; E-mail: deposit@ccdc.cam.ac.uk.

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