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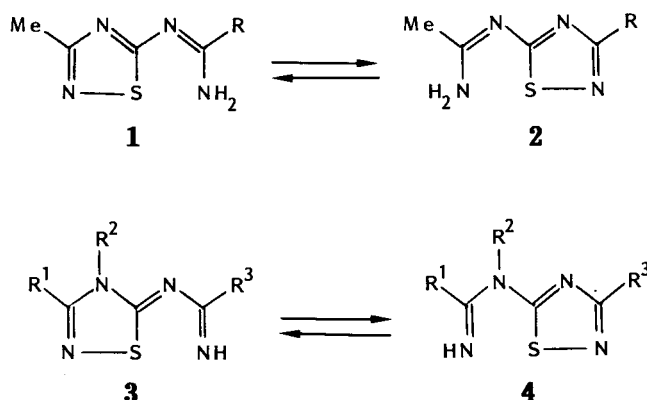
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5-Amino-3-oxo- $\Delta^4$ -1,2,4-thiadiazolines **5a,b** react with isocyanates to yield 1,2,4-thiadiazolidine derivatives **9a-d** via bond switching of the corresponding isomers **7**. The same type of products **9e-m** was obtained by treatment of 5-amino-1,2,3,4-thiadiazoles **6a-d** with two equivalents of isocyanate.

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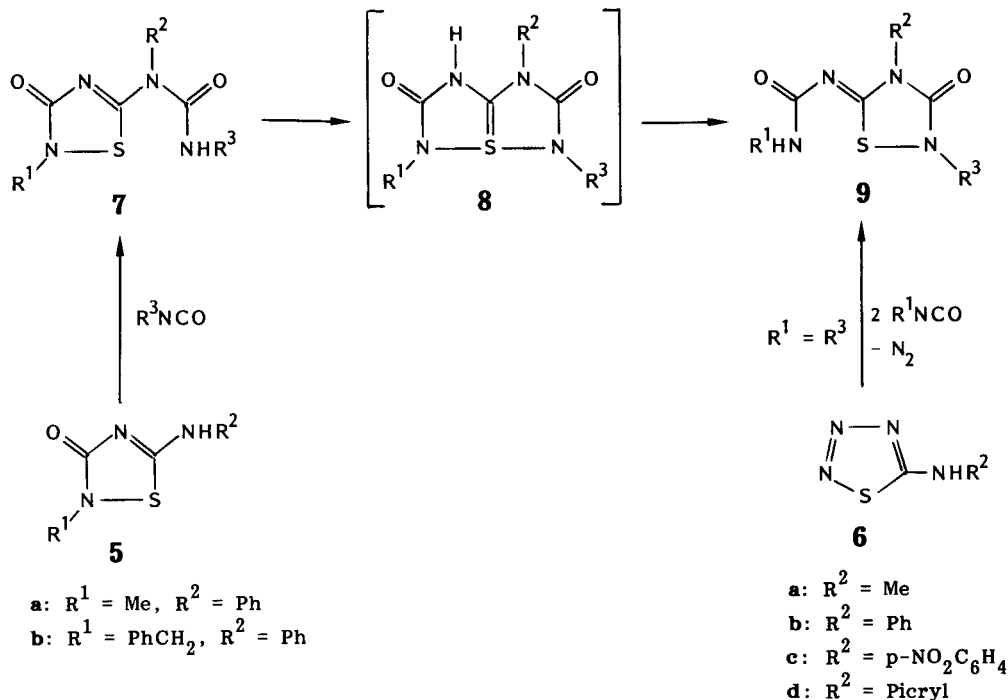
1,2,4-Thiadiazoles bearing a heteroallyl substituent at the 5-position can rearrange to other five-membered ring heterocycles with the participation of three side-chain atoms [1]. Typical examples are **1**  $\rightleftharpoons$  **2** and **3**  $\rightleftharpoons$  **4** which were described by Akiba [2] as bond-switch reactions proceeding through hypervalent sulfur intermediates. These ring-degenerate rearrangements [1] are reversible and the equilibrium positions depend on the nature of the R-substituents, temperature, solvent and the acidity of the reaction medium.

In 1979 Kaugars and Rizzo [3] reported the reactions of 5-amino-3-oxo- $\Delta^4$ -1,2,4-thiadiazolines **5** and of 5-amino-1,2,3,4-thiadiazoles **6** with isocyanates and assigned structure **7** to the products on the basis of  $^1\text{H}$  and  $^{13}\text{C}$  nmr data. The arguments discussed in their paper do not, however, exclude the isomeric structure **9** which is derived from **7** by bond-switching via the thiapentalene intermediate **8**.



Hence, we have synthesized a series of compounds (see Table 1) starting from **5a,b** and **6a-d** and found that they all have structure **9** instead of **7** (Scheme 1).

SCHEME 1



## SCHEME 2

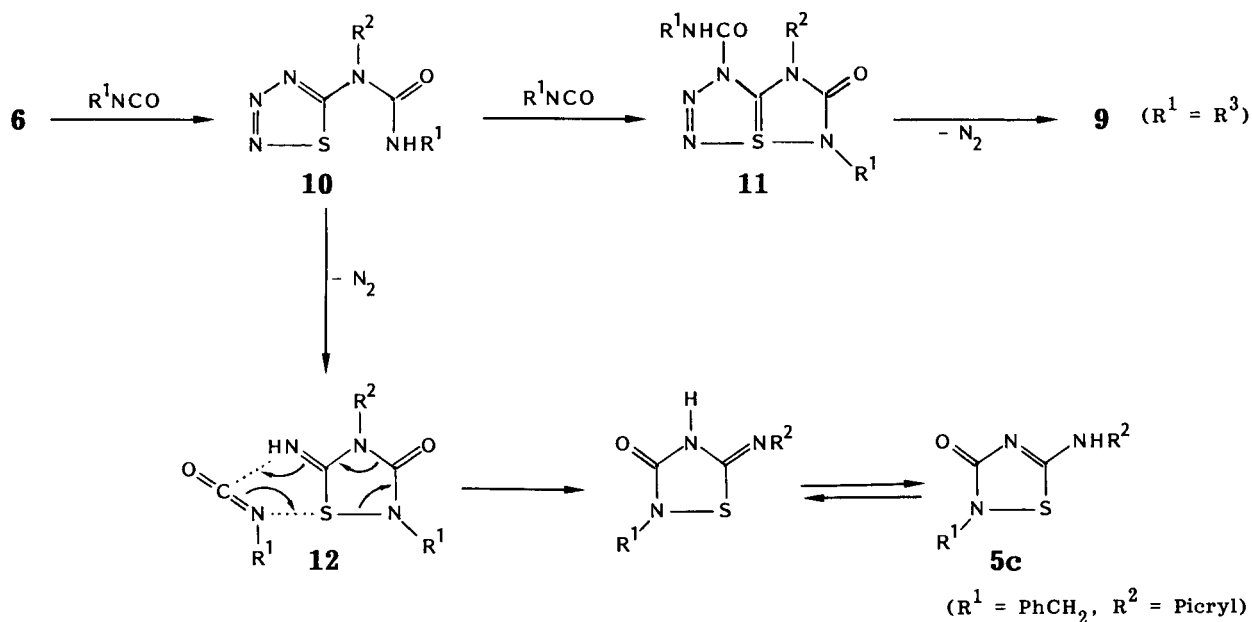


Table 1  
Selected  $^{13}\text{C}$  NMR Chemical Shifts of the Heterocycles

Compound	R <sup>1</sup>	R <sup>2</sup>	R <sup>3</sup>	Solvent	C-3	C-5	CONH
5a	Me	Ph		DMSO-d <sub>6</sub>	165.1	166.9	
5b	PhCH <sub>2</sub>	Ph		DMSO-d <sub>6</sub>	164.8	167.2	
9a	Me	Ph	Et	CDCl <sub>3</sub>	151.8	166.4	165.2
9b	PhCH <sub>2</sub>	Ph	Et	CDCl <sub>3</sub>	151.9	166.8	164.6
9c	PhCH <sub>2</sub>	Ph	<i>i</i> -Pr	CDCl <sub>3</sub>	151.4	166.8	164.5
9d	PhCH <sub>2</sub>	Ph	<i>p</i> -NO <sub>2</sub> C <sub>6</sub> H <sub>4</sub>	CDCl <sub>3</sub>	150.4	166.3	165.1
9e	PhCH <sub>2</sub>	Me	PhCH <sub>2</sub>	CDCl <sub>3</sub>	153.0	166.6	164.5
				C <sub>6</sub> D <sub>6</sub>	152.9	166.8	164.9
				THF-d <sub>8</sub>	153.6	167.1	165.8
				CD <sub>3</sub> CN	154.0	167.3	165.7
9f	Ph	Me	Ph	DMSO-d <sub>6</sub>	150.6	165.7	162.7
9g	PhCH <sub>2</sub>	Ph	PhCH <sub>2</sub>	CDCl <sub>3</sub>	152.1	166.8	164.5
9h	Ph	Ph	Ph	CDCl <sub>3</sub>	150.3	167.0	162.7
9i	PhCH <sub>2</sub>	<i>p</i> -NO <sub>2</sub> C <sub>6</sub> H <sub>4</sub>	PhCH <sub>2</sub>	CDCl <sub>3</sub>	151.2	166.2	164.2
9j	Ph	<i>p</i> -NO <sub>2</sub> C <sub>6</sub> H <sub>4</sub>	Ph	DMSO-d <sub>6</sub>	149.5	166.1	162.6
9k	PhCH <sub>2</sub>	Picryl	PhCH <sub>2</sub>	DMSO-d <sub>6</sub>	148.8	163.7	163.3
9m	Ph	Picryl	Ph	CDCl <sub>3</sub>	147.3	165.0	161.5

The pertinent  $^{13}\text{C}$  nmr data for the heterocycles **9a-m** are summarized in Table 1. They were attributed on the basis of proton coupling, nuclear Overhauser effect, and by comparison with model compounds. Thus, **9a** exhibits absorptions at  $\delta$  151.8 (s x t), 165.2 (s x d x q) and 166.4 (s), corresponding to C-3, CONH and C-5 respectively. Similar resonances were observed for the other compounds **9b-m**, and in all cases the CONH carbon resonated at higher

field than C-5 and was easily recognized by its positive NOE.

If we compare the ring-carbonyl resonances of **5a,b** ( $\delta$  165) [4] with those of products **9a-m** ( $\delta$  147-153), an upfield shift of *ca* 15 ppm is noticed. This cannot be due to the substituent effect in going from **5** to **7**, but indicates a structural variation of the ring system. Furthermore, the values found for **9** are in consonance with those published

for such systems [5].

The structures of **9a-d** are also corroborated by the presence of doublet absorptions for the  $R^1$  substituents in the  $^1\text{H}$  nmr spectra (see Experimental).

The reactions of **5** and **6** with isocyanates gave single end-products, indicating that **9** does not equilibrate with **7**, even when the solvent polarity is changed (see Table 1 for **9e**). In only one case could **7** be detected by  $^1\text{H}$  nmr spectroscopy in the course of the reaction; namely when **5a** was treated with ethyl isocyanate in dimethyl sulfoxide as solvent. A singlet absorption at  $\delta$  3.08, observed in the early period, was gradually transformed into a doublet at  $\delta$  2.6 (1:1 ratio after 20 minutes). The singlet peak is attributed to the  $\text{NCH}_3$  protons of **7** ( $R^1 = \text{CH}_3$ ). After 2 hours, this peak had disappeared and only the absorptions of **9a** remained.

Whereas **7** is a key intermediate in the conversion of **5a,b** to **9a-d** (Scheme 1), the formation of **9e-m** from **6a-d** can be explained without the need to assume the intervention of **7**. A plausible mechanism is outlined in Scheme 2. Evidence for the existence of **10** and **11** was obtained by carrying out the reaction of **6d** with benzyl isocyanate in acetonitrile. Two products, **10** and **11** ( $R^1 = \text{PhCH}_2$ ,  $R^2 = \text{picryl}$ ), were isolated as a 1:4 mixture and characterized by  $^1\text{H}$  and  $^{13}\text{C}$  nmr spectroscopy (see Experimental). They slowly decomposed in dimethyl sulfoxide solution with evolution of nitrogen to give a 1:4 mixture of **5c** and **9k**. The formation of the side product **5c** is rationalized through the decomposition product **12**, which isomerizes to **5c** by a cycloaddition-elimination mechanism [5] catalyzed by traces of isocyanate.

## EXPERIMENTAL

The ir spectra (potassium bromide) were recorded on a Perkin Elmer 1720 FT spectrometer, the nmr spectra (solvents see Table 1) on a Bruker WM-250 spectrometer at 250 ( $^1\text{H}$ ) and 62.9 ( $^{13}\text{C}$ ), and the mass spectra on a Kratos MS50TC instrument operating at 70 eV.

5-Anilino-2-methyl-3-oxo- $\Delta^4$ -1,2,4-thiadiazoline (**5a**, mp 206°) was prepared following the procedure of Kaugars and Rizzo [3]. The 5-aminothiadiazoles **6a-c** were prepared by the method of Lieber *et al.* [6].

5-Anilino-2-benzyl-3-oxo- $\Delta^4$ -1,2,4-thiadiazoline (**5b**).

Benzyl chloride (17 g, 0.13 mole) was added to a suspension of 1-phenylthiourea (20 g, 0.13 mole) in ethanol (150 ml) and the mixture was stirred at 80°. After removal of the solvent, aqueous potassium carbonate was added and the precipitate was filtered off and washed with water,  $\text{PhN}=\text{C}(\text{SCH}_2\text{Ph})-\text{NH}_2$  80% yield (25.47 g), mp 77°.

To this compound (7.26 g, 0.03 mole) in tetrahydrofuran (40 ml) was added dropwise benzyl isocyanate (1.05 equivalents, 4.19 g) and the solution was stirred at room temperature for 4.5 hours, and then refluxed for 30 minutes. After evaporation of the solvent, the residue was triturated with ether to give a precipitate of  $\text{PhN}=\text{C}(\text{SCH}_2\text{Ph})-\text{NHCONHCH}_2\text{Ph}$  in 92% yield (10.36 g), mp

110°.

This compound (10.36 g, 28 mmoles) was added to a filtered solution of sodium sulfide nonahydrate (7.13 g) in ethanol (100 ml) and a slow stream of hydrogen sulfide was passed through the suspension. A clear solution was obtained which was poured into ice-water (500 ml). The precipitate was collected and washed with water;  $\text{PhNH}-\text{C}(\text{S})-\text{NHCONHCH}_2\text{Ph}$  97% (7.63 g), mp 125°.

To this compound (7.63 g, 27 mmoles) in ethanol (100 ml) was added bromine (4.3 g, 27 mmoles) while the solution was cooled in an ice bath. Ice was added and the precipitate **5b** was filtered off and washed several times with water; yield 90% (6.86 g), mp 200° (acetonitrile); ir: 1646 (s), 1510  $\text{cm}^{-1}$  (s);  $^1\text{H}$  nmr:  $\delta$  4.8 (s, 2H,  $\text{CH}_2$ ), 7.1-7.6 (three m, 10H, two Ph), 10.8 (br, 1H, NH);  $^{13}\text{C}$  nmr:  $\delta$  46.2 ( $\text{CH}_2$ ,  $^1J_{\text{CH}} = 141$  Hz), 119.1, 124.0, 127.7, 128.6, 129.2, 137.1 and 138.7 (Ph C-atoms), 164.8 (C-3), 167.2 (C-5); ms:  $m/z$  (%) 283 (42,  $\text{M}^+$ ), 145 (32,  $\text{M}^+-\text{PhCH}_2\text{NH}-\text{S}$ ), 91 (100,  $\text{C}_2\text{H}_7^+$ ).

Anal. Calcd. for  $\text{C}_{15}\text{H}_{13}\text{N}_3\text{OS}$  (mol wt 283): C, 63.60; H, 4.59. Found: C, 63.32; H, 4.62.

5-Picrylamino-1,2,3,4-thiadiazole (**6d**).

Picryl isothiocyanate [7] (0.54 g, 2 mmoles) was allowed to react with an excess of hydrazoic acid (prepared from 7 g of sodium azide) in chloroform (50 ml) at room temperature for 4 hours. The solution was concentrated to 80% of its volume and the pale-yellow crystals were filtered off and washed with chloroform, yield 96% (0.6 g), mp 160° dec (acetone-dichloromethane); ir: 3230 (m), 3150 (m), 1620 (s), 1540 (s) and 1345  $\text{cm}^{-1}$  (s);  $^1\text{H}$  nmr (dimethyl sulfoxide- $d_6$ ):  $\delta$  7.0 (br, 1H, NH), 9.1 (s, 2H, picryl);  $^{13}\text{C}$  nmr (dimethyl sulfoxide- $d_6$ ):  $\delta$  125.2, 133.2, 141.3 and 143.3 (picryl), 174.5 (C-5).

Anal. Calcd. for  $\text{C}_7\text{H}_5\text{N}_3\text{O}_2\text{S}$  (mol wt 313): C, 26.84; H, 0.96. Found: C, 26.99; H, 0.89.

2-Ethyl-5-methylcarbamoylimino-4-phenyl-1,2,4-thiadiazolidin-3-one (**9a**).

To a suspension of **5a** (500 mg, 2.4 mmoles) in tetrahydrofuran (20 ml) was added 1.1 equivalents of ethyl isocyanate (189 mg) and five drops of triethylamine. After being stirred at room temperature for 5 hours, a clear solution was obtained which was evaporated. The residue was subjected to flash chromatography on silica gel with dichloromethane as the eluent to give **9a** in 54% yield (360 mg), mp 159° (chloroform-hexane, 1:2); ir: 3380 (m), 1706 (s), 1630 (s), 1499  $\text{cm}^{-1}$  (s);  $^1\text{H}$  nmr:  $\delta$  1.35 and 3.65 (t and q, 5H, Et), 2.8 (d, 3H, MeN), 5.65 (br, 1H, NH), 7.3-7.5 (m, 5H, Ph);  $^{13}\text{C}$  nmr:  $\delta$  13.9 and 39.0 (Et), 27.0 (MeNH,  $^1J_{\text{CH}} = 138$  Hz,  $^2J_{\text{CH}} = 3$  Hz), 127.6, 128.8, 129.0 and 134.9 (Ph C-atoms), 151.8 (C-3,  $^3J_{\text{CH}} = 4$  Hz), 165.2 (CONH,  $^2J_{\text{CH}} = 1.5$  Hz,  $^3J_{\text{CH}} = 3$  Hz), 166.4 (C-5); ms:  $m/z$  (%) 278 (45,  $\text{M}^+$ ), 220 (11,  $\text{M}^+-\text{MeNHCO}$ ), 207 (55,  $\text{M}^+-\text{EtNCO}$ ), 177 (17,  $\text{M}^+-\text{EtNCO}-\text{MeNH}$ ), 150 (100,  $\text{M}^+-\text{EtNCO}-\text{MeNCO}$ ), 145 (15,  $\text{M}^+-\text{EtNCO}-\text{MeNH}-\text{S}$ ), 123 (27), 118 (28,  $\text{PhNHCN}^+$ ), 104 (12,  $\text{PhNHC}^+$ ), 103 (18,  $\text{PhNC}^+$ ), 91 (24,  $\text{PhN}^+$ ), 77 (53,  $\text{Ph}^+$ ).

Anal. Calcd. for  $\text{C}_{12}\text{H}_{14}\text{N}_4\text{O}_2\text{S}$  (mol wt 278): C, 51.80; H, 5.04. Found: C, 51.78; H, 5.03.

Note: When this reaction was followed by  $^1\text{H}$  nmr spectroscopy in dimethyl sulfoxide- $d_6$  solution, **7** ( $R^1 = \text{Me}$ ,  $R^2 = \text{Ph}$ ,  $R^3 = \text{Et}$ ) was observed as an intermediate with absorptions at  $\delta$  1.0 (t) and 3.10 (br q) (Et), 3.08 (s, MeN), 7.0 (t, NH) and 7.3-7.7 (m, Ph). These resonances were gradually transformed into those of **9a** as the reaction progressed.

5-Benzylcarbamoylimino-2-ethyl-4-phenyl-1,2,4-thiadiazolidin-3-one (**9b**).

To a suspension of **5b** (500 mg, 1.77 mmoles) in tetrahydrofuran (20 ml) was added 1.1 equivalents of ethyl isocyanate (138 mg) and five drops of triethylamine. After being stirred at room temperature for 5 hours, a clear solution was obtained which was evaporated. The residue was triturated with ethanol to give **9b** in 93% yield (580 mg), mp 150° (benzene); ir: 3340 (s), 1720 (s), 1620 (s), 1490 cm<sup>-1</sup> (s); <sup>1</sup>H nmr: δ 1.3 and 3.65 (t and q, 5H, Et), 4.4 (d, 2H, CH<sub>2</sub>), 5.85 (t, 1H, NH), 7.2-7.5 (m, 10H, two Ph); <sup>13</sup>C nmr: δ 14.0 and 39.1 (Et), 44.7 (CH<sub>2</sub>), 127.4-129.0, 134.9 and 137.8 (Ph C-atoms), 151.9 (C-3), 164.6 (CONH), 166.8 (C-5); ms: m/z (%) 354 (100, M<sup>+</sup>), 283 (16, M<sup>+</sup>-EtNCO), 248 (22, M<sup>+</sup>-PhCH<sub>2</sub>NH), 220 (13, M<sup>+</sup>-PhCH<sub>2</sub>NHCO), 150 (50, M<sup>+</sup>-EtNCO-PhCH<sub>2</sub>NCO), 106 (22, PhCH<sub>2</sub>NH<sup>+</sup>), 91 (90, C<sub>7</sub>H<sub>7</sub><sup>+</sup>).

*Anal.* Calcd. for C<sub>18</sub>H<sub>18</sub>N<sub>4</sub>O<sub>2</sub>S (mol wt 354): C, 61.02; H, 5.08. Found: C, 61.23; H, 5.12.

5-Benzylcarbamoylimino-2-isopropyl-4-phenyl-1,2,4-thiadiazolidin-3-one (**9c**).

To a suspension of **5b** (500 mg, 1.77 mmoles) in tetrahydrofuran (20 ml) was added 1.1 equivalents of isopropyl isocyanate (165 mg) and five drops of triethylamine. After being stirred at room temperature for 5 hours, a clear solution was obtained which was evaporated. The residue was subjected to flash chromatography on silica gel with dichloromethane-ether (3:1) as the eluent to give **9c** in 80% yield (520 mg), mp 73° (chloroform-hexane, 1:2); ir: 3432 and 3321 (m), 1707 (s), 1617 (s), 1494 cm<sup>-1</sup> (s); <sup>1</sup>H nmr: δ 1.4 (d, 6H, two Me), 4.4 (d, 2H, CH<sub>2</sub>), 4.55 (sept., 1H, CH), 5.85 (t, 1H, NH), 7.2-7.5 (m, 10H, two Ph); <sup>13</sup>C nmr: δ 21.4 and 46.9 (i-Pr), 44.7 (CH<sub>2</sub>), 127.5-129.1, 134.7 and 137.8 (Ph C-atoms), 151.4 (C-3, <sup>3</sup>J<sub>CH</sub> = 2.8 Hz), 164.5 (CONH), 166.8 (C-5); ms: m/z (%) 368 (84, M<sup>+</sup>), 283 (25, M<sup>+</sup>-i-PrNCO), 251 (25, m/z 283 -S), 220 (19, M<sup>+</sup>-PhCH<sub>2</sub>NCO-Me), 150 (28, M<sup>+</sup>-i-PrNCO-PhCH<sub>2</sub>NCO), 106 (25, PhCH<sub>2</sub>NH<sup>+</sup>), 91 (100, C<sub>7</sub>H<sub>7</sub><sup>+</sup>), 43 (19, i-Pr<sup>+</sup>).

*Anal.* Calcd. for M<sup>+</sup>: 368.1307. Found: 368.1313. Note: No satisfactory elemental analysis could be obtained, although the nice crystalline product showed clean nmr spectra and a single spot on tlc.

5-Benzylcarbamoylimino-2-(*p*-nitrophenyl)-4-phenyl-1,2,4-thiadiazolidin-3-one (**9d**).

To a suspension of **5b** (500 mg, 1.77 mmoles) in tetrahydrofuran (20 ml) was added a tetrahydrofuran solution of *p*-nitrophenyl isocyanate (1.1 equivalents, 319 mg in 20 ml). After being stirred at room temperature for 5 hours, a clear solution was obtained which was evaporated. The residue was triturated with ether to give **9d** in 85% yield (670 mg), mp 157° (acetonitrile); ir: 3439 (m), 1719 (s), 1616 (s), 1485 (s), 1326 cm<sup>-1</sup> (s); <sup>1</sup>H nmr (at 45°): δ 4.45 (d, 2H, CH<sub>2</sub>), 5.9 (br t, 1H, NH), 7.1-7.5 (two m, 10H, two Ph), 7.9 and 8.3 (two d, 4H, *p*-NO<sub>2</sub>C<sub>6</sub>H<sub>4</sub>); <sup>13</sup>C nmr (at 45°): δ 45.1 (CH<sub>2</sub>), 121.3, 124.7, 127.6-129.5, 134.5, 137.3, 143.0 and 144.6 (aromatic C-atoms), 150.4 (C-3), 165.1 (CONH), 166.3 (C-5); ms: m/z (%) 447 (0.3, M<sup>+</sup>), 283 (44, M<sup>+</sup>-*p*-NO<sub>2</sub>C<sub>6</sub>H<sub>4</sub>NCO), 164 (22, *p*-NO<sub>2</sub>C<sub>6</sub>H<sub>4</sub>NCO<sup>+</sup>), 145 (31), 91 (100, C<sub>7</sub>H<sub>7</sub><sup>+</sup>).

*Anal.* Calcd. for C<sub>22</sub>H<sub>17</sub>N<sub>5</sub>O<sub>4</sub>S (mol wt 447): C, 59.06; H, 3.80. Found: C, 58.96; H, 3.93.

2-Benzyl-5-benzylcarbamoylimino-4-methyl-1,2,4-thiadiazolidin-3-one (**9e**).

To a solution of **6a** (478 mg, 4 mmoles) in dry tetrahydrofuran (15 ml) was added 2 equivalents of benzyl isocyanate (1.1 g) and five drops of triethylamine. After being stirred overnight at room temperature, the solvent was evaporated and the residue crystallized from ether-light petroleum (2:1) to give **9e** in 90% yield (1.31 g), mp 89° (ether); ir: 3280 (m), 1705 (s), 1620 (s), 1515 cm<sup>-1</sup> (s); <sup>1</sup>H nmr: δ 3.35 (s, 3H, CH<sub>3</sub>), 4.45 (d, 2H, CH<sub>2</sub>NH), 4.7 (s, 2H, CH<sub>2</sub>N<), 6.0 (br, 1H, NH), 7.2-7.4 (m, 10H, two Ph); <sup>13</sup>C nmr: δ 30.8 (Me, <sup>1</sup>J<sub>CH</sub> = 142 Hz), 44.8 (CH<sub>2</sub>NH), 47.8 (CH<sub>2</sub>N<), 127.5-128.8, 135.6 and 138.0 (Ph C-atoms), 153.0 (C-3), 164.5 (CONH), 166.6 (C-5); ms: m/z (%) 354 (16, M<sup>+</sup>), 240 (31), 149 (19, PhCH<sub>2</sub>NHCONH<sup>+</sup>), 106 (77, PhCH<sub>2</sub>NH<sup>+</sup>), 91 (100, C<sub>7</sub>H<sub>7</sub><sup>+</sup>).

*Anal.* Calcd. for C<sub>18</sub>H<sub>18</sub>N<sub>4</sub>O<sub>2</sub>S (mol wt 354): C, 61.02; H, 5.08. Found: C, 60.91; H, 5.01.

4-Methyl-2-phenyl-5-phenylcarbamoylimino-1,2,4-thiadiazolidin-3-one (**9f**).

To a solution of **6a** (508 mg, 4.4 mmoles) in dry tetrahydrofuran (15 ml) was added 2.1 equivalents of phenyl isocyanate (1.1 g) and five drops of triethylamine. After being stirred overnight at room temperature, the precipitate was filtered off and washed with ether-light petroleum (1:1) to give **9f** in 84% yield (1.2 g), mp 172° (ethanol); ir: 3330 (m), 1705 (s), 1635 (s), 1600 (s), 1525 cm<sup>-1</sup> (s); <sup>1</sup>H nmr: δ 3.4 (s, 3H, Me), 7.0-7.7 (four m, 10H, two Ph), 10.5 (s, 1H, NH); <sup>13</sup>C nmr: δ 31.0 (Me, <sup>1</sup>J<sub>CH</sub> = 142.5 Hz), 118.7, 122.9, 123.1, 126.1, 128.7, 129.3, 136.4 and 138.7 (Ph C-atoms), 150.6 (C-3), 162.7 (CONH), 165.7 (C-5); ms: m/z (%) 326 (35, M<sup>+</sup>), 234 (100, M<sup>+</sup>-PhNH), 119 (10, PhNCO<sup>+</sup>), 115 (17, M<sup>+</sup>-PhNCO-PhNH), 93 (19, PhNH<sub>2</sub><sup>+</sup>), 83 (41, M<sup>+</sup>-PhNCO-PhNH-S).

*Anal.* Calcd. for C<sub>16</sub>H<sub>14</sub>N<sub>4</sub>O<sub>2</sub>S (mol wt 326): C, 58.90; H, 4.29. Found: C, 58.84; H, 4.41.

2-Benzyl-5-benzylcarbamoylimino-4-phenyl-1,2,4-thiadiazolidin-3-one (**9g**).

To a solution of **6b** (470 mg, 2.6 mmoles) in tetrahydrofuran (25 ml) was added 2.1 equivalents of benzyl isocyanate (737 mg) and five drops of triethylamine. After being stirred overnight at room temperature, the solvent was evaporated under reduced pressure and the residual oil was triturated with ethanol to give **9g** (730 mg). From the filtrate a second crop of product (255 mg) was obtained by evaporation and trituration with ethanol; total yield 90% (985 mg), mp 120° (toluene); ir: 3400 (m), 1710 (s), 1620 (s), 1490 cm<sup>-1</sup> (s); <sup>1</sup>H nmr: δ 4.35 (d, 2H, CH<sub>2</sub>NH), 4.75 (s, 2H, CH<sub>2</sub>N<), 5.9 (t, 1H, NH), 7.2-7.5 (m, 15H, three Ph); <sup>13</sup>C nmr: δ 44.6 (CH<sub>2</sub>NH), 47.9 (CH<sub>2</sub>N<), 127.5-129.1, 134.7, 135.4 and 137.7 (Ph C-atoms), 152.1 (C-3), 164.5 (CONH), 166.8 (C-5); ms: m/z (%) 416 (5, M<sup>+</sup>), 283 (13, M<sup>+</sup>-PhCH<sub>2</sub>NCO), 133 (43, PhCH<sub>2</sub>NCO<sup>+</sup>), 104 (19, PhCHN<sup>+</sup>), 91 (100, C<sub>7</sub>H<sub>7</sub><sup>+</sup>).

*Anal.* Calcd. for C<sub>22</sub>H<sub>20</sub>N<sub>4</sub>O<sub>2</sub>S (mol wt 416): C, 66.34; H, 4.81. Found: C, 66.51; H, 4.98.

2,4-Diphenyl-5-phenylcarbamoylimino-1,2,4-thiadiazolidin-3-one (**9h**).

To a solution of **6b** (485 mg, 2.7 mmoles) in tetrahydrofuran (25 ml) was added 2.1 equivalents of phenyl isocyanate (681 mg) and five drops of triethylamine. After being stirred overnight at room temperature, the solvent was evaporated at reduced pressure and the residue subjected to flash chromatography on silica gel with dichloromethane as the eluent. This furnished **9h** in 91% yield (960 mg), mp 188° (toluene); ir: 3270 (m), 1700 (s), 1630 (s), 1600 cm<sup>-1</sup> (s); <sup>1</sup>H nmr: δ 7.0-7.6 (m, Ph); <sup>13</sup>C nmr: δ 118.8,

123.1, 124.1, 126.6, 127.8, 129.1, 129.4, 134.6, 136.3 and 137.4 (Ph C-atoms), 150.3 (C-3), 162.7 (CONH), 167.0 (C-5); ms: m/z (%) 388 (5, M<sup>+</sup>), 296 (24, M<sup>+</sup>-PhNH), 269 (19, M<sup>+</sup>-PhNCO), 145 (67), 119 (100, PhNCO<sup>+</sup>).

*Anal.* Calcd. for C<sub>21</sub>H<sub>16</sub>N<sub>4</sub>O<sub>2</sub>S (mol wt 388): C, 64.95; H, 4.12. Found: C, 65.18; H, 4.23.

2-Benzyl-5-benzylcarbamoilimino-4-(*p*-nitrophenyl)-1,2,4-thiadiazolidin-3-one (**9i**).

To a solution of **6c** (442 mg, 2 mmoles) in acetonitrile (60 ml) was added dropwise 2.1 equivalents of benzyl isocyanate (554 mg) and the whole mixture was stirred overnight at room temperature. After removal of the solvent, the residual oil was triturated with ethanol-hexane (3:1) to give **9i** (285 mg). From the filtrate a second crop of product (225 mg) was isolated by evaporation and trituration with ethanol-hexane (3:1); total yield 56% (510 mg), mp 125° (chloroform-hexane); ir: 3430 (w), 1715 (s), 1620 (s), 1490 (s), 1350 cm<sup>-1</sup> (m); <sup>1</sup>H nmr:  $\delta$  4.45 (d, 2H, CH<sub>2</sub>NH), 4.8 (s, 2H, CH<sub>2</sub>N<), 5.4 (t, 1H, NH), 7.2-7.3 (m, 10H, two Ph), 7.7 and 8.4 (two d, 4H, *p*-NO<sub>2</sub>C<sub>6</sub>H<sub>4</sub>); <sup>13</sup>C nmr:  $\delta$  44.8 (CH<sub>2</sub>NH), 48.1 (CH<sub>2</sub>N<), 124.2, 127.6-129.0, 135.0, 137.4, 139.9 and 147.3 (aromatic C-atoms), 151.2 (C-3), 164.2 (CONH), 166.2 (C-5); ms: m/z (%) no M<sup>+</sup>. 328 (13, M<sup>+</sup>-PhCH<sub>2</sub>NCO), 133 (12, PhCH<sub>2</sub>NCO<sup>+</sup>), 91 (100, C<sub>7</sub>H<sub>7</sub><sup>+</sup>).

*Anal.* Calcd. for C<sub>23</sub>H<sub>19</sub>N<sub>5</sub>O<sub>4</sub>S (mol wt 461): C, 59.87; H, 4.12. Found: C, 59.60; H, 4.07.

4-(*p*-Nitrophenyl)-2-phenyl-5-phenylcarbamoilimino-1,2,4-thiadiazolidin-3-one (**9j**).

To a solution of **6c** (435 mg, 1.95 mmoles) in acetonitrile (60 ml) was added dropwise 2.1 equivalents of phenyl isocyanate (487 mg) and the whole mixture was stirred overnight at room temperature. After removal of the solvent under reduced pressure, the residual oil was triturated with ethanol to give **9j** in 48% yield (405 mg), mp 242° (acetonitrile); ir: 3350 (m), 1720 (s), 1630 (s), 1600 (s), 1510 and 1320 cm<sup>-1</sup> (s); <sup>1</sup>H nmr:  $\delta$  7.0-7.7 (four m, 10H, two Ph), 8.0 and 8.45 (two d, 4H, *p*-NO<sub>2</sub>C<sub>6</sub>H<sub>4</sub>), 10.4 (s, 1H, NH); <sup>13</sup>C nmr:  $\delta$  119.0, 123.3, 124.3, 126.5, 128.7, 129.4, 130.1, 136.3, 138.4, 140.5 and 147.5 (aromatic C-atoms), 149.5 (C-3), 162.6 (CONH), 166.1 (C-5); ms: m/z (%) 433 (0.6, M<sup>+</sup>), 314 (21, M<sup>+</sup>-PhNCO), 190 (35), 119 (100, PhNCO<sup>+</sup>), 91 (46, PhN<sup>+</sup>).

*Anal.* Calcd. for C<sub>21</sub>H<sub>15</sub>N<sub>5</sub>O<sub>4</sub>S (mol wt 433): C, 58.20; H, 3.46. Found: C, 58.07; H, 3.51.

2-Benzyl-5-benzylcarbamoilimino-4-picryl-1,2,4-thiadiazolidin-3-one (**9k**).

To a solution of **6d** (508 mg, 1.6 mmoles) in dimethyl sulfoxide (10 ml) was added dropwise 2.1 equivalents of benzyl isocyanate (453 mg). After being stirred at room temperature for 4 hours, the reaction mixture was poured into ice-water, sodium chloride was added, and the whole was extracted with ethyl acetate. The extracts were dried over magnesium sulfate, evaporated and crystallized from chloroform-ether (1:2) to give **9k** in 60% yield (535 mg), mp 166° (ethanol); ir: 3340 (w), 3100 (w), 1735 (s), 1630 (s), 1550 and 1340 cm<sup>-1</sup> (s); <sup>1</sup>H nmr:  $\delta$  4.2 (d, 2H, CH<sub>2</sub>NH), 4.8 (s, 2H, CH<sub>2</sub>N<), 7.2-7.5 (m, 10H, two Ph), 8.7 (t, 1H, NH), 9.3 (s, 2H, picryl); <sup>13</sup>C nmr:  $\delta$  43.6 (CH<sub>2</sub>NH), 46.7 (CH<sub>2</sub>N<), 125.5-128.8, 135.6, 138.5, 146.4 and 147.5 (aromatic C-atoms), 148.8 (C-3), 163.3 (CONH), 163.7 (C-5); ms: m/z (%) 551 (0.2, M<sup>+</sup>), 133 (16,

PhCH<sub>2</sub>NCO<sup>+</sup>), 105 (11, PhCH<sub>2</sub>N<sup>+</sup>), 91 (100, C<sub>7</sub>H<sub>7</sub><sup>+</sup>).

*Anal.* Calcd. for C<sub>23</sub>H<sub>17</sub>N<sub>7</sub>O<sub>8</sub>S (mol wt 551): C, 50.09; H, 3.09. Found: C, 49.91; H, 3.13.

Note: When this reaction was carried out in acetonitrile, a product mixture was isolated which, in dimethyl sulfoxide, slowly evolved nitrogen within 2 days. The nmr spectrum of a freshly prepared sample showed **10** and **11** in a 1:4 ratio, which were transformed after nitrogen evolution into **5c** and **9k** respectively. Spectral data of **10**: <sup>1</sup>H nmr:  $\delta$  4.45 (CH<sub>2</sub>), 9.45 (picryl); <sup>13</sup>C nmr (tentative assignment):  $\delta$  44.1 (CH<sub>2</sub>), 161.3 (CONH), 169.9 (C-5). Spectral data of **11**: <sup>1</sup>H nmr:  $\delta$  4.32 and 4.8 (two CH<sub>2</sub>), 9.4 (picryl); <sup>13</sup>C nmr (tentative assignment):  $\delta$  44.7 and 45.9 (CH<sub>2</sub>), 151.4 (ring C=O), 153.1 (CONH), 167.6 (C=S). Spectral data of **5c**: <sup>1</sup>H nmr:  $\delta$  4.75 (CH<sub>2</sub>), 9.05 (picryl).

4-Picryl-2-phenyl-5-phenylcarbamoilimino-1,2,4-thiadiazolidin-3-one (**9m**).

To a solution of **6d** (400 mg, 1.3 mmoles) in dry tetrahydrofuran (10 ml) was added dropwise 2.1 equivalents of phenyl isocyanate (319 mg) and the whole mixture was stirred at room temperature for 2 hours. After removal of the solvent, the residual oil was triturated with ether to give **9m**·Et<sub>2</sub>O in 72% yield (550 mg), mp 133° (Note: this compound becomes brown-black at 75°); ir: 3380 (m), 3100 (m), 1725 (s), 1630 (s), 1600 (s), 1550 (s), 1500 (s), 1335 cm<sup>-1</sup> (s); <sup>1</sup>H nmr:  $\delta$  1.2 (t, 6H, two Me), 3.5 (q, 4H, two CH<sub>2</sub>), 7.1-7.6 (m, 10H, two Ph), 9.1 (s, 2H, picryl); <sup>13</sup>C nmr:  $\delta$  15.2 and 65.8 (Et<sub>2</sub>O), 119.1, 123.7-129.7, 135.2, 136.7 and 147.3 (aryl C-atoms), 147.3 (C-3), 161.5 (CONH), 165.0 (C-5); ms: m/z (%) no M<sup>+</sup>, 404 (57, M<sup>+</sup>-PhNCO), 123 (100, PhNS<sup>+</sup>), 119 (75, PhNCO<sup>+</sup>), 91 (48, PhN<sup>+</sup>).

*Anal.* Calcd. for C<sub>21</sub>H<sub>12</sub>N<sub>7</sub>O<sub>8</sub>S·(C<sub>2</sub>H<sub>5</sub>)<sub>2</sub>O (mol wt 597): C, 50.25; H, 3.85. Found: C, 50.00; H, 3.86.

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