Monatshefte für Chemie 135, 97–108 (2004)
DOI 10.1007/s00706-003-0089-y

Monatshefte für Chemie
Chemical Monthly
Printed in Austria

Diastereoselective *Diels-Alder* Reaction of 2-Thienyl and 2-Furyl Substituted 3-Propenethioamides with Electron Deficient Dienophiles

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Received June 12, 2003; accepted June 13, 2003
Published online October 6, 2003

Summary. The hetero-*Diels-Alder* reaction of *N*-aryl-3-(2-thienyl)-2-propenethioamides with *N*-phenylmaleimide and maleimide yielded a mixture of *endo*- and *exo*-2-arylimino-4-(2-thienyl)tetrahydrothiopyran[2,3-*c*]pyrroles. Cycloaddition to diethyl fumarate required acylation and furnished a mixture of diastereoisomeric 5-(*N*-acetylphenylamino)-2,3-bis-(ethoxycarbonyl)-4-(2-thienyl)-3,4-dihydro-*2H*-thiopyrans. Reactions of 3-(2-furyl)-2-propenethioamides with *N*-arylmaleimides furnished the correspondent 2-arylimino-4-(2-furyl)tetrahydrothiopyran[2,3-*c*]pyrroles. In the cycloadditions of the heterodienes with *N*-arylmaleimides the *endo*-cycloadducts were formed as the major products.

Keywords. α,β-Unsaturated thioamides; Hetero-*Diels-Alder* reaction; Thiopyrans.

Introduction

The hetero-*Diels-Alder* reactions have attracted considerable attention from both synthetic utility and mechanistic point of view. Particularly, reactions employing α,β-unsaturated thiocarbonyl compounds, which can formally be treated as 1-thia-1,3-butadiene, with electron deficient dienophiles represent a straightforward and useful route to sulphur-containing six-membered heterocycles. Its efficiency and versatility combined with regio- and stereochemical control render the thia-*Diels-Alder* reaction an attractive approach to 3,4-dihydro-*2H*-thiopyrans, which are potential precursors of a wide range of sulphur heterocycles that exhibit interesting biological properties [1–3].

Recently, we have described the hetero-*Diels-Alder* reaction of 2-furyl and 2-thienyl substituted enaminothiones with electron deficient dienophiles, which led to functionalized 3,4-dihydro-*2H*-thiopyrans [4–6]. In the present work we

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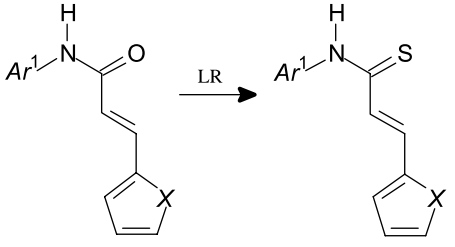
extended our study to heterodiene cycloadditions of α,β-unsaturated thioamides possessing heterocyclic substituents. To our knowledge *Fishwick* et al. [7–10] have studied cycloadditions of *N*-alkylthiocinnamamides with *N*-phenylmaleimide, cyclopentene and diethyl fumarate. They found that only *N*-acylated thiocinnamamides were reactive towards dienophiles. These authors reported also an intramolecular heterodiene reaction of 2-allyloxy and 2-propynoxy substituted *N*-alkylthiocinnamamides, which underwent cycloadditon after preliminary *N*-acylation [11]. Thus, acylation of the *N*-alkylthioamide fragment of the heterodiene was necessary to prevent from *retro*-cycloaddition or dimerization.

Results and Discussion

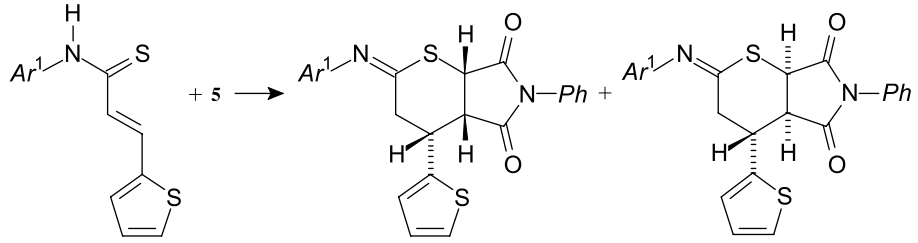
The aim of our study was to investigate the influence of heterocyclic substituents at C-3 of α,β-unsaturated thioamides on yields as well as the regio- and diastereoselectivity of cycloadditions. We focused our attention on *N*-aryl substituted thioamides, which were supposed to be more reactive in cycloaddition reactions. In our first approach we synthesized *N*-aryl-3-(2-thienyl)-2-propenethioamides **3a**–**3c**, which has not been published so far. They were prepared from commercially available 3-(2-thienyl)-2-propenoic acid and arylamines *via* an acid chloride intermediate [12]. Thioamides **3a**–**3c** were prepared from amides **1a**–**1c** using the *Lawesson* reagent (*LR*) [13]. The appropriate 2-furyl-thioamides **4a**–**4c** [12–14] were synthesized in a similar way (Scheme 1). These compounds were stable and did not dimerize like the *N*-alkylthiocinnamamides [8]. Compounds **3** and **4** contain two conjugated diene systems, which are susceptible to competition in *Diels-Alder* reaction with an active dienophile. The first 1,3-butadiene system consists of the C=C bond of thiophene or furane ring together with a conjugated vinyl fragment. The second one is presented by the 1-thia-1,3-butadiene system.



1, 2 **3, 4**

Amide	Thioamide	*X*	Ar^1	Yield/%
1a	**3a**	S	C_6H_5	56
1b	**3b**	S	*p*-$NO_2C_6H_4$	54
1c	**3c**	S	*p*-$CH_3OC_6H_4$	68
2a	**4a**	O	C_6H_5	42
2b	**4b**	O	*p*-$CH_3C_6H_4$	74
2c	**4c**	O	*p*-ClC_6H_4	70

Scheme 1



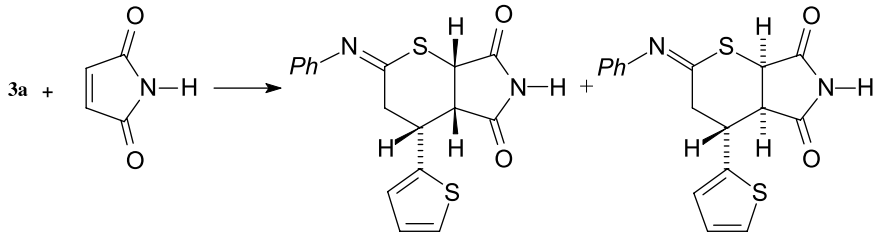
3a: $Ar^1 = C_6H_5$
3b: $Ar^1 = p\text{-}NO_2C_6H_4$

Scheme 2

In the following experiment the cycloaddition of **3a** to *N*-phenylmaleimide (**5**) was studied. The best results were obtained by heating the reagents for 36 h in acetone solution and leaving the reaction mixture for one week at room temperature. The desired products **6a** and **7a** (Scheme 2) were obtained in good yield (84%). The ratio of **6a**:**7a** = 14.7:1 was calculated on the basis of integration of diagnostic signals in the ^{1}H NMR spectrum. Compounds **6a** and **7a** were separated by column chromatography on silica gel. The ^{1}H NMR spectra of both products revealed the presence of two diastereotopic protons of a CH_2 group, *e.g.* for **6a** at $\delta = 3.20$ ($J = 16.2$, 8.0 Hz) and 3.28 ppm ($J = 16.2$, 3.4 Hz). However, the amine proton could not be observed. Thus, both compounds exist in the phenylimine tautomeric form. The structure, configuration, and conformation of **6a** were established by NMR studies employing ^{1}H^{1}H COSY, ^{1}H^{13}C COSY, and HMBC measurements. For **6a** the two vicinal protons attached to C-4 and C-4a resonated at $\delta = 4.29$ ($^3J = 8.0$, 6.1, 3.4 Hz) and at 3.81 ppm ($^3J = 9.3$, 6.1 Hz). The distinction between *endo*- and *exo*-isomers was resolved by N*O*ESY experiment. The N*O*ESY spectrum of **6a** showed steric proximity of protons at H-4 and H-4a, as well as H-4a and H-7a indicating in both cases *cis*-relationship. Thus, **6a** was the *endo*-diastereoisomer [16, 17]. In a similar way we established the stereochemistry of the *exo*-diastereoisomer **7a**. Its N*O*ESY spectrum revealed a correlation between protons H-4a and H-7a, but did not show the correlation between H-4 and H-4a. This indicated that the latter protons were in *trans*-relationship. Thus, the compound **7a** was the *exo*-diastereoisomer. The large coupling constants between H-4a and H-7a suggested also that the thiopyran rings in both compounds exist in a boat conformation.

Cycloaddition of **3b** to **5** in acetonitrile afforded almost exclusively the *endo*-diastereoisomer **6b** in 17% yield (Scheme 2). The presence of the nitro group in **3b** decreased considerably the yield of product, however, the diastereoselectivity was very high (*d.e.* = 94%). All attempts of reactions of **3c** and **5** led to complex mixtures. The ^{1}H NMR spectra of the reaction mixtures showed only traces of the desired cycloadducts.

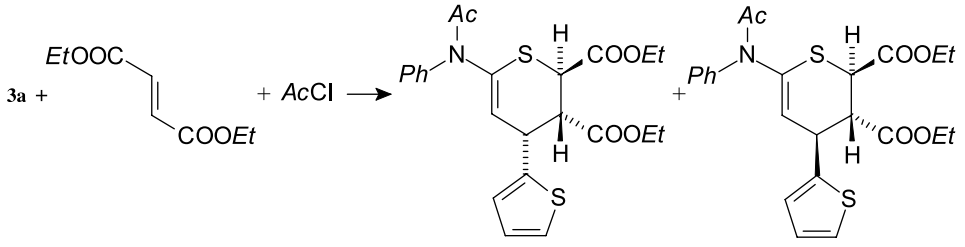
Reactions of **3a** with maleimide (**8**) conducted in boiling acetone furnished a mixture **9a**:**10a** = 8.9:1 (63%, Scheme 3). Poor solubility of the products in



8 **9a** **10a**

mixture 8.9:1

Scheme 3



11 **12a** **13a**

mixture 24:1

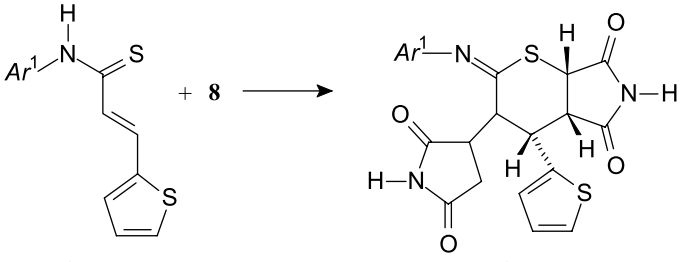
Scheme 4

common organic solvents excluded their separation by column chromatography. Fractional crystallization of the mixture increased the ratio **9a**:**10a** to 16.5:1. The spectral features of obtained products were similar to those of **6a** and **7a**. The only difference was the presence of a band at $\bar{\nu} = 3464\,\mathrm{cm}^{-1}$ (N–H) in the IR spectrum and the signal of a NH imide proton at $\delta = 11.54$ ppm.

Reaction of **3a** with diethyl fumarate (**11**) in boiling acetone solution proceeded very slowly. Since prolonged heating did not influence the reaction, acetyl chloride and pyridine were added to the reaction mixture. This resulted in the formation of **12a**:**13a** = 24:1 in 31% yield (Scheme 4). The structures were established on the basis of the ^{1}H NMR spectrum of the purified mixture of **12a** and **13a**.

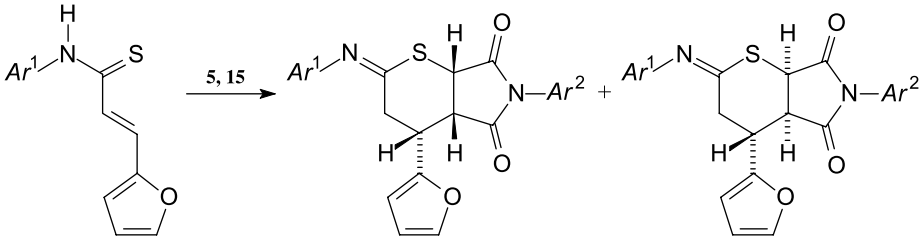
The reaction of **3c** with maleimide (**8**) in dry acetone furnished an unexpected product **14c** (31%) (Scheme 5). The ^{1}H NMR spectrum of a crude reaction mixture showed only traces of a simple [4 + 2] cycloadduct. Analytical and spectral data of **14c** as well as the molecular weight obtained from a MS spectrum indicated that **3c** reacted with **8** in a molar ratio 1:2. The mechanism of this reaction can be considered to involve an initial [4 + 2] cycloaddition followed by a *Michael* reaction of the formed thiopyran to **8**. The structure of **14c** was established by ^{1}H^{1}H COSY, ^{1}H^{13}C COSY, and N*O*ESY measurements. Unfortunately, the stereochemistry of the protons at C-3 and C′-3 could not be determined.

In the next experimental series we studied the reactions of 3-(2-furyl)-2-propenethioamides **4a**–**4c** [15] (Scheme 1) with *N*-phenylmaleimide (**5**) and *N*-(4-methylphenyl)maleimide (**15**). Reactions of **4** with appropriate dienophiles were conducted



3c: Ar^1 = *p*-$CH_3OC_6H_4$ **14c**: Ar^1 = *p*-$CH_3OC_6H_4$

Scheme 5



4a-4c **16b, 16c, 18a-18c** **17b, 17c, 19a-19c**

Thioamide	Dienophile	Ar^1	Ar^2	Isolated products	Ratio of *endo*:*exo*	D.e.*/%
4b	**5**	*p*-CH_3-C_6H_4	C_6H_5	**16b**	9.8:1	81
4c	**5**	*p*-Cl-C_6H_4	C_6H_5	**16c**	8:1	78
4a	**15**	C_6H_5	*p*-CH_3-C_6H_4	**18a**	8.9:1	80
4b	**15**	*p*-CH_3-C_6H_4	*p*-CH_3-C_6H_4	**18b, 19b**	10:1	82
4c	**15**	*p*-Cl-C_6H_4	*p*-CH_3-C_6H_4	**18c, 19c**	7.8:1	77

* Diastereoisomeric excess

Scheme 6

in acetonitrile at 60°C. The ratios of diastereoisomers were determined on the basis of ^{1}H NMR spectra of crude reaction mixtures. All reactions were stereoselective and favoured formation of *endo*-cycloadducts. The reactions of the heterodiene with a *p*-tolyl substituent at the amino group proceeded with higher diastereoselectivity. The products were separated by column chromatography, however, only in two cases we isolated *exo*-diastereoisomers **19b** and **19c** in 1% yield. The results of the reactions of dienes **4a**–**4c** with **5** and **15** are outlined in Scheme 6.

The structures, relative configurations, and conformations of the obtained cycloadducts were deduced from chemical shift values and coupling constants of protons at C-3, C-4, C-4a, and C-7a. The ^{1}H NMR spectrum of **18a** in $CDCl_3$ revealed two diastereotopic protons of the CH_2 group at $\delta = 3.04$ ($^2J = 16.5$, $^3J = 9.3$ Hz) and at 3.23 ppm ($^2J = 16.5$, $^3J = 2.6$ Hz). However the IR spectrum in KBr exhibited the presence of a band at $\bar{\nu} = 3483\ cm^{-1}$ of the NH group. This indicated that in the solid state the enamine form is preferred, whereas in $CDCl_3$ solution the ketoimine form is predominant. The proton C(4)-H of **18a** resonated at $\delta = 3.98$ ($^3J = 9.3$, 6.0, 2.6 Hz) and the proton C(4a)-H at 3.85 ppm ($^3J = 9.5$,

6.0 Hz). It indicated that they are in a *cis*-relationship. The spectral features of other *endo*-cycloadducts were similar to those of **18a**. In the case of *exo*-cycloadducts **19b** and **19c** protons at C-4 and C-4a were in a *trans*-relationship.

In conclusion, an efficient diastereoselective synthesis of 2-thienyl and 2-furyl substituted tetrahydrothiopyrano[2,3-*c*]pyrrole systems was developed. In spite of the presence of two and three diene systems in the substrates, only the 1-thia-1,3-butadiene fragment was reactive in the *Diels-Alder* reactions. Besides it was proved, that an introduction of aryl groups into the thioamide fragment decreases the electron releasing influence of the amino nitrogen and allows to obtain cycloadducts without preliminary acylation of heterodienes. Low yields of some products were probably due to a *retro Diels-Alder* reaction. It is worth to note that cycloadditions of heterodienes **4** containing the 2-furyl substituent furnished almost exclusively the *endo*-cycloadducts and required shorter times to complete reactions than in the case of heterodienes **3**.

Experimental

Mps were determined on a *Boetius* hot-stage apparatus and are uncorrected. IR spectra were run in KBr pellets on a Bruker IFS 48 spectrometer. Mass spectra were obtained on a Finnigan Mat 95 (70 eV) mass spectrometer. NMR spectra were recorded on a Bruker AMX 500 spectrometer (^{1}H: 500.14 MHz, ^{13}C: 125.76 MHr) or Mercury-300 Varian in $CDCl_3$ or *DMSO*-d_6 using *TMS* as internal standard. Microanalyses were performed on an Euro EA 3000 Elemental Analyzer, their results were in satisfactory agreement with the calculated values. 2-Furyl-, 2-thienylacrylic acids, and the *Lawesson* reagent were commercially available. Silica Gel 60, 0.063–0.2 mm, was used for column chromatography. The appropriate arylamides **1a**–**1c** and **2a**–**2c** were synthesized according to Refs. [12, 14].

General Procedure for the Synthesis of 3-(2-Thienyl)- and 3-(2-Furyl)-2-propene-N-arylamides

To a solution of 0.05 mol of the appropriate acid chloride in 30–50 cm^3 of dry CH_2Cl_2, a solution of 0.049 mol of arylamine and 4.0 g of pyridine (0.05 mol) in 40–50 cm^3 of dry CH_2Cl_2 (300 cm^3 in case of **1b**) was added dropwise over a period of 1 h and stirred for additional 2 h. The precipitated products **1b**, and **2b**, **2c** were collected by filtration, washed with H_2O, and recrystallized from toluene. In the case of **1c** and **2a** the reaction mixtures were washed with H_2O and dried ($MgSO_4$). After removing the solvent, the crude products were purified by flash chromatography ($CHCl_3$) and crystallized from toluene.

N-(4-Nitrophenyl)-3-(2-thienyl)-2-propeneamide (**1b**, $C_{13}H_{10}N_2O_3S$)

Pale yellow crystals; mp 216°C; yield 81%; IR (KBr): $\bar{\nu} = 3378$ (N–H), 1688 (C=O), 1619, 1610, 1595, 1537 cm^{-1}; ^{1}H NMR (*DMSO*-d_6): $\delta = 6.60$ (d, $J = 15.4$ Hz, CH vinyl), 7.17 (dd, $J = 5.0$, 3.6 Hz, CH), 7.52 (d, $J = 3.6$ Hz, CH), 7.72 (d, $J = 5.0$ Hz, CH), 7.84 (d, $J = 15.4$ Hz, CH vinyl), 7.92 (d, $J = 9.2$ Hz, 2CH arom), 8.25 (d, $J = 9.2$ Hz, 2CH arom), 10.79 (s, NH) ppm; ^{13}C NMR (*DMSO*-d_6): $\delta = 118.8$, 119.8, 125.0, 128.5, 129.1, 132.0, 134.6, 139.4, 142.1, 145.4, 163.9 ppm; MS: m/z (%) = 274.0 (15) $[M]^{+\cdot}$, 137.0 (100), 109.0 (21), 65.0 (8).

N-(4-Methoxyphenyl)-3-(2-thienyl)-2-propeneamide (**1c**, $C_{14}H_{13}NO_2S$)

Pale yellow crystals; mp 137°C; yield 80%; IR (KBr): $\bar{\nu} = 3329$ (N–H), 3080, 3011, 2961, 2836 (C–H), 1660 (C=O), 1626, 1542, 1513 cm^{-1}; ^{1}H NMR (*DMSO*-d_6): $\delta = 3.73$ (s, OCH_3), 6.56 (d, $J = 15.4$ Hz, CH vinyl), 6.91 (d, $J = 9.1$ Hz, 2CH arom), 7.14 (dd, $J = 5.1$, 3.5 Hz, 2CH), 7.43 (d,

$J = 3.5$ Hz, CH), 7.60 (d, $J = 9.1$ Hz, 2CH arom), 7.65 (d, $J = 5.1$ Hz, CH), 7.71 (d, $J = 15.4$ Hz, CH vinyl), 10.07 (s, NH) ppm; ^{13}C NMR (*DMSO*-d_6): $\delta = 55.1$, 113.9, 120.5, 121.0, 128.2, 128.4, 131.0, 132.4, 132.6, 139.8, 155.3, 162.7 ppm; MS: m/z (%) = 259.0 (100) $[M]^{+\cdot}$, 137.0 (27), 123.1 (21), 109.0 (10), 92.1 (13), 91.0 (22), 63.0 (15).

*General Procedure for the Reactions of **1** and **2** with the Lawesson Reagent*

A suspension of 20 mmol of appropriate *N*-arylamide (**1** or **2**) and 4.85 g of the *Lawesson* reagent (12 mmol) in 150 cm^3 of dry toluene was stirred at 70°C for 30 h. Then the reaction mixture was concentrated to 30–60 cm^3. The crude product was collected by filtration, purified by flash chromatography ($CHCl_3$), and recrystallized from toluene.

N-Phenyl-3-(2-thienyl)-2-propenethioamide (**3a**, $C_{13}H_{11}NS_2$)

Orange crystals; mp 128°C; yield 56%; IR (KBr): $\bar{\nu} = 3450$ (N–H), 3256–3205, 3130–3017 (C–H), 1625, 1603, 1552 cm^{-1}; ^{1}H NMR (*DMSO*-d_6): $\delta = 7.11$ (d, $J = 15.0$ Hz, CH vinyl), 7.15 (dd, $J = 5.0$, 3.6 Hz, CH), 7.24 (t, $J = 7.4$ Hz, CH arom), 7.41 (dd, $J \approx 7.8$ Hz, 2CH arom), 7.50 (d, $J = 3.6$ Hz, CH), 7.67 (d, $J = 5.0$ Hz, CH), 7.93 (d, $J = 7.8$ Hz, 2CH arom), 8.01 (d, $J = 15.0$ Hz, CH vinyl), 11.58 (s, NH) ppm; ^{13}C NMR (*DMSO*-d_6): $\delta = 123.0$, 125.8, 127.6, 128.4, 128.6, 131.7, 135.0, 139.5, 140.0, 191.3 ppm; MS: m/z (%) = 245.0 (81) $[M]^{+\cdot}$, 244.0 (61), 212.0 (28), 153.0 (100), 109.0 (15), 92.1 (36), 91.1 (55), 77.1 (13), 69.0 (11).

N-(4-Nitrophenyl)-3-(2-thienyl)-2-propenethioamide (**3b**, $C_{13}H_{10}N_2O_2S_2$)

A suspension of 3.01 g of **3b** (11 mmol) and 2.67 g of the *Lawesson* reagent (6.6 mmol) in 200 cm^3 of dry *THF* was gently refluxed in an oil bath for 24 h. Then the reaction mixture was concentrated to 30 cm^3 and 40 cm^3 of toluene were added. The crude product was collected by filtration, and recrystallized from toluene:*THF* = 1:1.

Orange plates, mp 236–238°C; yield 54%; IR (KBr): $\bar{\nu} = 3208$ (N–H), 3012, 2923, 2853 (C–H), 1614, 1593, 1541, 1515 cm^{-1}; ^{1}H NMR (*DMSO*-d_6): $\delta = 7.14$ (d, $J = 14.9$ Hz, CH vinyl), 7.18 (dd, $J = 5.0$, 3.6 Hz, CH), 7.58 (d, $J = 3.6$ Hz, CH), 7.74 (d, $J = 5.0$ Hz, CH), 8.05 (d, $J = 15.4$ Hz, CH vinyl), 8.30 (d, $J = 9.3$ Hz, 2CH arom), 8.34 (d, $J = 9.3$ Hz, 2CH arom), 12.02 (s, NH) ppm; ^{13}C NMR (*DMSO*-d_6): $\delta = 122.5$, 124.3, 127.5, 128.7, 129.3, 132.5, 136.2, 139.9, 143.7, 145.3, 192.8 ppm; MS: m/z (%) = 290.0 (71) $[M]^{+\cdot}$, 257.0 (23), 243.0 (9), 222.0 (41), 211.0 (9), 171.1 (11), 153.0 (100), 149.0 (33), 137.0 (50).

N-(4-Methoxyphenyl)-3-(2-thienyl)-2-propenethioamide (**3c**, $C_{14}H_{13}NOS_2$)

Orange crystals; mp 158°C; yield 68%; IR (KBr): $\bar{\nu} = 3189$ (N–H), 3004, 2947–2905, 2830 (C–H), 1625, 1533, 1506 cm^{-1}; ^{1}H NMR (*DMSO*-d_6): $\delta = 3.78$ (s, OCH_3), 6.97 (d, $J = 9.0$ Hz, 2CH arom), 7.07 (d, $J = 15.0$ Hz, CH vinyl), 7.15 (dd, $J = 5.0$, 3.5 Hz, CH), 7.48 (d, $J = 3.5$ Hz, CH), 7.66 (d, $J = 5.0$ Hz, CH), 7.84 (d, $J = 9.0$ Hz, 2CH arom), 7.98 (d, $J = 15.0$ Hz, CH vinyl), 11.49 (s, NH) ppm; ^{13}C NMR (*DMSO*-d_6): $\delta = 55.2$, 113.5, 124.5, 127.6, 128.4, 128.5, 131.4, 132.6, 134.6, 140.1, 157.0, 190.3 ppm; MS: m/z (%) = 275.1 (65) $[M]^{+\cdot}$, 274.1 (16), 242.1 (46), 153.0 (100), 140.0 (27).

N-Phenyl-3-(2-furyl)-2-propenethioamide (**4a**)

Orange crystals; mp 101°C (Ref. [15] 101–102°C); 42%; IR (KBr): $\bar{\nu} = 3227$ (N–H), 3130, 3070 (C–H), 1631, 1600, 1548 cm^{-1}; ^{1}H NMR (*DMSO*-d_6): $\delta = 6.64$ (dd, $J = 3.3$, 1.8 Hz, CH), 6.93 (d, $J = 3.3$ Hz, CH), 7.15 (d, $J = 15.1$ Hz, CH vinyl), 7.24 (t, $J = 7.2$ Hz, CH arom), 7.41 (dd, $J \approx 7.8$ Hz,

2CH arom), 7.67 (d, $J = 15.1$ Hz, CH vinyl), 7.83 (d, $J = 1.8$ Hz, CH), 7.93 (d, $^3J = 7.8$ Hz, 2CH arom), 11.61 (bs, NH) ppm; ^{13}C NMR (*DMSO*-d_6): $\delta = 112.7$, 115.2, 123.0, 125.8, 126.0, 128.3, 128.9, 139.5, 145.1, 151.1, 191.3 ppm; MS: m/z (%) = 229.0 (100) $[M]^{+\cdot}$, 201.0 (18), 200.0 (11), 196.1 (12), 175.0 (48), 137.0 (51), 109.0 (27), 77.0 (14), 65.0 (17).

N-(4-Methylphenyl)-3-(2-furyl)-2-propenethioamide (**4b**)

Orange crystals; mp 144°C (Ref. [15] 142–143°C); yield 74%; IR (KBr): $\bar{\nu} = 3224$ (N–H), 3192, 3045 (C–H), 1635, 1539 cm^{-1}; ^{1}H NMR (*DMSO*-d_6): $\delta = 2.31$ (s, CH_3), 6.64 (dd, $J = 3.4$, 1.8 Hz, CH), 6.92 (d, $J = 3.4$ Hz, CH), 7.13 (d, $J = 15.1$ Hz, CH vinyl), 7.21 (d, $J = 8.2$ Hz, 2CH arom), 7.65 (d, $J = 15.1$ Hz, CH vinyl), 7.79–7.83 (m, 3CH), 11.54 (s, NH) ppm; ^{13}C NMR (*DMSO*-d_6): $\delta = 20.5$, 112.6, 115.0, 122.9, 126.0, 128.7, 135.1, 137.0, 145.0, 151.1, 190.8 ppm; MS: m/z (%) = 243.0 (100) $[M]^{+\cdot}$, 215.0 (11), 210.1 (13), 189.0 (37), 137.0 (49), 109.0 (16), 65.0 (13).

N-(4-Chlorophenyl)-3-(2-furyl)-2-propenethioamide (**4c**, $C_{13}H_{10}ClNOS$)

Orange crystals; mp 183°C; yield 70%; IR (KBr): $\bar{\nu} = 3245$ (N–H), 3119 (C–H), 1691, 1637, 1583 cm^{-1}; ^{1}H NMR (*DMSO*-d_6): $\delta = 6.64$ (d, $J = 3.4$ Hz, CH), 6.95 (d, $J = 3.4$ Hz, CH), 7.13 (d, $J = 14.9$ Hz, CH vinyl), 7.47 (d, $J = 9.1$ Hz, 2CH arom), 7.66 (d, $J = 14.9$ Hz, CH vinyl), 7.83 (s, CH), 7.99 (d, $J = 9.1$ Hz, 2CH arom), 11.69 (bs, NH) ppm; ^{13}C NMR (*DMSO*-d_6): $\delta = 112.7$, 115.5, 124.6, 125.8, 128.3, 129.1, 129.4, 138.4, 145.2, 151.1, 191.6 ppm; MS: m/z (%) = 265.0 (36) [M + 2], 263.0 (100) $[M]^{+\cdot}$, 230.0 (11), 209.0 (35), 137.0 (84), 114.0 (19), 109.0 (22), 65.1 (16).

*General Procedure for the Reactions of Thioamides **3** with N-Arylmaleimides*

A solution of 2 mmol of **3a** and 2.4 mmol of *N*-phenylmaleimide (**5**) in 20 cm^3 of dry acetonitrile (200 cm^3 in the case of **3b**) or acetone was stirred at 60°C for 96 h and left at room temperature for several days. Then the solvent was removed under reduced pressure and the residue was submitted to column chromatography using $CHCl_3$ or $CHCl_3$:CH_3OH = 50:1 as eluent. The oily products were recrystallized from *t*-butyl methyl ether.

(4RS,4aSR,7aSR)-6-Phenyl-2-(phenylimino)-4-(2-thienyl)-2,3,4,4a-tetrahydrothiopyrano[2,3-c]pyrrole-5,7(6H,7aH)-dione (*endo*-**6a**, $C_{23}H_{18}N_2O_2S_2$)

Colorless crystals; mp 199–200°C; yield 83%; IR (KBr): $\bar{\nu} = 3099$–3061, 2935 (C–H), 1711 (C=O), 1623, 1591 cm^{-1}; ^{1}H NMR ($CDCl_3$): $\delta = 3.20$ (dd, $J = 16.2$, 8.0 Hz, 3-H), 3.28 (dd, $J = 16.2$, 3.4 Hz, 3-H), 3.81 (dd, $J = 9.3$, 6.1 Hz, 4a-H), 4.29 (m, 4-H), 4.49 (d, $J = 9.3$ Hz, 7a-H), 6.89 (d, $J = 7.3$ Hz, 2CH arom), 6.96 (d, $J = 7.1$ Hz, 2CH arom), 7.00 (dd, $J = 5.1$, 3.5 Hz, CH), 7.04 (m, $J \approx 3.5$ Hz, CH), 7.15 (t, $J \approx 7.3$ Hz, CH arom), 7.29 (dd, $J = 5.1$, 1.2 Hz, CH), 7.35–7.41 (m, 5CH arom) ppm; ^{13}C NMR ($CDCl_3$): $\delta = 37.2$, 40.6, 42.2, 45.3, 119.5, 124.9, 125.5, 126.2, 127.0, 127.3, 129.0, 129.2, 129.3, 131.0, 139.7, 149.0, 160.4, 173.2 ppm; MS: m/z (%) = 418.1 (100) $[M]^{+\cdot}$, 245.0 (21), 244.0 (13), 212.0 (99), 167.0 (15), 153.0 (18), 117.1 (15), 110.0 (33), 82.9 (15), 77.0 (28).

(4RS,4aRS,7aRS)-6-Phenyl-2-(phenylimino)-4-(2-thienyl)-2,3,4,4a-tetrahydrothiopyrano[2,3-c]pyrrole-5,7(6H,7aH)-dione (*exo*-**7a**, $C_{23}H_{18}N_2O_2S_2$)

Colorless crystals; mp 221–223°C; yield 1.2%; IR (KBr): $\bar{\nu} = 3108$, 3056, 2949, 2923, 2854 (C–H), 1713 (C=O), 1617, 1591 cm^{-1}; ^{1}H NMR ($CDCl_3$): $\delta = 3.02$ (dd, $J = 15.8$, 3.1 Hz, 3-H), 3.27 (dd, $J = 15.8$, 7.5 Hz, 3-H), 3.89 (dd, $J = 9.1$, 4.8 Hz, 4a-H), 4.29 (m, 4-H), 4.49 (d, $J = 9.1$ Hz, 7a-H), 6.77 (d, $J = 7.3$ Hz, 2CH arom), 7.04 (dd, $J = 5.1$, 3.6 Hz, CH), 7.12 (m, 2CH), 7.27–7.34 (m, 5CH) 7.43 (t,

$J \approx 7.4$ Hz, CH arom), 7.49 (dd, $J \approx 7.6$ Hz, CH arom) ppm; ^{13}C NMR ($CDCl_3$): $\delta = 36.3$, 40.9, 41.9, 46.5, 119.5, 124.7, 124.9, 125.5, 127.2, 129.1, 129.2, 129.3, 131.2, 143.5, 148.8, 160.5, 173.2, 174.9 ppm; MS: m/z (%) = 418.1 (100) $[M]^{+\cdot}$, 386.1 (13), 385.1 (12), 315.0 (26), 245.0 (18), 212.0 (56), 167.0 (38), 153.0 (32), 142.0 (22), 135.0 (11), 117.0 (15), 110.0 (46), 77.0 (39).

(4RS,4aSR,7aSR)-2-(4-Nitrophenylimino)-6-phenyl-4-(2-thienyl)-2,3,4,4a-tetrahydro-thiopyrano[2,3-c]pyrrole-5,7(6H,7aH)-dione (*endo*-**6b**, $C_{23}H_{17}N_3O_4S_2$)

Pale yellow crystals; mp 215–216°C; yield 17%; IR (KBr): $\bar{\nu} = 3109$, 3072, 2918 (C–H), 1706 (C=O), 1625, 1587, 1511, 1492 cm^{-1}; ^{1}H NMR ($CDCl_3$): $\delta = 3.20$–3.29 (m, $J = 16.2$, 3.7, 4.9 Hz, 3-H), 3.83 (dd, $J = 9.4$, 6.2 Hz, 4a-H), 4.35 (m, 4-H), 4.56 (d, $J = 9.4$ Hz, 7a-H), 6.92 (d, $J = 7.2$ Hz, 2CH arom), 7.00 (m, 4CH), 7.32 (dd, $J = 5.0$, 1.0 Hz, CH), 7.35–7.41 (m, 3CH arom), 8.26 (d, $J = 8.8$ Hz, 2CH arom) ppm; ^{13}C NMR ($CDCl_3$): $\delta = 37.1$, 40.8, 42.2, 45.0, 120.0, 125.4, 125.8, 126.1, 127.1, 127.6, 129.1, 129.2, 130.9, 144.8, 154.7, 162.6, 172.7, 172.9 ppm; MS: m/z (%) = 463.0 (53) $[M]^{+\cdot}$, 343.0 (20), 317.0 (10), 315.0 (90), 311.0 (17), 290.0 (38), 289.0 (22), 257.0 (41), 211.0 (11), 173.1 (52), 168.0 (20), 167.0 (48), 153.0 (100), 142.0 (26), 137.0 (19), 135.0 (16).

(4RS,4aSR,7aSR)-2-(Phenylimino)-4-(2-thienyl)-2,3,4,4a-tetrahydrothiopyrano [2,3-c]pyrrole-5,7(6H,7aH)-dione (*endo*-**9a**) and *(4RS,4aSR,7aSR)-2-(Phenylimino)-4-(2-thienyl)-2,3,4,4a-tetrahydrothiopyrano[2,3-c]pyrrole-5,7(6H,7aH)-dione* (*exo*-**10a**, $C_{17}H_{14}N_2O_2S_2$) – *Diastereoisomeric Mixture of **9a** and **10a***

A mixture of 0.49 g of **3a** (2 mmol) and 0.21 g of maleimide **8** (2.1 mmol) in 15 cm^3 of dry acetone was refluxed for 36 h and left at room temperature for 7 days. The solvent was evaporated and the residue was treated with $CHCl_3$. The crude product was filtered off and recrystallized from ethyl acetate: acetone = 1:1. Colorless crystals; mp 206–208°C; yield 63%; IR (KBr): $\bar{\nu} = 3464$ (N–H), 3166, 3058, 2931, 2744 (C–H), 1779, 1713 (C=O), 1642, 1590 cm^{-1}. ^{1}H NMR (*DMSO*-d_6): **9a**: $\delta = 2.91$ (dd, $J = 16.0$, 8.2 Hz, 3-H), 3.17 (dd, $J = 16.0$, 2.7 Hz, 3-H), 3.82 (dd, $J = 9.3$, 6.7 Hz, 4a-H), 4.13 (m, 4-H), 4.69 (d, $J = 9.3$ Hz, 7a-H), 6.77 (d, $J = 7.4$ Hz, 2CH arom), 6.98 (m, 2CH), 7.12 (t, $J = 7.4$ Hz, CH arom), 7.36 (t, $J = 7.4$ Hz, 2CH arom), 7.43 (dd, $J = 4.7$, 1.5 Hz, CH), 11.54 (bs, NH) ppm; **10a**: $\delta = 2.84$ (dd, $J = 16.3$, 2.5 Hz, 3-H), 3.17 (m, 3-H), 3.77 (dd, $J = 9.2$, 6.1 Hz, 4a-H), 3.97 (m, 4-H), 4.74 (d, $J = 9.2$ Hz, 7a-H), 6.64 (d, $J = 7.6$ Hz, 2CH arom), 6.86 (d, $J = 3.5$ Hz, CH), 6.91 (dd, $J = 5.1$, 3.5 Hz, CH), 7.04 (t, $J = 7.6$ Hz, CH arom), 7.27 (t, $J = 7.6$ Hz, 2CH arom), 7.36 (m, CH), 11.54 (bs, NH) ppm; ^{13}C NMR (*DMSO*-d_6): $\delta = 35.6$, 40.3, 42.5, 45.5, 119.2, 124.2, 125.1, 126.5, 129.1, 141.6, 149.3, 162.4, 175.9, 176.2 ppm; MS: m/z (%) = 342.1 (100) $[M]^{+\cdot}$, 239.0 (16), 224.0 (11), 222.1 (13), 212.0 (33), 167.0 (25), 153.0 (16), 142.0 (13).

(2RS,3RS,4RS)-5-(N-Acetyl-N-phenylamino)-2,3-bis(ethoxycarbonyl)-4-(2-thienyl)-3,4-dihydro-2H-thiopyran; (*endo*-**12a**) and *(2RS,3RS,4SR)-5-(N-Acetyl-N-phenylamino)-2,3-bis(ethoxycarbonyl)-4-(2-thienyl)-3,4-dihydro-2H-thiopyran* (*exo*-**13a**; $C_{23}H_{25}NO_5S_2$) – *Diastereoisomeric Mixture of **12a** and **13a***

To a mixture of 0.49 g of diene **3a** (2 mmol), 0.38 g of diethyl fumarate (**11**, 2.2 mmol), and 0.32 g of pyridine (4 mmol) in 15 cm^3 of dry acetone a solution of 0.32 g of acetyl chloride (4 mmol) in 5 cm^3 of dry acetone was added dropwise. Then the reaction mixture was refluxed for 24 h. After evaporation of the solvent, the oily residue was dissolved in CH_2Cl_2, and washed with H_2O. The organic layer was dried ($MgSO_4$). The solvent was removed, and the residue was purified by column chromatography using $CHCl_3$ as eluent and crystallized from *t*-butyl methyl ether:petrol ether = 1:1. Pale yellow crystals; mp 108–111°C; yield 31%; IR (KBr): $\bar{\nu} = 3105$–3036, 2979, 2935 (C–H), 1735, 1725, 1698 (C=O), 1637, 1594 cm^{-1}; ^{1}H NMR (*DMSO*-d_6, $T = 385$ K): **12a**: $\delta = 1.11$ (t, $J = 7.1$ Hz, CH_3), 1.15 (t, $J = 7.1$ Hz,

CH_3), 2.15 (s, CH_3), 3.25 (dd, $J = 11.0$, 4.7 Hz, 3-H), 3.99 (dq, $J = 10.8$, 7.1 Hz, CH_2), 4.10 (dq, $J = 10.9$, 7.1 Hz, CH_2), 4.16 (d, $J = 11.0$ Hz, 2-H), 4.53 (dd, $J = 6.4$, 4.7 Hz, 4-H), 6.37 (d, $J = 6.4$ Hz, 5-H), 6.82 (d, $J = 3.5$ Hz, CH), 6.97 (dd, $J = 5.1$, 3.5 Hz, CH), 7.29 (t, $J = 7.1$ Hz, CH arom), 7.33–7.41 (m, 5CH); **13a**: $\delta = 1.02$ (t, $J = 7.1$ Hz, CH_3), 1.11 (m, CH_3), 2.12 (s, CH_3), 3.12 (dd, $J = 9.4$, 9.4 Hz, 3-H), 3.95 (m, CH_2), 3.99 (m, CH_2), 4.33 (dd, $J = 9.4$, 3.4 Hz, 4-H), 4.45 (d, $J = 9.4$ Hz, 2-H), 6.11 (d, $J = 3.4$ Hz, 5-H), 6.87 (d, $J = 3.6$ Hz, CH), 6.94 (dd, $J = 5.2$, 3.6 Hz, CH), 7.29 (m, CH), 7.33–7.41 (m, 5CH) ppm; ^{13}C NMR (*DMSO*-d_6, $T = 385$ K): $\delta = 13.6$, 22.2, 37.3, 41.4, 45.9, 60.7, 61.5, 124.7, 125.9, 126.7, 126.9, 127.1, 128.8, 134.3, 140.9, 141.2, 168.7, 169.1, 169.8 ppm; MS: m/z (%) = 459.1 (87) $[M]^{+\cdot}$, 416.1 (18), 344.1 (30), 325.1 (10), 312.1 (42), 279.0 (35), 270.0 (28), 251.0 (27), 245.0 (26), 244.0 (31), 212.1 (100), 167.0 (11), 153.0 (53), 136.0 (10), 118.1 (13), 109.0 (11), 77.1 (26).

2-(4-Methoxyphenylimino)-3-(2,5-dioxotetrahydropyrrol-3-yl)-4-(2-thienyl)-2,3,4,4a-tetrahydrothiopyrano[2,3-c]pyrrole-5,7(6H,7aH)-dione (**14c**, $C_{22}H_{19}N_3O_5S_2$)

A suspension of 0.55 g of **3c** (2 mmol) and 0.21 g of **8** (2.1 mmol) in 15 cm^3 of dry acetone was refluxed for 48 h and left at room temperature for 2 weeks. The solvent was removed and the oily residue was left for solidification. The crystalline product was treated with 10 cm^3 of $CHCl_3$, filtered off, and crystallized from ethyl acetate:acetone = 1:1. Colorless crystals; mp 241–244°C; yield 31%; IR (KBr): $\bar{\nu} = 3464$, 3183 (N–H), 1778, 1708 (C=O) cm^{-1}; ^{1}H NMR (*DMSO*-d_6): $\delta = 2.86$–2.97 (m, 4′-H), 3.20–3.27 (m, 3-H, 3′-H), 3.76 (s, CH_3O), 3.90 (dd, $J = 9.4$, 6.0 Hz, 4a-H), 4.30 (dd, $J \approx 6.0$, 6.2 Hz, 4-H), 4.69 (d, $J = 9.2$ Hz, 7a-H), 6.64 (d, $J = 8.8$ Hz, 2CH arom), 6.92 (d, $J = 8.8$ Hz, 2CH arom), 6.99 (dd, $J = 5.1$, 3.4 Hz, CH), 7.09 (dd, $J = 3.4$, 1.0 Hz, CH), 7.43 (dd, $J = 5.1$, 1.0 Hz, CH), 11.16 (bs, NH), 11.50 (bs, NH) ppm; ^{13}C NMR (*DMSO*-d_6): $\delta = 35.4$, 38.6, 42.2, 42.5, 50.9, 55.1, 114.2, 120.1, 125.7, 126.3, 128.1, 140.3, 142.1, 156.2, 161.4, 176.0, 176.3, 177.4, 178.3 ppm; MS: m/z (%) = 469.0 (15) $[M]^{+\cdot}$, 372.0 (100), 340.1 (28), 275.0 (17), 242.0 (47), 167.0 (16), 153.0 (25), 134.0 (55), 110.0 (29), 77.0 (12).

Reactions of Thioamides **4** *with N-Arylmaleimides*

All the reactions of **4a**–**4c** with **5** or **15** were carried out according to the procedure described for **3** using acetonitrile as solvent. The obtained products were separated by column chromatography and crystallized from *t*-butyl methyl ether:petrol ether = 1:1.

(4RS,4aSR,7aSR)-4-(2-Furyl)-2-(4-methylphenylimino)-6-phenyl-2,3,4,4a-tetrahydrothiopyrano[2,3-c]pyrrole-5,7(6H,7aH)-dione (*endo*-**16b**, $C_{24}H_{20}N_2O_3S$)

Colorless crystals; mp 188–190°C; yield 60%; IR (KBr): $\bar{\nu} = 3479$ (N–H), 2933 (C–H), 1710 (C=O), 1627 cm^{-1}; ^{1}H NMR ($CDCl_3$): $\delta = 2.33$ (s, CH_3), 3.03 (dd, $J = 16.4$, 9.3 Hz, 3-H), 3.24 (dd, $J = 16.4$, 2.5 Hz, 3-H), 3.88 (dd, $J = 9.5$, 6.1 Hz, 4a-H), 3.99 (ddd, $J = 9.3$, 6.1, 2.5 Hz, 4-H), 4.43 (d, $J = 9.5$ Hz, 7a-H), 6.26 (d, $J = 3.3$ Hz, CH), 6.37 (dd, $J = 3.3$, 1.9 Hz, CH), 6.76 (d, $J = 8.1$ Hz, 2CH arom), 7.15 (d, $J = 8.1$ Hz, 2CH arom), 7.19 (d, $J = 7.5$ Hz, 2CH arom), 7.35–7.46 (m, 4CH arom) ppm; ^{13}C NMR ($CDCl_3$): $\delta = 21.2$, 35.6, 38.2, 42.7, 43.4, 76.8, 108.0, 111.0, 119.7, 126.4, 129.2, 129.5, 130.1, 131.4, 134.8, 142.3, 146.6, 151.8, 161.2, 173.5, 173.8 ppm; MS: m/z (%) = 416.1 (24) $[M]^{+\cdot}$, 131.1 (10), 84.9 (30), 82.9 (49), 73.0 (100), 57.0 (22).

(4RS,4aSR,7aSR)-2-(4-Chlorophenylimino)-4-(2-furyl)-6-phenyl-2,3,4,4a-tetrahydrothiopyrano[2,3-c]pyrrole-5,7(6H,7aH)-dione (*endo*-**16c**, $C_{24}H_{19}ClN_2O_3S$)

Colorless crystals; mp 212°C; yield 70%; IR (KBr): $\bar{\nu} = 3486$ (N–H), 2923 (C–H), 1717(C=O), 1624 cm^{-1}; ^{1}H NMR ($CDCl_3$): $\delta = 2.36$ (s, CH_3), 3.03 (dd, $J = 16.3$, 9.2 Hz, 3-H), 3.19 (dd, $J = 16.3$, 2.6 Hz, 3-H), 3.85 (dd, $J = 9.4$, 6.0 Hz, 4a-H), 3.99 (ddd, $J = 9.2$, 6.0, 2.6 Hz, 4-H), 4.44 (d, $J = 9.4$ Hz, 7a-H), 6.25 (d, $J = 3.2$ Hz, CH), 6.37 (dd, $J = 3.2$, 1.8 Hz, CH), 6.78 (d, $J = 8.6$ Hz, 2CH

arom), 7.04 (d, $J = 8.3$ Hz, 2CH arom), 7.23 (d, $J = 8.3$ Hz, 2CH arom), 7.30 (d, $J = 8.6$ Hz, 2CH arom), 7.39 (d, $J = 1.8$ Hz, CH) ppm; ^{13}C NMR ($CDCl_3$): $\delta = 21.2$, 35.3, 38.2, 42.5, 43.2, 107.9, 110.7, 121.0, 125.9, 128.6, 129.4, 129.8, 130.2, 139.1, 142.1, 147.4, 151.4, 162.3, 173.1, 173.4 ppm; MS: m/z (%) = 452.0 (37) [M + 2], 450.0 (100) $[M]^{+\cdot}$, 422.1 (13), 313.0 (36), 230.0 (27), 187.1 (34), 151.0 (62), 137.0 (18), 111.0 (12), 94.0 (26).

(4RS,4aSR,7aSR)-4-(2-Furyl)-6-(4-methylphenyl)-2-(phenylimino)-2,3,4,4a-tetrahydro-thiopyrano[2,3-c]pyrrole-5,7(6H,7aH)-dione (*endo*-**18a**, $C_{24}H_{20}N_2O_3S$)

Colorless crystals; mp 175–178°C; yield 27%; IR (KBr): $\bar{\nu} = 3483$ (N–H), 3112, 2927 (C–H), 1716 (C=O), 1625, 1592, 1513 cm^{-1}; ^{1}H NMR ($CDCl_3$): $\delta = 2.36$ (s, CH_3), 3.04 (dd, $J = 16.5$, 9.3 Hz, 3-H), 3.23 (dd, $J = 16.5$, 2.6 Hz, 3-H), 3.85 (dd, $J = 9.5$, 6.0 Hz, 4a-H), 3.98 (ddd, $J = 9.3$, 6.0, 2.6 Hz, 4-H), 4.42 (d, $J = 9.5$ Hz, 7a-H), 6.26 (dd, $J = 3.3$, 0.7 Hz, CH), 6.37 (dd, $J = 3.3$, 1.8 Hz, CH), 6.84 (d, $J = 8.4$ Hz, 2CH arom), 7.05 (d, $J = 8.3$ Hz, 2CH arom), 7.13 (t, $J = 7.4$ Hz, CH arom), 7.22 (d, $J = 8.3$ Hz, 2CH arom), 7.34 (dd, $J = 7.4$, 8.4 Hz, 2CH arom), 7.39 (dd, $J = 1.8$, 0.7 Hz) ppm; ^{13}C NMR ($CDCl_3$): $\delta = 21.2$, 35.4, 38.1, 42.5, 43.2, 76.8, 107.8, 110.7, 119.5, 124.8, 125.9, 128.6, 129.3, 129.8, 139.0, 142.0, 149.0, 151.6, 161.2, 173.2, 173.6 ppm; MS: m/z (%) = 416.1 (100) $[M]^{+\cdot}$, 388.1 (32), 313.1 (34), 201.1 (14), 196.1 (21), 187.1 (24), 151.0 (23), 137.0 (18), 132.0 (26), 123.0 (14), 117.0 (45), 104.0 (24), 94.0 (26), 91.0 (31), 77.0 (72), 65.0 (22).

(4RS,4aSR,7aSR)-4-(2-Furyl)-2-(4-methylphenylimino)-6-(4-methylphenyl)-2,3,4,4a-tetrahydrothiopyrano[2,3-c]pyrrole-5,7(6H,7aH)-dione (*endo*-**18b**, $C_{25}H_{22}N_2O_3S$)

Colorless crystals; mp 203–205°C; yield 71%; IR (KBr): $\bar{\nu} = 34879$, (N–H), 3112–2925 (C–H), 1785, 1714 (C=O), 1615 cm^{-1}; ^{1}H NMR ($CDCl_3$): $\delta = 2.33$ (s, CH_3), 2.36 (s, CH_3), 3.03 (dd, $J = 16.4$, 9.3 Hz, 3-H), 3.22 (dd, $J = 16.4$, 2.6 Hz, 3-H), 3.86 (dd, $J = 9.4$, 6.0 Hz, 4a-H), 3.98 (ddd, $J = 9.4$, 6.0, 2.6 Hz, 4-H), 4.41 (d, $J = 9.4$ Hz, 7a-H), 6.25 (d, $J = 3.4$ Hz, CH), 6.36 (dd, $J = 3.4$, 1.8 Hz, CH), 6.75 (d, $J = 8.1$ Hz, 2CH arom), 7.05 (d, $J = 8.2$ Hz, 2CH arom), 7.14 (d, $J = 8.1$ Hz, 2CH arom), 7.22 (d, $J = 8.2$ Hz, 2CH arom), 7.39 (d, $J = 1.8$ Hz, CH) ppm; ^{13}C NMR ($CDCl_3$): $\delta = 20.9$, 21.1, 35.3, 38.0, 42.5, 43.2, 107.7, 110.6, 119.4, 125.9, 128.6, 129.7, 134.4, 139.0, 142.0, 146.4, 151.6, 160.8, 173.2, 173.5 ppm; MS: m/z (%) = 430.1 (100) $[M]^{+\cdot}$, 402.1 (18), 313.1 (23), 210.1 (19), 187.1 (18), 152.0 (12), 151.0 (16), 131.1 (52), 94.0 (14), 91.0 (29), 73.1 (58).

(4RS,4aRS,7aRS)-4-(2-Furyl)-2-(4-methylphenylimino)-6-(4-methylphenyl)-2,3,4,4a-tetrahydrothiopyrano[2,3-c]pyrrole-5,7(6H,7aH)-dione (*exo*-**19b**, $C_{25}H_{22}N_2O_3S$)

Pale yellow crystals; mp 164–168°C; yield 1%; IR (KBr): $\bar{\nu} = 3480$, 3366 (N–H), 3116–2921 (C–H), 1785, 1716 (C=O), 1625 cm^{-1}; ^{1}H NMR ($CDCl_3$): $\delta = 2.31$ (s, CH_3), 2.39 (s, CH_3), 2.88 (dd, $J = 15.9$, 2.8 Hz, 3-H), 3.26 (dd, $J = 15.9$, 6.7 Hz, 3-H), 3.98–4.04 (m, 4-H, 4a-H), 4.36 (d, $J = 8.9$ Hz, 7a-H), 6.34 (d, $J = 3.2$ Hz, CH), 6.40 (dd, $J = 3.2$, 1.8 Hz, CH), 6.69 (d, $J = 8.1$ Hz, 2CH arom), 7.11 (d, $J = 8.1$ Hz, 2CH arom), 7.19 (d, $J = 8.2$ Hz, 2CH arom), 7.28 (d, $J = 8.2$ Hz, 2CH arom), 7.42 (d, $J = 1.8$ Hz, CH) ppm; ^{13}C NMR ($CDCl_3$): $\delta = 20.9$, 21.1, 34.7, 38.1, 41.7, 42.9, 107.2, 110.7, 119.4, 125.9, 128.6, 129.7, 129.8, 134.4, 139.2, 142.0, 146.3, 152.8, 160.3, 173.6, 175.1 ppm; MS: m/z (%) = 430.1 (100) $[M]^{+\cdot}$, 402.1 (22), 215.1 (19), 210.1 (50), 187.1 (63), 131.1 (65), 121.0 (13), 117.1 (11), 94.0 (49), 91.0 (30).

(4RS,4aSR,7aSR)-2-(4-Chlorophenylimino)-4-(2-furyl)-6-(4-methylphenyl)-2,3,4,4a-tetrahydrothiopyrano[2,3-c]pyrrole-5,7(6H,7aH)-dione (*endo*-**18c**, $C_{24}H_{19}ClN_2O_3S$)

Colorless crystals; mp 202°C; yield 70%; IR (KBr): $\bar{\nu} = 3486$ (N–H), 2923 (C–H), 1717(C=O), 1624 cm^{-1}; ^{1}H NMR ($CDCl_3$): $\delta = 2.36$ (s, CH_3), 3.03 (dd, $J = 16.3$, 9.2 Hz, 3-H), 3.19 (dd,

$J = 16.3$, 2.6 Hz, 3-H), 3.85 (dd, $J = 9.4$, 6.0 Hz, 4a-H), 3.99 (ddd, $J = 9.2$, 6.0, 2.6 Hz, 4-H), 4.44 (d, $J = 9.4$ Hz, 7a-H), 6.25 (d, $J = 3.2$ Hz, CH), 6.37 (dd, $J = 3.2$, 1.8 Hz, CH), 6.78 (d, $J = 8.6$ Hz, 2CH arom), 7.04 (d, $J = 8.3$ Hz, 2CH arom), 7.23 (d, $J = 8.3$ Hz, 2CH arom), 7.30 (d, $J = 8.6$ Hz, 2CH arom), 7.39 (d, $J = 1.8$ Hz, CH arom) ppm; ^{13}C NMR ($CDCl_3$): $\delta = 21.2$, 35.3, 38.2, 42.5, 43.2, 107.9, 110.7, 121.0, 125.9, 128.6, 129.4, 129.8, 130.2, 139.1, 142.1, 147.4, 151.4, 162.3, 173.1, 173.4 ppm; MS: m/z (%) = 452.0 (37) [M + 2], 450.0 (100) $[M]^{+\cdot}$, 422.1 (13), 313.0 (36), 230.0 (27), 187.1 (34), 151.0 (62), 137.0 (18), 111.0 (12), 94.0 (26).

(4RS,4aRS,7aRS)-2-(4-Chlorophenylimino)-4-(2-furyl)-6-(4-methylphenyl)-2,3,4,4a-tetrahydrothiopyrano[2,3-c]pyrrole-5,7(6H,7aH)-dione (*exo*-**19c**, $C_{24}H_{19}ClN_2O_3S$)

Pale yellow crystals; mp 172–175°C; yield 1%; IR (KBr): $\bar{\nu} = 3482$ (N–H), 3116–2921 (C–H), 1786, 1715 (C=O), 1625 cm^{-1}; ^{1}H NMR ($CDCl_3$): $\delta = 2.39$ (s, CH_3), 2.86 (dd, $J = 16.1$, 2.8 Hz, 3-H), 3.27 (dd, $J = 16.1$, 6.4 Hz, 3-H), 4.03 (dd, $J = 9.0$, 4.2 Hz, 4a-H), 4.04–4.07 (m, 4-H), 4.38 (d, $J = 9.0$ Hz, 7a-H), 6.33 (d, $J = 3.2$ Hz, CH), 6.41 (dd, $J = 3.2$, 2.0 Hz, CH), 6.71 (d, $J = 8.8$ Hz, 2CH arom), 7.19 (d, $J = 8.4$ Hz, 2CH arom), 7.26–7.31 (m, 4CH arom), 7.43 (d, $J = 2.0$ Hz, CH) ppm; ^{13}C NMR ($CDCl_3$): $\delta = 21.2$, 34.8, 38.1, 41.7, 42.7, 107.2, 110.8, 121.0, 125.9, 128.6, 129.4, 129.9, 130.2, 139.3, 142.1, 147.3, 152.6, 161.8, 173.5, 175.0 ppm; MS: m/z (%) = 452.0 (16) [M + 2], 450.1 (41) $[M]^{+\cdot}$, 265.0 (14), 263.0 (38), 232.0 (12), 230.0 (36), 209.0 (12), 187.1 (100), 153.0 (25), 151.0 (43), 137.0 (51), 133.1 (21), 132.1 (15).

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