Novel reactions of *N*-sulfonylamines with 3-dimethylamino-2*H*-azirines. Competitive formation of 1,2,5-thiadiazoles, 1,2,3-oxathiazoles and acrylamidines. X-Ray molecular structure of *N*-(4-dimethylamino-5-methyl-2-oxo-5-phenyl-5*H*-1,2λ^6,3-oxathiazol-2-ylidene)benzamide

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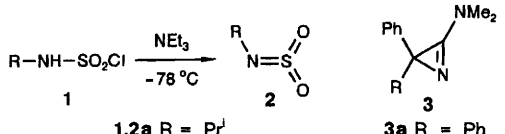
Reaction of 3-dimethylamino-2,2-diphenyl-2*H*-azirine 3a with *N*-sulfonylalkylamines 2a,b provides 1,2,5-thiadiazoles 5a,b, whereas use of *N*-carbonylsulfonylamines 2c,e as reaction partners primarily results in 1,2,3-oxathiazoles 6a,b which isomerise to the corresponding thiadiazoles 5c,d on treatment with silica gel at room temperature. In contrast, use of 2-alkyl-3-dimethylamino-2-phenyl-2*H*-azirines 3b,c in the reaction with the *N*-sulfonylamide 2c and the *N*-sulfonylcarbamates 2e,f leads to mixtures of thiadiazoles 5 and oxathiazoles 6 along with isomeric acrylamidines 7.

Introduction

N-Sulfonylamines have been recognised since 1967 as electrophilic heterocumulenes useful as reactive intermediates in organic syntheses.[1] The electrophilicity of the central sulfur is increased significantly by electron-withdrawing groups on the sp^2-hybridised N atom. Therefore the reactivity, *i.e.* the tendency to thiophilic attack, distinctly decreases from *N*-sulfonylcarbamates (*e.g.* **2e,f**) *via* *N*-sulfonylcarbamides (*e.g.* **2c,d**) to *N*-sulfonylalkylamines (*e.g.* **2a,b**).[2] So far, in analogy to similar unstable heterocumulenes, the most common access to these only transient synthons employs the low-temperature, base-induced dehydrohalogenation of the corresponding chlorides **1**.[1]

We have applied the reaction of such *in situ*-generated *N*-sulfonylamines with 3-dialkylamino-2*H*-azirines **3** as part of a program to synthesise novel five-membered heterocycles, containing an endocyclic sulfamide moiety which might possess interesting pharmacological properties.[3]



1,2a R = Pr^i
b Bu^t
c Bz
d Cinnamoyl (*E*)
e CO_2Me
f CO_2Et

3a R = Ph
b Me
c Et

Ring-strain makes 2*H*-azirines quite reactive,[4] but in 3-aminoazirines **3** the tendency to undergo ring-opening reactions is further enhanced by resonance interaction within the amidine moiety, making the endocyclic nitrogen highly nucleophilic.[5] Thus, synthons **3** should be efficient traps for the heterocumulenes **2** and, in fact, such a reaction of *N*-sulfonylalkylamines with azirines of type **3b,c** carrying an alkyl residue with hydrogen adjacent to the C-2 ring atom has been observed.[6] However, instead of five-membered heterocycles, acrylamidines of type **7** were obtained exclusively in good yields. The products ultimately result from a [1,6] hydrogen shift at the stage of a zwitterion of type **4**.[6]

This process would be excluded in the reaction of the *N*-sulfonylalkylamines **2a,b** with the 2,2-diphenylazirine **3a** lacking a transferable hydrogen, so that cyclisation by attack of the anionic moiety on the diphenylmethyl cation could be anticipated. In addition, we have looked for changes in the product distribution when the more electrophilic *N*-carbonyl sulfonylamines **2c–f** are used in the reaction with the azirines **3a–c**.

Reactions with 3-dimethylamino-2,2-diphenyl-2*H*-azirine 3a

The heterocumulenes **2a,b** and the azirine **3a** reacted to give the anticipated 1,2,5-thiadiazole 1,1-dioxides **5a,b**, as shown particularly by the typical ^{13}C NMR shifts of C-3 (δ_C ~79) and C-4 (δ_C ~168). The putative multistage mechanism involves initial thiophilic attack of the endocyclic azirine nitrogen, with subsequent or concerted 1,2 opening of the three-membered ring to form a 1,5 zwitterionic intermediate **4** promoted by the resonance stabilisation of the ambident anionic moiety as well as by the high stability of the diphenylcarbenium ion. Subsequently ring closure to product **5** completes the sequence.

In contrast, if the *N*-sulfonylamide **2c** or the *N*-sulfonylcarbamate **2e** was treated with compound **3a**, the reaction took an unexpected course, giving the 1,2,3-oxathiazoles **6a,b** with a chiral sulfur(VI) moiety. The ^{13}C NMR spectra of these heterocycles show characteristic low-field resonances (δ_C ~98) for the C-5 ring atom, indicating a neighbouring oxygen. But the definite structural assignment was only possible by comparison of the spectroscopic features of compound **6c** with proven constitution (*vide infra*). The surprising regioselectivity, *i.e.* ring closure involving the sulfonyl oxygen, can probably be attributed to the reduced nucleophilicity of the competing nitrogen caused by the $-M$ effect of the carbonyl group in group R. However, in solution at ambient temperature the heterocycles **6a,b** very slowly isomerise to the thermodynamically favoured thiadiazoles **5c,d** probably *via* zwitterions **4a,b**. Rapid and quantitative oxathiazole–thiadiazole isomerisation was observed on refluxing the substrate in ethyl acetate, or, more conveniently, by stirring of the reactant with catalytic amounts of silica gel or during column chromatography on silica gel.

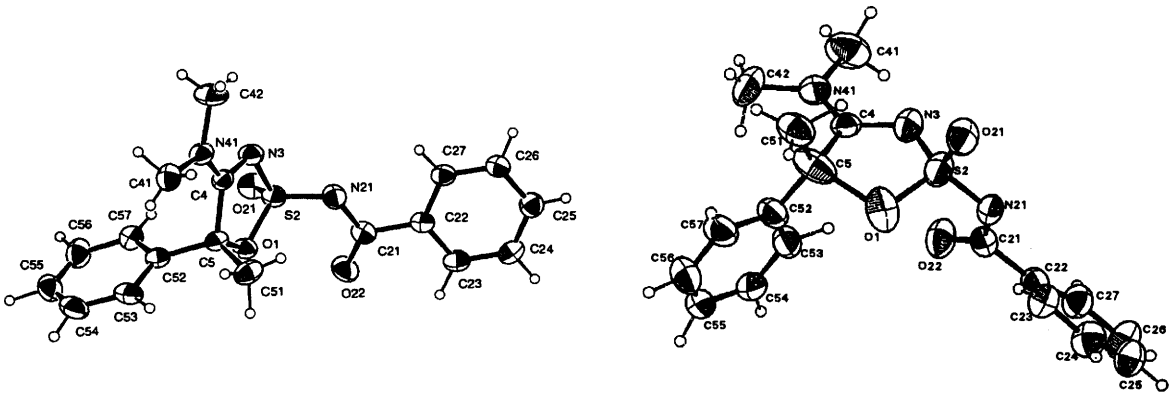
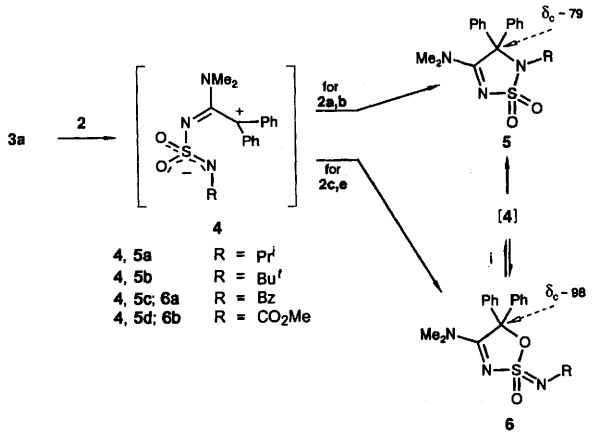


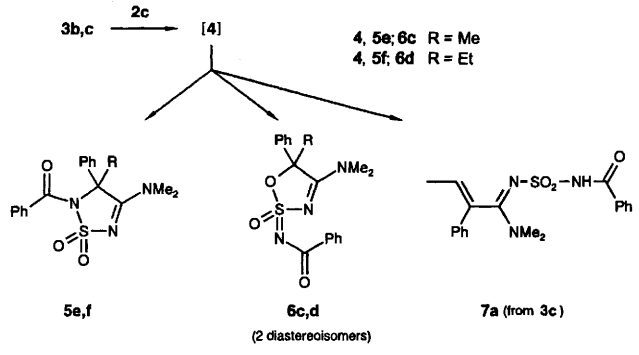
Fig. 1 ORTEP representation of the diastereoisomeric *trans*[(a)]- and *cis*[(b)]-oxathiazoles **6c**. Significant bond distances (pm) O1–S2, 159.0(4)[(a)] and 151.8(6)[(b)]; O1–C5, 146.4(6)[(a)] and 176.6(11)[(b)] (see text); C4–C5, 154.6(7)[(a)] and 152.3(9)[(b)]; N3–C4, 131.5(6)[(a)] and 130.8(8)[(b)]; S2–N3, 160.5(4)[(a)] and 158.9(6)[(b)].



Reagents and conditions: i, silica gel, CH_2Cl_2, room temp., 12 h

Reactions with 2-alkyl-3-dimethylamino-2-phenyl-2*H*-azirines 3b,c

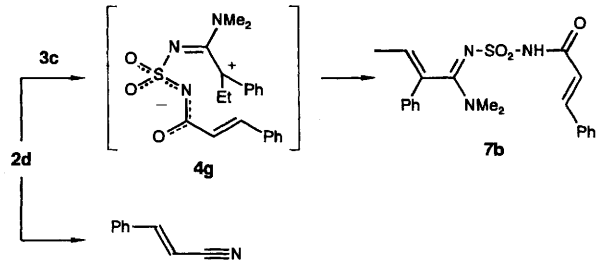
N-Sulfonylbenzamide **2c** and the azirines **3b,c** reacted to give mainly both diastereoisomers of the 1,2,3-oxathiazoles **6c,d** along with the isomeric 1,2,5-thiadiazoles **5e,f**. For an unambiguous proof of the oxathiazole structure, we carried out X-ray analyses of each racemic diastereoisomer of compound **6c** (Fig. 1).



The heterocyclic ring in isomer *trans*-**6c** is almost planar as observed in another 1,2,3-oxathiazole derivative.[7] However, isomer *cis*-**6c** shows a tilting of O1 out of the C5, C4, N3, S2 plane and, as a striking feature, a very long O1–C5 bond. Such a bond distance is quite unusual and may be an artifact of a random distribution of quasi-planar and envelope conformations. However, decomposition of the crystal during the measurement prevented a detailed study.

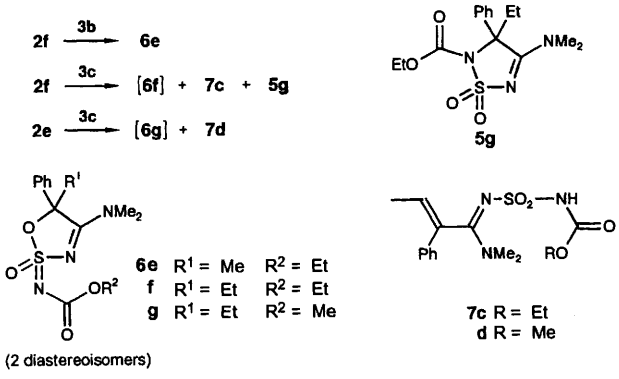
In contrast to N-alkyl derivatives, the reaction of sulfonylbenzamide **2c** with the azirine **3b** gave no acrylamidine, whereas with the azirine **3c** only trace amounts of the open-chain compound **7a** were present as indicated by the ^{1}H NMR spectrum of the crude product mixture.

On the other hand, a cinnamoyl substituent, as in zwitterion **4g**, results in better stabilisation of the negative charge, whereby, as it appears, the intramolecular ring closure is efficiently blocked. Thus, the reaction of *N*-sulfonylcinnamamide **2d** with the azirine **3c** provided exclusively acyclic compounds, *i.e.* acrylamidine **7b** along with cinnamonitrile. Formation of the latter is known [8] as a consequence of a base-induced dehydrochlorination coupled with a desulfonation of the sulfamoyl chloride **1d** in the absence of nucleophilic traps.



Finally, treatment of the *N*-sulfonylcarbamate **2f** with the azirine **3b** furnished the oxathiazole **6e** as a mixture of stereoisomers. The reaction of compounds **2e,f** with azirine **3c** afforded primarily the oxathiazoles **6f,g** along with the corresponding acrylamidines **7c,d** as well as a small amount of the thiadiazole **5g**. However, except for compound **6e** (in our hands) the oxathiazoles **6** are not stable enough to survive preparative chromatography. Accordingly, in the crude product mixture we could identify each diastereoisomer of compounds **6f** and **6g**, respectively, by the typical ^{13}C shifts [δ_C(C-5) ~97–97.5], but only the isomeric compounds **7c,d** and **5g** could be isolated analytically pure.

Consistent with these observations, reaction pathways



involving the carbonyl moiety, as reported for [4+2] cycloadditions of *N*-sulfonylcarbamates with ynamines[9] or acetonitrile,[10] were not observed.

Experimental

General information

Mps are uncorrected and were taken on a Büchi melting point apparatus. Elemental analyses were carried out by Institut für Pharmazeutische Chemie, Technische Universität Braunschweig. NMR spectra were measured on a Bruker ARX-400, AC 250 P or Varian XL-200 spectrometer; δ values are given relative to internal $SiMe_4$, and J values are given in Hz. IR spectra were recorded on a PYE UNICAM SP3-200 spectrometer. For column chromatography (CC), Merck silica gel 60 (70–230 mesh) was used. LP = Light petroleum (distillation range 60–70 °C), EA = ethyl acetate.

The sulfamoyl chlorides **1a**,**b** were provided by BASF AG. Compounds **1c–f**[11] and the azirines **3a**,[12] **3b**,**c**[13] were obtained according to literature procedures.

Typical procedure for the reaction of *N*-sulfonylamines 2 with 3-dimethylamino-2*H*-azirines 3

To a stirred solution of sulfamoyl chloride **1a** (667 mg, 4.23 mmol) in dry dichloromethane (15 ml) was added triethylamine (0.59 ml, 4.23 mmol) within 20 min under anhydrous nitrogen at −78 °C. After 10 min a solution of azirine **3a** (1 g, 4.23 mmol) in dichloromethane (~3 ml) was added dropwise. Subsequently, the mixture was stirred for 2 h at −78 °C, for an additional 4 h at −40 °C, and allowed to warm to room temperature overnight. Then it was diluted with dichloromethane (100 ml), washed with two 10 ml portions of water, dried ($MgSO_4$), and the solvent was removed *in vacuo* at room temperature to yield a red–brown oil. In other cases we obtained colourless or yellow crude oils and the solid products were separated by direct crystallisation from suitable solvents or by CC on silica gel (*vide infra*). Here, the crude solid product separated on sequential addition of dichloromethane and diethyl ether. Finally, recrystallisation from ethanol–dichloromethane gave pure 4-*dimethylamino*-2,3-*dihydro*-2-*isopropyl*-3,3-*diphenyl*-1,2,5-*thiadiazole* 1,1-*dioxide* **5a** (1.07 g, 71%) as faintly beige coloured crystals, mp 274 °C (Found: C, 63.6; H, 6.5; N, 11.6; S, 8.95. $C_{19}H_{23}N_3O_2S$ requires C, 63.84; H, 6.49; N, 11.75; S, 8.97%); ν_{max}(KBr)/cm^{-1} 1598, 1282, 1159 and 1148; δ_H(400 MHz; $CDCl_3$) 0.99 [6 H, d, J 6.8, Me (Pr^i)], 2.58 and 3.12 (each 3 H, br s, Me_2N), 3.24 (1 H, sept, J 6.8, CH) and 7.42–7.50 and 7.69 (10 H, m, ArH); δ_C(100 MHz; $CDCl_3$) 21.56 [Me (Pr^i)], 39.4 and 41.0 (br, Me_2N), 47.16 (CH), 79.48 (C-3), 129.00, 129.14, 129.36 [CH (Ar)], 134.82 [C (Ar)] and 167.80 (C=N).

Analogous procedures

Reaction of substrates **1b** and **3a** gave 2-tert-*butyl*-4-*dimethylamino*-2,3-*dihydro*-3,3-*diphenyl*-1,2,5-*thiadiazole* 1,1-*dioxide* **5b** (69%) isolated by CC using LP–EA (1:1) as crystals, mp 252 °C (Found: C, 64.2; H, 6.75; N, 11.3; S, 8.65. $C_{20}H_{25}N_3O_2S$ requires C, 64.66; H, 6.78; N, 11.31; S, 8.63%); ν_{max}(KBr)/cm^{-1} 1608, 1283 and 1144; δ_H(400 MHz; $CDCl_3$) 1.02 (9 H, s, Me_3C), 2.76 (6 H, br s, Me_2N) and 7.43–7.50 and 7.91 (m, 10 H, ArH); δ_C(100 MHz; $CDCl_3$) 29.82 (Me_3C), 40.3 (br, Me_2N), 58.34 (*C*-Me), 79.09 (C-3), 128.85, 129.01 and 129.55 [CH (Ar)], 136.29 [C (Ar)] and 168.28 (C=N).

Reaction of substrates 1c and 3a. CC using LP–EA (1:1) gave 2-*benzoyl*-4-*dimethylamino*-2,3-*dihydro*-3,3-*diphenyl*-1,2,5-*thiadiazole* 1,1-*dioxide* **5c** (63%) as crystals, mp 261–262.5 °C (Found: C, 65.8; H, 5.0; N, 10.0; S, 7.6. $C_{23}H_{21}N_3O_3S$ requires C, 65.85; H, 5.05; N, 10.02; S, 7.64%); ν_{max}(KBr)/cm^{-1} 1675, 1608, 1326, 1297, 1161 and 1138; δ_H(400 MHz; $CDCl_3$) 2.57 and 3.15 (each 3 H, s, Me_2N) and 7.31, 7.40–7.51 and 7.78 (15 H, m, ArH); δ_C(100 MHz; $CDCl_3$) 39.83 and 41.48 (Me), 79.55 (C-3), 127.71, 127.76, 128.32, 129.01, 129.12 and 131.14 [CH (Ar)], 134.30, 134.68 [C (Ar)] and 165.97 and 166.00 (C=N and C=O).

Reaction of substrates **1c** and **3a** (no CC to avoid isomerisation) gave *N*-(4-dimethylamino-2-oxo-5,5-diphenyl-5*H*-1,2λ^6,3-oxathiazol-2-ylidene)benzamide **6a** (93%, includes ~6% **5c**) as crystals (from dichloromethane–cyclohexane), mp 113–120 °C; ν_{max}(KBr)/cm^{-1} 1644, 1633, 1621, 1294–1243 (several max.) and 1175–1153 (several max.); δ_H(400 MHz; $CDCl_3$) 2.71 and 3.36 (each 3 H, s, Me_2N) and 7.35, 7.44–7.66 and 8.08 (15 H, m, ArH); δ_C(100 MHz; $CDCl_3$) 40.54 and 42.10 (Me), 98.00 (C-5), 127.81, 128.47, 128.82, 129.08, 129.61 and 131.89 [CH (Ar)], 134.78, 135.37 and 135.92 [C (Ar)] and 170.64 and 171.64 (C=N and C=O).

Reaction of substrates 1e and 3a. CC using LP–EA (1:2) gave *methyl* 4-*dimethylamino*-2,3-*dihydro*-3,3-*diphenyl*-1,2,5-*thiadiazole*-2-*carboxylate* 1,1-*dioxide* **5d** (40%) as crystals (from dichloromethane–cyclohexane), mp 247 °C (Found: C, 57.6; H, 5.2; N, 10.95. $C_{18}H_{19}N_3O_4S$ requires C, 57.90; H, 5.13; N, 11.25%); ν_{max}(KBr)/cm^{-1} 1734, 1616, 1335, 1312, 1182 and 1163; δ_H(400 MHz; $CDCl_3$) 2.56 and 3.17 (each 3 H, s, Me_2N), 3.69 (3 H, s, MeO) and 7.44 and 7.71 (10 H, m, ArH); δ_C(100 MHz; $CDCl_3$) 39.74 and 41.51 (MeN), 53.82 (MeO), 77.83 (C-3), 128.81, 128.95 and 129.34 [CH (Ar)], 133.71 [C (Ar)], 149.12 (C=O) and 165.87 (C=N).

Reaction of substrates **2e** and **3a** (no CC to avoid isomerisation) gave ethyl *N*-(4-dimethylamino-2-oxo-5,5-diphenyl-5*H*-1,2λ^6,3-oxathiazol-2-ylidene)carbamate **6b** (78%, includes ~6% **5d**) as crystals (from dichloromethane–cyclohexane); ν_{max}(KBr)/cm^{-1} 1740, 1693, 1617, 1434br and 1270br; δ_H(400 MHz; $CDCl_3$) 2.70 and 3.35 (each 3 H, s, Me_2N), 3.62 (3 H, s, MeO) and 7.45 and 7.58 (10 H, m, ArH); δ_C(100 MHz; $CDCl_3$) 40.50 and 42.07 (MeN), 52.98 (MeO), 98.04 (C-5), 128.48, 128.88, 129.14, 129.42 and 130.11 [CH (Ar)], 134.60 and 135.06 [C (Ar)], 157.25 (C=O) and 170.63 (C=N).

Reaction of substrates **1c** and **3b** gave, after CC using dichloromethane–EA–triethylamine (20:1:0.01), three products. 1st fraction: 2-benzoyl-4-dimethylamino-2,3-dihydro-3-methyl-3-phenyl-1,2,5-thiadiazole 1,1-dioxide **5e** (13%) as crystals, mp 155–157 °C (Found: C, 59.2; H, 5.1; N, 11.4; S, 9.5. $C_{18}H_{19}N_3O_3S$ requires C, 60.49; H, 5.36; N, 11.76; S, 8.97%); ν_{max}(KBr)/cm^{-1} 1670, 1602, 1325, 1305, 1168 and 1154; δ_H(200 MHz; $CDCl_3$) 2.42 (3 H, s, 3-Me), 2.69 and 3.18 (each 3 H, s, Me_2N) and 7.37–7.62 (10 H, m, ArH); δ_C(63 MHz; $CDCl_3$) 19.32 (3-Me), 38.45 and 41.20 (MeN), 72.86 (C-3), 126.78, 127.65, 127.74, 128.71, 129.05 and 130.90 [CH (Ar)], 134.52 and 136.83 [C (Ar)], 166.72 and 167.57 (C=N and C=O); 2nd fraction: trans-N-(4-*dimethylamino*-5-*methyl*-2-*oxo*-5-*phenyl*-5H-1,2λ^6,3-*oxathiazol*-2-*ylidene*)*benzamide* trans-**6c** (27%) as crystals, mp 154 °C (Found: C, 60.6; H, 5.3; N, 11.6; S, 9.0. $C_{18}H_{19}N_3O_3S$ requires C, 60.49; H, 5.36; N, 11.76; S, 8.97%); ν_{max}(KBr)/cm^{-1} 1618br, 1278, 1249, 1147 and 1132; δ_H(200 MHz; $CDCl_3$) 2.47 (3 H, s, 5-Me), 2.82 and 3.27 (each 3 H, s, Me_2N) and 7.39–7.64 and 8.22 (10 H, m, ArH); δ_C(63 MHz; $CDCl_3$) 19.89 (5-Me), 38.92 and 41.78 (MeN), 94.24 (C-5), 126.45, 127.96, 129.54, 129.63, 130.38 and 132.07 [CH (Ar)], 135.86 and 136.02 [C (Ar)], 171.75 and 172.54 (C=N and C=O); 3rd fraction: cis-N-(4-*dimethylamino*-5-*methyl*-2-*oxo*-5-*phenyl*-5H-1,2λ^6,3-*oxathiazol*-2-*ylidene*)*benzamide* cis-**6c** (15%) as crystals, mp 158–159 °C (Found: C, 60.4; H, 5.4; N, 11.7; S, 9.0%); ν_{max}(KBr)/cm^{-1} 1641, 1615, 1270br, 1174 and 1154; δ_H(200 MHz; $CDCl_3$) 2.28 (3 H, s, 5-Me), 2.67 and 3.28 (each 3 H, s, Me_2N) and 7.38–7.58, 7.89 and 8.20 (10 H, m, ArH); δ_C(63 MHz; $CDCl_3$) 22.85 (5-Me), 39.04 and 41.66 (MeN), 92.76 (C-5), 127.47, 127.87, 129.42, 129.66, 130.48 and 131.97 [CH (Ar)], 134.81 and 135.97 [C (Ar)] and 171.76 and 172.84 (C=N and C=O).

Reaction of substrates **1c** and **3c** gave, after CC using dichloromethane–EA (20:1), 4 products: 1st fraction: 2-benzoyl-4-dimethylamino-3-ethyl-2,3-dihydro-3-phenyl-1,2,5-thiadiazole 1,1-dioxide **5f** (6%) as crystals, mp 225–227 °C

(Found: C, 60.4; H, 5.7; N, 11.5; S, 8.7. $C_{19}H_{21}N_3O_3S$ requires C, 61.44; H, 5.70; N, 11.31; S, 8.63%); ν_{max}(KBr)/cm^{-1} 1612, 1327, 1306 and 1168; δ_H(200 MHz; $CDCl_3$) 1.19 (3 H, t, *J* 7.4, CH_3CH_2), 2.44 (1 H, dq, *J* 7.4 and ^2J 14.8, CH_3CH*H*), 2.74 and 3.19 (each 3 H, s, Me_2N), 3.51 (1 H, dq, *J* 7.4 and ^2J 14.8, CH_3CH*H*) and 7.35–7.65 (10 H, m, ArH); δ_C(63 MHz; $CDCl_3$) 8.54 (CH_3CH_2), 23.45 (CH_2), 77.85 (C-3), 126.96, 127.55, 127.72, 129.07, 129.12 and 130.79 [CH (Ar)], 134.71 and 137.32 [C (Ar)] and 166.08 and 166.74 (C=N and C=O); the peaks of the NMe groups were too weak for an exact assignment; 2nd fraction: 1st diastereoisomer (without assignment of configuration) of *N*-(4-dimethylamino-5-ethyl-2-oxo-5-phenyl-5*H*-1,2λ^6,3-oxathiazol-2-ylidene)benzamide **6d** (7%) as crystals, mp 163–164 °C (Found: C, 60.8; H, 5.7; N, 11.7; S, 8.8. $C_{19}H_{21}N_3O_3S$ requires C, 61.44; H, 5.70; N, 11.31; S, 8.63%); ν_{max}(KBr)/cm^{-1} 1637, 1617, 1311, 1285, 1253, 1172 and 1149; δ_H(200 MHz; $CDCl_3$) 1.22 (3 H, t, *J* 7.4, CH_3CH_2), 2.72 (1 H, dq, *J* 7.4 and ^2J 14.8, CH_3CH*H*), 2.86 (3 H, s, MeN), 3.02 (1 H, dq, *J* 7.4 and ^2J 14.8, CH_3CH*H*), 3.24 (3 H, s, MeN) and 7.38–7.66 and 8.22 (10 H, m, ArH); δ_C(63 MHz; $CDCl_3$) 8.84 (CH_3CH_2), 25.73 (CH_2), 38.70 (MeN), 97.28 (C-5), 127.40, 127.94, 129.51, 129.62, 130.06 and 131.95 [CH (Ar)], 134.75 and 136.07 [C (Ar)] and 171.72 and 172.19 (C=N and C=O); the 2nd NMe peak was too weak for detection; 3rd fraction: 2nd diastereoisomer of compound **6d** (17%) as crystals, mp 90–91 °C (from CCl_4) (Found: C, 52.8; H, 5.5; N, 9.4; S, 7.3. $C_{19}H_{21}N_3O_3S$·0.5 CCl_4 requires C, 52.24; H, 4.72; N, 9.37; S, 7.15%); ν_{max}(KBr)/cm^{-1} 1618 br, 1311, 1287, 1263, 1173 and 1150; δ_H(200 MHz; $CDCl_3$) 1.29 (3 H, t, *J* 7.4, CH_3CH_2), 2.48 (1 H, dq, *J* 7.4 and ^2J 14.8, CH_3CH*H*), 2.77 (4 H, s and dq, MeN and CH_3CH*H*), 3.30 (3 H, s, MeN) and 7.36–7.50, 7.73 and 8.15 (10 H, m, ArH); δ_C(50 MHz; $CDCl_3$) 8.40 (CH_3CH_2), 27.98 (CH_2), 38.88 and 41.74 (MeN), 97.42 (C-5), 127.27, 127.80, 129.31, 129.54, 130.27 and 131.76 [CH (Ar)], 134.78 and 135.94 [C (Ar)] and 171.08 and 171.59 (C=N and C=O); *m*/*z* (70 eV) 371 (M^+); in addition, a trace of *N*-benzoyl-*N*′-(1-dimethylamino-2-phenylbut-2-enylidene)sulfamide **7a** was detected based on δ_H 1.86 and 6.47 (d and q, CH_3CH=C) in the NMR spectrum of the crude product mixture prior to CC.

Reaction of substrates **1d** and **3c** gave, after CC using LP–EA (1:1), 2 products: 1st fraction: (*E*)-cinnamonitrile (37%); 2nd fraction: N-*cinnamoyl*-N′-(1-*dimethylamino*-2-*phenylbut*-2-*enylidene*)*sulfamide* **7b** (45%) as crystals, mp 210–211 °C (decomp.) (Found: C, 63.3; H, 5.6; N, 10.5; S, 8.1. $C_{21}H_{23}N_3O_3S$ requires C, 63.46; H, 5.83; N, 10.57; S, 8.07%); ν_{max}(KBr)/cm^{-1} 3180, 1665, 1618, 1553, 1443, 1317 and 1129; δ_H(400 MHz; $CDCl_3$) 1.83 (3 H, d, *J* 7.1, CH_3CH=), 2.99 and 3.31 (each 3 H, s, Me_2N), 6.24 (1 H, br d, HC=C*H*C=O), 6.53 (1 H, q, *J* 7.1, CH_3CH=), 7.05 and 7.22–7.40 (10 H, m, ArH), 7.52 (1 H, d, *H*C=CH–C=O) and 8.61 (1 H, br s, HN); δ_C(100 MHz; $CDCl_3$) 16.38 (*Me*C=), 38.25 and 38.88 (MeN), 118.53 (O=C–*C*H=), 124.99, 127.71, 128.11, 128.29, 128.78, 129.11 and 130.17 [CH (Ar) and MeC*H*=], 133.64, 134.45 and 134.48 [MeC=*C* and C (Ar)], 143.55 (O=C–CH=*C*H), 163.77 (C=N) and 166.45 (C=O).

Reaction of substrates **1f** and **3b** gave, after CC using dichloromethane–EA–triethylamine (10:1:0.01), a mixture of both diastereoisomers (*a*/*b* 2:1) of *ethyl* N-(4-*dimethylamino*-5-*methyl*-2-*oxo*-5-*phenyl*-5H-1,2λ^6,3-*oxathiazol*-2-*ylidene*)*carbamate* **6e** (68%) as crystals, mp 145–146 °C (Found: C, 51.4; H, 5.9; N, 12.3; S, 9.9. $C_{14}H_{19}N_3O_4S$ requires C, 51.68; H, 5.89; N, 12.91; S, 9.85%); ν_{max}(KBr)/cm^{-1} 1691, 1680, 1623, 1291, 1270, 1250br and 910; δ_H(400 MHz; $CDCl_3$) 1.26^b and 1.30^a (3 H, t, *J* 7.2, CH_3CH_2), 2.24^b and 2.36^a (3 H, s, 5-Me), 2.66^b, 2.80^a and 3.26^{a,b} (6 H, s, Me_2N), 4.13^b and 4.14^a (2 H, q, CH_3CH_2) and 7.50–7.58^{a,b} and 7.78^{a,b} (5 H, m, ArH); δ_C(100 MHz; $CDCl_3$) 14.36^{a,b} (CH_3CH_2), 19.89^a and 22.57^b (5-Me), 38.88^a, 38.98^b, 41.62^b and 41.74^a (MeN), 61.69^a and 61.80^b (CH_2), 92.57^b and 94.05^a (C-5), 126.38^a, 127.22^b, 129.42^b, 129.60^a, 130.40^a and 130.48^b [CH (Ar)], 134.77^b and 135.59^a [C (Ar)], 156.94^b and 157.62^a (C=O) and 171.78^a and 172.70^b (C=N).

Reaction of substrates **1f** and **3c** gave, after CC using dichloromethane–EA–triethylamine (10:1:0.01), three products. 1st fraction: ethyl 4-dimethylamino-3-ethyl-2,3-dihydro-3-phenyl-1,2,5-thiadiazole-2-carbamate 1,1-dioxide **5g** (1%) as crystals, mp 134 °C; δ_H(400 MHz; $CDCl_3$) 1.09 (3 H, dd, *J* 7.4 and 7.3, 3-CH_2CH_3), 1.23 (3 H, br t, CH_3CH_2O), 2.36 (1 H, dq, *J* 7.3 and ^2J 14.7, 3-CH*H*), 2.69 (3 H, s, MeN), 3.15 and 3.17 (4 H, m and s, 3-C*H*H and MeN), 4.11 and 4.19 (each 1 H, m, CH_2O) and 7.38 and 7.50 (5 H, m, ArH); δ_C(100 MHz; $CDCl_3$) 8.24 (3-CH_2CH_3), 14.04 (CH_3CH_2O), 23.71 (3-CH_2), 38.32 and 41.15 (MeN), 63.11 (CH_2O), 75.73 (C-3), 126.90, 129.08 and 129.14 [CH (Ar)], 136.98 [C (Ar)], 148.79 (C=N) and 165.82 (C=O); 2nd fraction: *ethyl* N-(1-*dimethylamino*-2-*phenylbut*-2-*enylidenesulfamoylamino*)*carbamate* **7c** (43%) as crystals, mp 186–192 °C (Found: C, 53.0; H, 6.2; N, 12.2; S, 9.4. $C_{15}H_{21}N_3O_4S$ requires C, 53.08; H, 6.24; N, 12.38; S, 9.45%); ν_{max}(KBr)/cm^{-1} 3220, 1742, 1551, 1443, 1322 and 1134; δ_H(400 MHz; $CDCl_3$) 1.22 (3 H, t, *J* 7.1, CH_3CH_2), 1.88 (3 H, d, *J* 7.1, CH_3CH), 2.99 and 3.28 (each 3 H, s, MeN), 4.07 and 4.13 (each 1 H, m, CH_3CH_2), 6.49 (1 H, q, *J* 7.1, CH_3CH), 7.01 (1 H, s, HN) and 7.27, 7.34 and 7.35 (5 H, m, ArH); δ_C(100 MHz; $CDCl_3$) 14.26 (CH_3CH_2), 16.35 (CH_3CH), 38.09 and 38.85 (MeN), 62.13 (CH_2), 125.17 (*C*H=C), 127.71, 128.08 and 128.96 [CH (Ar)], 134.00 and 134.76 [C (Ar) and *C*=CH], 151.07 (C=N) and 166.32 (C=O); in the crude product mixture both diastereoisomers of ethyl *N*-(4-dimethylamino-5-ethyl-2-oxo-5-phenyl-5*H*-1,2λ^6,3-oxathiazol-2-ylidene)carbamate **6f** were detected (δ_C 97.24 and 97.39).

Reaction of substrates **1e** and **3c** gave methyl N′-(1-dimethylamino-2-phenylbut-2-enylidenesulfamoylamino)carbamate **7d** (68%) as crystals (from dichloromethane–LP), mp 190 °C (Found: C, 51.25; H, 5.8; N, 12.9. $C_{14}H_{19}N_3O_4S$ requires C, 51.68; H, 5.89; N, 12.91%); ν_{max}(KBr)/cm^{-1} 3220, 1750, 1563, 1330, 1227 and 1138; δ_H(400 MHz; $CDCl_3$) 1.87 (3 H, d, *J* 7.1, CH_3CH), 3.00 and 3.29 (each 3 H, s, Me_2N), 3.62 (3 H, s, MeO), 6.49 (1 H, q, *J* 7.1, CH_3CH=), 7.18 (1 H, br s, HN) and 7.27–7.33 (5 H, m, ArH); δ_C(100 MHz; $CDCl_3$) 16.31 (*Me*C=), 38.13 and 38.86 (MeN), 52.94 (MeO), 125.14 (Me*C*H=) 127.74, 128.09 and 128.97 [CH (Ar)], 133.92 and 134.73 [CH (Ar) and CH=*C*), 151.59 (C=N) and 166.35 (C=O); in the crude product mixture both diastereoisomers of methyl *N*-(4-dimethylamino-5-ethyl-2-oxo-5-phenyl-5*H*-1,2λ^6,3-oxathiazol-2-ylidene)carbamate **6g** were detected (δ_C 97.37 and 97.54).

Structure determinations of compound 6c

For *trans*-**6c**, rotating crystal (0.15 × 0.29 × 0.30 mm), Weissenberg and precession photographs gave approximate lattice constants and suggested the monoclinic space group $P2_1$. Refinement of the lattice constants led to the cell dimensions: a = 914.9(1), b = 1032.5(1), c = 1030.8(1) pm, β = 115.68(1)°, V = 878 × 10^6 pm^3, Z = 2, D_x = 1.35 g cm^{-3}, μ(Cu-Kα) = 17.85 cm^{-1}. Intensity data were collected on a CAD 4-SDP diffractometer (Enraf Nonius) using Cu-Kα radiation in the range 2° ⩽ θ ⩽ 70° on a graphite monochromator. The final refinement was based on 1618 symmetry-independent reflections with $I \geqslant 3\sigma(I)$. The structure was solved by the direct-methods program MULTAN.[14] The *E* map revealed the position of all the non-hydrogen atoms. After the refinement of these positions,[15] the H atoms were found from a difference Fourier synthesis and were included in the final refinement. Convergence was achieved at R 0.029 (R_w 0.027).

A rotating crystal (0.20 × 0.29 × 0.33 mm) of isomer *cis*-**6c** was measured analogously. However, decomposition of the crystal interfered with this measurement which was terminated at 35% decomposition. Cell dimensions: a = 1156.7(2), b = 1170.5(1), c = 1317.5(1) pm, V = 1734 × 10^6 pm^3, orthorhombic, space group = $P2_12_12_1$, Z = 4, D_x = 1.33 g cm^{-3}, μ(Cu-Kα) = 17.56 cm^{-1}; range of measurement 2° ⩽ θ ⩽ 65°; 1500 symmetry-independent reflections with $I \geqslant 3\ \sigma(I)$;

R 0.066 (R_w 0.054). Further crystal structure data (atomic coordinates, thermal parameters and bond lengths and angles) for both compounds have been deposited at the Cambridge Crystallographic Data Centre (CCDC). See Instructions for Authors, *J. Chem. Soc., Perkin Trans 1*, 1996, Issue 1. Any request to the CCDC for this material should quote the full literature citation and the reference number 207/6.

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References

1 G. M. Atkins, Jr., and E. M. Burgess, *J. Am. Chem. Soc.*, 1967, **89**, 2502; 1968, **90**, 4744; 1972, **94**, 6135; E. M. Burgess and W. M. Williams, *J. Am. Chem. Soc.*, 1972, **94**, 4386.
2 *cf.* Review: S. Bleisch and R. Mayer, in *Methoden der Organischen Chemie (Houben-Weyl)*, George Thieme Verlag, Stuttgart, 1985, vol. E. 11/2, pp. 1031–1036.
3 *cf.* V. J. Arán, P. Goya and C. Ochoa, *Adv. Heterocycl. Chem.*, 1988, **44**, 81 and references cited therein.
4 *cf.*, *e.g.*, A. Padwa and A. D. Woolhouse, in A. R. Katritzky and C. W. Rees, *Comprehensive Heterocyclic Chemistry*, ed. W. Lwowski, Pergamon Press, Oxford, 1984, vol. 7, part 5, p. 47.
5 *cf.* Review: H. Heimgartner, *Isr. J. Chem.*, 1986, **27**, 3; *Angew. Chem.*, 1991, **103**, 271; *Angew. Chem., Int. Ed. Engl.*, 1991, **30**, 238.
6 A. Lender and E. Schaumann, to be published; A. Lender, Ph.D. Thesis, University of Hamburg, 1990.
7 G. L'abbé, C.-C. Yu, J.-P. Declecq, G. Germain and M. Van Meerssche, *Angew. Chem.*, 1978, **90**, 394; *Angew. Chem., Int. Ed. Engl.*, 1978, **17**, 352.
8 H. Vorbrüggen, *Tetrahedron Lett.*, 1968, 1631.
9 J. A. Kloek and K. L. Leschinsky, *J. Org. Chem.*, 1980, **45**, 721.
10 E. M. Burgess and W. M. Williams, *J. Org. Chem.*, 1973, **38**, 1249.
11 A. Dorlars, in *Methoden der Organischen Chemie (Houben-Weyl)*, Georg Thieme Verlag, Stuttgart, 1958, vol. 11/2, p. 693.
12 I. Handke, E. Schaumann and R. Ketcham, *J. Org. Chem.*, 1988, **53**, 5298.
13 M. Rens and L. Ghosez, *Tetrahedron Lett.*, 1970, 3765; M. Rens, Ph.D. Thesis, Université Catholique de Louvain, 1973.
14 G. Germain, P. Main and M. M. Woolfson, *Acta Crystallogr., Sect. A*, 1971, **27**, 368.
15 Structure determination package B. A. Frenz and Associates, Inc., College Station, Texas 77840, and Enraf Nonius, Delft, Holland.

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