170. Reactions of 2-Monosubstituted 3-Amino-2*H*-azirines with NH-Acidic Heterocycles

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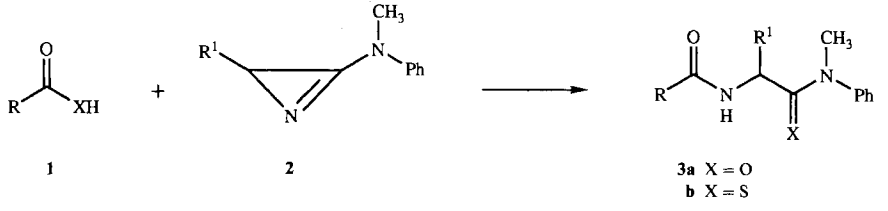
2-Monosubstituted 3-amino-2*H*-azirines **2** react with several heterocycles containing acidic NH groups *via* ring expansions, leading to benzo[*g*][1,2,5]thiadiazocin 1,1-dioxide derivatives **6** and imidazoles **9**, **10**, and **13**, respectively.

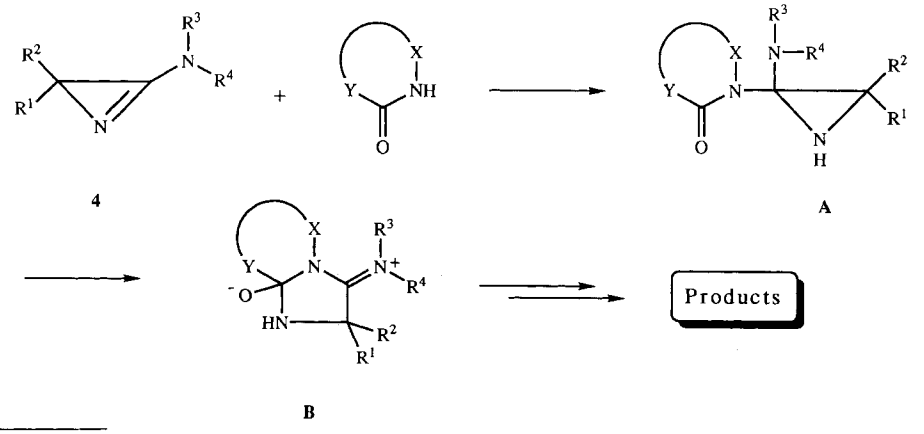
1. Introduction. – As already described in [1], 2-monosubstituted 3-amino-2*H*-azirines of type **2**, react with carboxylic and thiocarboxylic acids under mild conditions to furnish diamides **3a** or thiodiamides **3b**, respectively, in good yields. The reactions show, in principle, no differences to the corresponding ones with the 2,2-disubstituted analogues [2–5] (*Scheme 1*).

Scheme 1



1 **2** **3a** X = O, **b** X = S

Scheme 2



4 **A** **B**

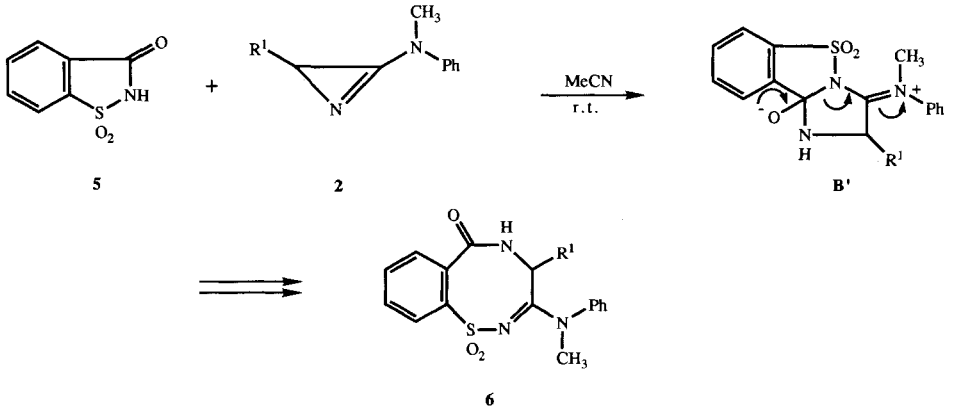
[1]) Part of the planned Ph. D. thesis of *J. M. V.*, Universität Zürich.

In this paper, we describe reactions of **2**, with some heterocycles containing NH acidic groups and the influence of the monosubstitution at C(2) of the azirine ring on the involved mechanistic pathways.

As it is already known, 2,2-disubstituted 3-amino-2*H*-azirines **4** react with compounds containing NH acidic groups with $pK_a < 8$ [5–13]. The reaction takes place firstly by protonation of the amidine N(1)-atom of **4**, followed by the cleavage of the N(1)–C(3) bond in **A**, to form a zwitterion of type **B**, which undergoes ring expansion and leads to different products depending on the nature of X and Y (*Scheme 2*).

2. Results and Discussion. – When a solution of saccharin (1,2-benzoisothiazol-3(2*H*)-one 1,1-dioxide, **5**) in dry MeCN was reacted with 2-monosubstituted 3-amino-2*H*-azirines **2**, the corresponding benzo[*g*][1,2,5]thiadiazocin-6-one 1,1-dioxides **6** were isolated in good yields (see *Scheme 3* and *Table 1*).

Scheme 3



5 **2** **B'** **6**

Table 1. *Prepared Benzo[g][1,2,5]thiadiazocin-6-one 1,1-Dioxides* **6**

Compound	R^1	Yield [%]	M.p. [°]
6a	Ph	80	167.0–167.5
6b	Me	68	241.3–241.5
6c	Et	70	239.5–240.0
6d	*t*-Bu	65	237.0–238.0

The reaction most likely follows the route already discussed for 2,2-disubstituted azirines **4** [5] [10] (*cf. Scheme 2*). The bicyclic zwitterion **B'** then undergoes a ring expansion *via* cleavage of the central C–N-bond to furnish the eight-membered ring of **6** (*Scheme 3*).

The structure of **6c** has been established by X-ray crystallography (*Fig. 1*). In contrast to the 4,4-dimethyl analog, obtained form the reaction of 3-(dimethylamino)-2,2-dimethyl-2*H*-azirine and **5**, with and (*E*)-configurated lactam group [6], the lactam group of **6c** (*Z*)-configurated. The other derivatives were identified by comparison of the spectroscopical data with those of **6c**.

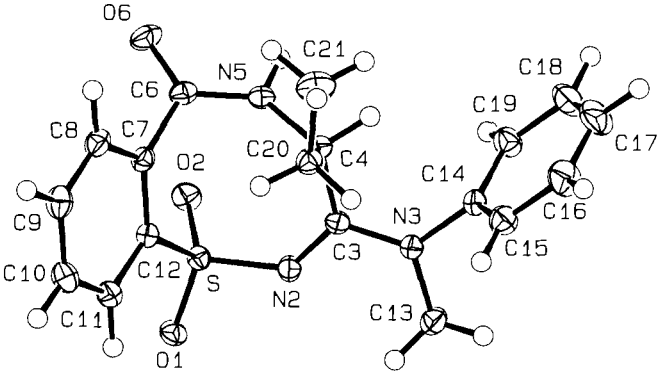
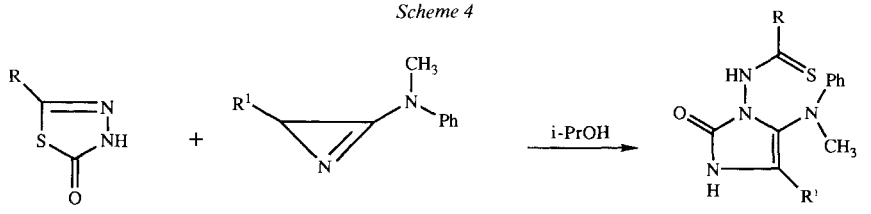


Fig. 1. *ORTEP Plot* [14] *with 50% probability ellipsoids of the molecular structure of 4-ethyl-4,5-dihydro-3-(*N*-methyl-*N*-phenylamino)benzo[g][1,2,5]thiadiazocin-6-one 1,1-dioxide* (**6c**)

Another type of heterocycles which contain acidic NH groups are 5-substituted 1,3,4-thiadiazol-2(3*H*)-ones **7** and **8**. It has been shown that these heterocycles react with 2,2-disubstituted 3-amino-2*H*-azirines **4** to give zwitterionic 1:1 adducts as stable and crystalline substances in good yields [5] [11].

When a solution of **7** (R = $MeSO_2$) in i-PrOH was treated with the azirines **2** at room temperature or when **8** (R = MeO) and **2** were heated to 80° under N_2 for 2–3 h, the corresponding imidazoles **9** and **10**, respectively, were isolated in good yields as crystalline solids (*Scheme 4*, *Table 2*).

Scheme 4



7 R = $MeSO_2$
8 R = MeO

2

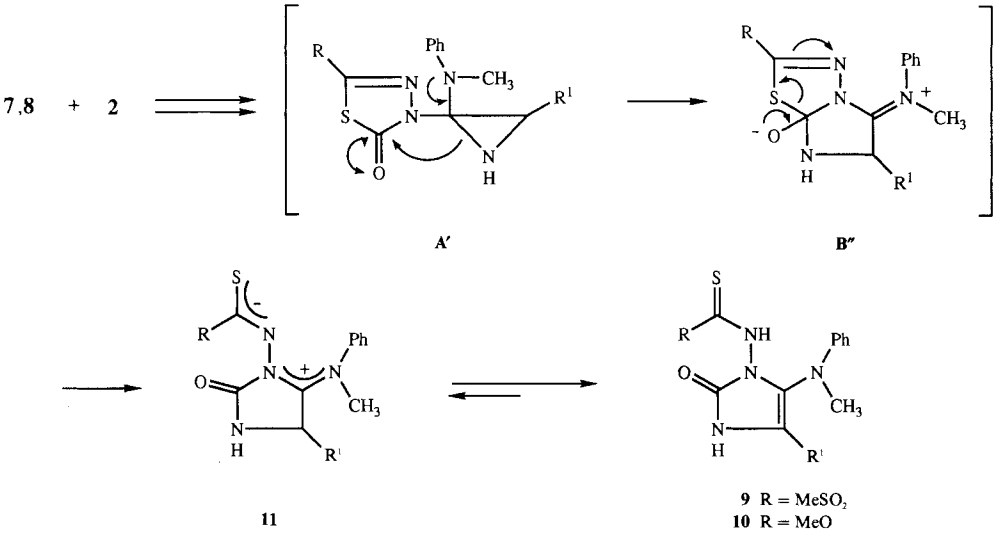
9 R = $MeSO_2$
10 R = MeO

Table 2. *Prepared* N-*[2,3-Dihydro-5-(*N*-methyl-*N*-phenylamino)-2-oxoimidazol-1-yl]thioformamides* **9** *and* **10**

Compound	R	R^1	Yield [%]	M.p. [°]
9a	$MeSO_2$	Ph	84	148
9b	$MeSO_2$	Me	95	108
9c	$MeSO_2$	Et	65	117
10a	MeO	Ph	82	207
10b	MeO	Me	96	215
10c	MeO	Et	71	180

The mechanism proposed for this transformation is shown in *Scheme 5:* protonation of the azirine **2**, followed by nucleophilic attack onto C(3), leads to intermediate **A′**, which, after cleavage of the N(1)–C(3) bond, reacts to the zwitterionic structure **B″**. This

Scheme 5



intermediate, in contrast to **B′** in the saccharin case, rearranges *via* opening of the 1,3,4-thiadiazole ring to give **11**. Because of the proton at C(4), **11** tautomerizes to give the imidazol-2-one derivatives **9** and **10** as stable, crystalline products, though **9b** and **9c** decompose readily on standing on air.

These compounds were identified and characterized by their spectroscopical data and elemental analysis. In the case of **10b**, an X-ray analysis was performed confirming the proposed structure (*Fig. 2*).

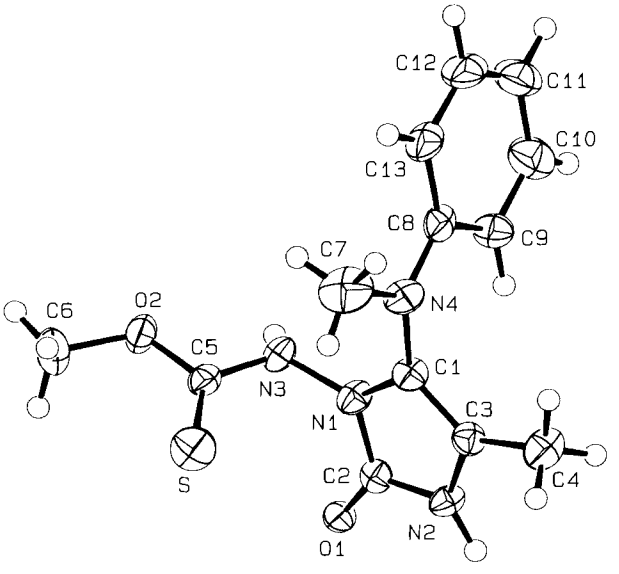
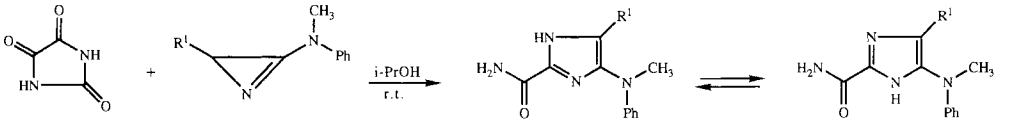


Fig. 2. *ORTEP Plot* [14] *with 50% probability ellipsoids of the molecular structure of* N-*[2,3-dihydro-5-(*N-*methyl-*N-*phenylamino)-4-methyl-2-oxoimidazol-1-yl]-1-methoxythioformamide* (**10b**)

As a third NH-acidic heterocycle, parabanic acid (= imidazolidine-2,4,5-trione, **12**) was reacted with the monosubstituted azirines **2**. It is well known, that five- and six-membered heterocycles containing the structural element NH–CO–NH–CO, in the reaction with **4** are converted into 4*H*-imidazoles without exception [5] [8] [9] [12] [13]. When a solution of **12** in i-PrOH was treated with **2** at room temperature under N_2 for 3–5 h, the corresponding 5-(*N*-methyl-*N*-phenylamino)imidazole-2-carboxamides **13** are formed in good yields (*Scheme 6*, *Table 3*). In solution, compounds **13** exist as a mixture of two tautomeric structures.

Scheme 6

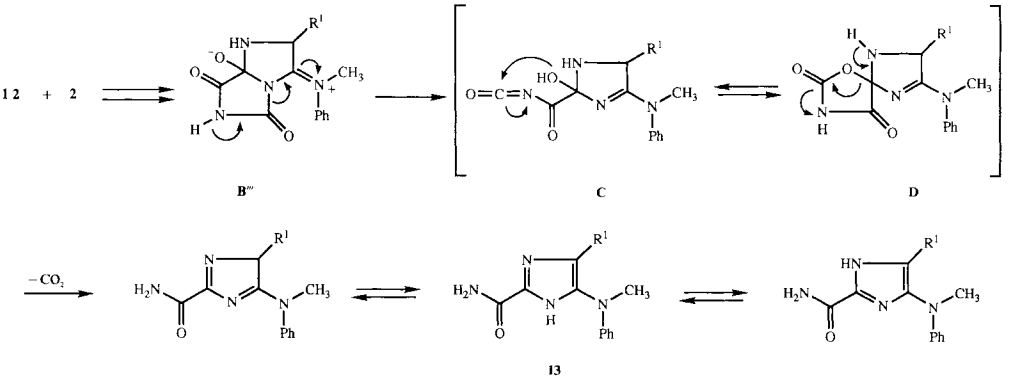


12 **2** **13**

Table 3. *Prepared 5-(N-Methyl-N-phenylamino)imidazole-2-carboxamides* **13**

Compound	R^1	Yield [%]	M.p. [°]
13a	Ph	78	230
13b	Me	63	231
13c	Et	57	197

Scheme 7



A mechanism that accounts for the presented results is formulated in *Scheme 7*. The zwitterions **B‴**, which arise as usual (*cf. Scheme 2*), have a new reaction pathway, leading *via* **C** and the cyclic urethane **D** and fragmentation with elimination of CO_2, to the corresponding imidazoles **13**. These compounds which are decarboxylated 1:1 adducts of **2** and **12**, were identified and characterized by their spectroscopical data and elemental analysis. In the case of **13c**, an X-ray analysis was performed which confirmed the proposed structure (*Fig. 3*).

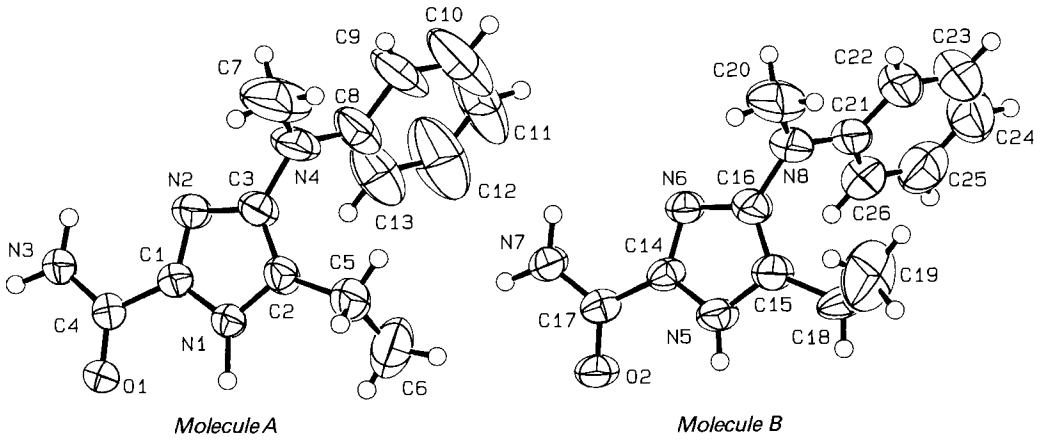


Fig. 3. *ORTEP Plot* [14] *with 50% probability ellipsoids of the two crystallographically independent molecules of 4-ethyl-5-(*N*-methyl-*N*-phenylamino)imidazole-2-carboxamide* (**13c**; *cf. Chapt. 3*)

In conclusion, we have shown that 2-monosubstituted 3-amino-2*H*-azirines of type **2** exhibit a similar behavior compared with their 2,2-disubstituted analogues **4**, in their reactivity towards NH-acidic heterocycles. *Via* the same mechanisms, the corresponding products were formed. Though, whenever there is a possibility of tautomerism because of the monosubstitution, it will occur as could be expected, in order to stabilize the system.

3. Crystal-Structure Determination of Compounds 6c, 10b, and 13c. – Crystals of **6c**, **10b**, and **13c** obtained from MeOH, were used for X-ray structure determination[2]). The intensities were collected on a *Rigaku AF5CR* diffractometer using graphite-monochromated MoK_α radiation ($\lambda = 0.71069$ Å) and a 12-kW rotating anode generator. The intensities were corrected for *Lorentz* and polarization effects and, for **6c** and **10b**, absorption corrections were applied using DIFABS [15]. Data collection and refinement are listed in *Table 4*. Views of the molecules are shown in *Figs. 1–3*.

The structures of **6c** and **13c** were solved by direct methods using SHELXS86 [16], which revealed the positions of all non-H-atoms. Structure **10b** was solved by *Patterson* methods [16], which revealed the position of the S-atom. All remaining non-H-atoms were located in a *Fourier* expansion of the *Patterson* solution. In all the structures, the non-H-atoms were refined anisotropically.

For **6c**, all of the H-atoms were located in a difference *Fourier* map, and their positions were allowed to refine together with individual isotropic temperature factors.

For **10b**, the H-atoms bonded to N-atoms were located in a difference *Fourier* map, and their positions were allowed to refine freely, while all other H-atoms were placed in geometrically calculated positions with a C–H distance of 0.95 Å, and their positions were held fixed. Individual isotropic temperature factors were refined for all H-atoms. A correction for secondary extinction was applied.

In **13c**, there are two crystallographically independent molecules in the asymmetric unit. One of these molecules contains positional disorder of the Et group; two orienta-

[2]) Atomic coordinates, bond lengths, and bond angles have been deposited with the *Cambridge Crystallographic Data Centre*, 12 Union Road, Cambridge CB2 1EZ, England.

Table 4. *Crystallographic Data for Compounds* **6c**, **10b**, *and* **13c**

	6c	**10b**	**13c**
Crystallized from	MeOH	MeOH	MeOH
Empirical formula	$C_{18}H_{19}N_3O_3S$	$C_{13}H_{16}N_4O_2S$	$C_{13}H_{16}N_4O$
Formula weight	357.43	292.35	244.30
Crystal color, habit	colorless prisms	colorless prisms	colorless prisms
Temp. [K]	173 (1)	173 (1)	294
Crystal dimensions [mm]	0.15 × 0.35 × 0.45	0.10 × 0.20 × 0.38	0.20 × 0.28 × 0.50
Crystal system	triclinic	orthorhombic	rhombohedral
Lattice parameters[a])			
a [Å]	10.610 (2)	14.141 (3)	32.008 (3)
b [Å]	10.858 (2)	27.676 (5)	32.008 (3)
c [Å]	8.389 (2)	7.512 (3)	14.101 (3)
α [°]	103.94 (1)	90	90
β [°]	97.70 (2)	90	90
γ [°]	106.02 (1)	90	120
V [Å^3]	880.6 (6)	2940 (1)	12511 (3)
Space group	$P\bar{1}$	*Pbca*	$R\bar{3}$
Z	2	8	36
D_x [g cm^{-3}]	1.348	1.321	1.167
Absorption coefficient $\mu(\text{Mo}K_\alpha)$ [cm^{-1}]	1.959	2.165	0.727
Absorp. correction min, max	0.852, 1.079	0.628, 1.189	–
Scan type	ω-2θ	ω	ω-2θ
2θ (max) [°]	60	55	55
Total reflections measured	5395	4563	7211
Symm. indep. reflections	5140	3373	6084
Reflections observed	4462	1622	2499
Criterion	$I > 3\sigma(I)$	$I > 2\sigma(I)$	$I > 2\sigma(I)$
Variables	302	204	356
Final R	0.0325	0.0615	0.0667
wR	0.0368	0.0569	0.0655
Goodness of fit s	2.317	1.731	2.469
Weighting scheme, p for $w = [\sigma^2(F_0) + (pF_0/2)^2]^{-1}$	0.01	0.01	0.01
Secondary extinct. coefficient	–	1.24×10^{-7}	2.80×10^{-8}
Final Δ_{max}/σ	0.0003	0.01	0.03
$\Delta\rho$ (max; min) [e Å^{-3}]	0.29; –0.41	0.37; –0.35	0.27; –0.26

[a]) The cell dimensions were obtained from 24 accurately centered reflections with $39° < 2\theta < 40°$, $22° < 2\theta < 26°$ and $23° < 2\theta < 37°$, respectively.

tions of the Et group were defined, each with 50% occupation, and the anisotropic refinement of the positions of the disordered atoms was successful. All of the H-atoms bonded to C-atoms were placed in geometrically calculated positions with a C–H distance of 0.95 Å and fixed isotropic temperature factors, the magnitude being $1.2 \times B_{eq}$ of the associated C-atom. The H-atoms bonded to N-atoms were located in a difference *Fourier* map and, for these atoms, individual isotropic temperature factors were refined, but their positions were held fixed. A correction for secondary extinction was applied.

All refinements were on F using full-matrix least-squares procedures [17], which minimized the function $\Sigma w\,(|F_0| - |F_c|)^2$. Neutral atom scattering factors for non-H-atoms were taken from [18a] and the scattering factors for H-atoms from [19]. Anomalous dispersion effects were included in F_{calc} [20]; the values for $\Delta f'$ and $\Delta f''$ were those of [18b].

All calculations were performed using the TEXSAN [21] crystallographic software package.

In **6c**, there is one H-bond between the amide H-atom and one of the O-atoms of the SO_2 group of an adjacent molecule. The H-bonding links the molecules into dimeric units, the two molecules of the dimer being related by a center of inversion (*Fig. 4*).

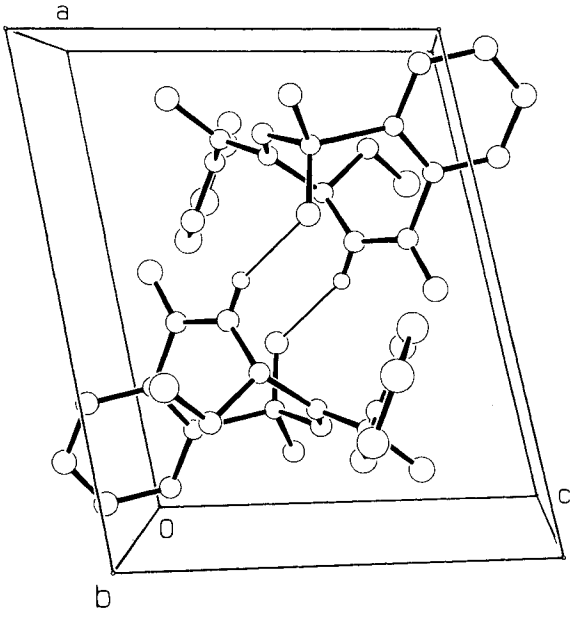


Fig. 4. *Dimeric H-bonded unit and unit cell contents of* **6c**. Uninvolved H-atoms have been omitted for clarity.

Each molecule of **10b** is involved in H-bonding, there being two donor and two acceptor interactions. The carbonyl O-atom acts as an acceptor for two H-bonds from the N*H*-atoms of different adjacent molecules, which are themselves related by one unit cell translation in the *z*-direction. Conversely, each of the N*H*-atoms acts as a donor to the corresponding carbonyl O-atoms of these adjacent molecules (*Fig. 5*). Thus, the H-bonds link the molecules into infinite chains running parallel to the *z*-axis. The five-membered ring is completely planar, as are all atoms in each of the Ph–N(Me) and MeO–C(S)–N groups. These latter two groups are almost perpendicular to the five-membered ring with dihedral angles between the least-squares planes of 88.5° (C(1), N(1), C(2), N(2), C(3)/Ph–N(Me)) and 92.6° (C(1), N(1), C(2), N(2), C(3)/MeO–C(S)–N).

There are two independent molecules in the asymmetric unit of **13c**, one of which exhibits disorder in the Et group. The Ph groups also exhibit significant thermal motion. The molecules are linked by a complex system of intermolecular H-bonds (*Fig. 6*). Although the two independent molecules are almost identical, except for the disorder, as can be seen in *Fig. 6*, each is involved in a completely different H-bonding pattern. It is this H-bonding which makes the molecules crystallographically independent. Type-A molecules always have contacts with type-B molecules. There are no contacts of the

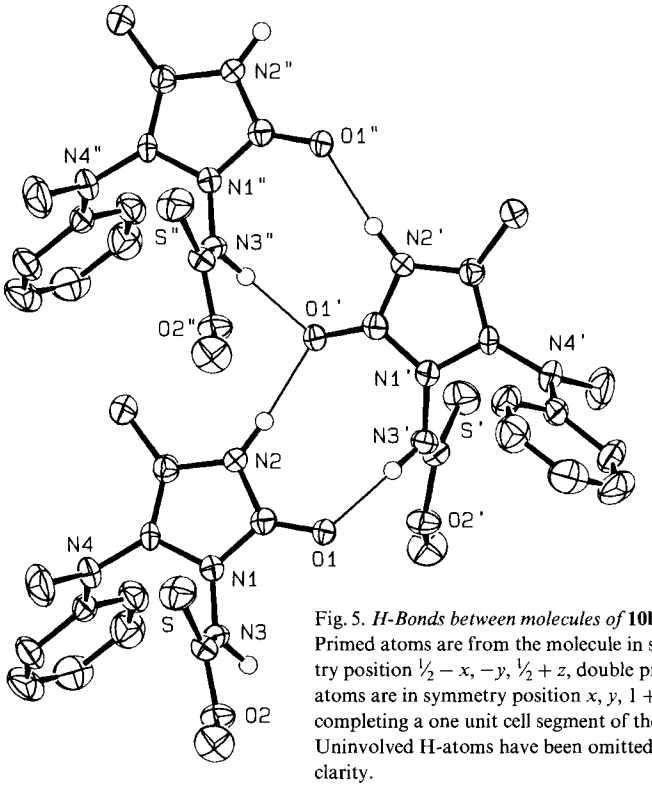


Fig. 5. *H-Bonds between molecules of* **10b**. Primed atoms are from the molecule in symmetry position $\frac{1}{2} - x, -y, \frac{1}{2} + z$, double primed atoms are in symmetry position $x, y, 1 + z$, thus completing a one unit cell segment of the chain. Uninvolved H-atoms have been omitted for clarity.

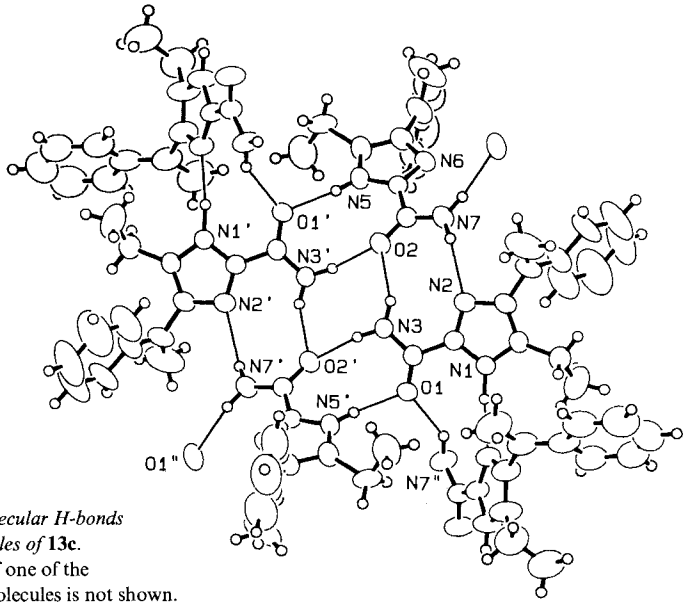


Fig. 6. *Intermolecular H-bonds between molecules of* **13c**. The disorder of one of the independent molecules is not shown.

A···A or B···B type. The NH_2 group (N(3)) of molecule A makes contacts with O(2) from two different molecules of type B, the two being related by the centre of inversion. The NH_2 group (N(7)) of molecule B, however, makes a contact with N(2) in the five-membered ring of molecule A, and also with O(1) of a different molecule A, this time not related by an inversion center. N(5)H in the five-membered ring of molecule B makes a contact with O(1) of the inversion related molecule A. The same NH in molecule A (N(1)H), however, makes a contact with N(6) from molecule B of a different asymmetric unit. The N-atoms of the aniline groups are not involved in any H-bonds. The amide O-atoms from both molecules are involved in bifurcated H-bonds. There are 4 NH···O contacts and 2 NH···N contacts. The net result of these contacts is that four of the six different H-bonds (3 of NH···O, 1 of NH···N) link one pair of A, B molecules into two sets of pairs related by a center of inversion, thereby forming 'clusters' of four molecules held by a total of eight H-bonds. These clusters are then woven into planes by the two H-bonds not linking inversion related molecules. Each cluster has a total of eight of these 'external' links as well. The planes of clusters extend in the *xy*-plane. There are no H-bonds that link the molecules continuously in the *z*-direction. The five-membered rings in each molecule are completely planar. In molecule A, the dihedral angle between the ring plane and the plane of the amide group is 2.2°, while in molecule B the corresponding angle is 14.3°.

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Experimental Part

General. See [1]. Unless otherwise stated, IR spectra in KBr and NMR spectra in (D_6)DMSO; ^1H (300 MHz) and ^{13}C (50.4 MHz). MS at 70 eV, CI-MS with 2-methylpropane or NH_3.

1. *Reaction of 2-Substituted 3-(*N*-Methyl-*N*-phenylamino)-2*H*-azirines* **2** *with 1,2-Benzoisothiazol-3(2*H*)-one 1,1-Dioxide* (**5**). *General Procedure.* To a well stirred soln. of 366 mg (2 mmol) of **5** in 5.5 ml of dry MeCN at r.t., a soln. of 2 mmol of the azirine **2** in 0.5 ml of dry MeCN was added. The mixture was stirred overnight, the resulting solid collected by filtration, washed with hexane/Et_2O, and dried in high vacuum.

1.1. *4,5-Dihydro-3-(*N*-methyl-*N*-phenylamino)-4-phenylbenzo[*g*][1,2,5]thiadiazocin-6-one 1,1-Dioxide* (**6a**). Recrystallized from EtOH: 648 mg (80%). Colorless microcrystals. M.p. 167.0–167.5°. IR: 3260*s*, 3060*w*, 3025*w*, 2920*w*, 1670*s*, 1550*s*, 1535*s*, 1495*m*, 1440*m*, 1405*m*, 1335*m*, 1310*s*, 1290*s*, 1225*m*, 1190*w*, 1160*s*, 1125*s*, 1090*w*, 1075*w*, 1060*m*, 1025*w*, 1010*w*, 995*w*, 925*w*, 850*w*, 860*m*, 830*w*, 755*s*, 730*m*, 720*w*, 700*s*, 675*w*, 630*s*. ^1H-NMR: 8.68 (*d*, $J = 8$, 1 H); 7.76 (*d*, $J = 8$, 1 H); 7.4–6.55 (*m*, 13 H); 5.42 (*d*, $J = 8$, 1 H); 3.42 (*s*, CH_3N). ^{13}C-NMR ((D_6) DMSO + TFA): 174.0 (*s*, C=N); 164.0 (*s*, C=O); 143.8, 140.2, 138.0 (3*s*, 3 arom. C); 136.0, 133.9 (2*d*, 2 arom. CH); 133.5 (*s*, arom. C); 133.4, 132.1, 131.8, 131.7, 130.7, 130.6, 130.0 (7*d*, 12 arom. CH); 59.8 (*q*, CH_3N); 45.8 (*d*, C(4)). CI-MS: 406 (22, $[M + 1]^+$), 342 (100, $[M - SO_2]^+$), 237 (10), 235 (18), 210 (46), 133 (20), 108 (14). Anal. calc. for $C_{22}H_{19}N_3SO_3$ (405.47): C 65.17, H 4.72, N 10.36, S 7.90; found: C 64.92, H 4.98, N 10.18, S 7.66.

1.2. *4,5-Dihydro-4-methyl-3-(*N*-methyl-*N*-phenylamino)benzo[*g*][1,2,5]thiadiazocin-6-one 1,1-Dioxide* (**6b**): 466 mg (68%). Colorless microcrystals. M.p. 241.3–241.5°. IR: 3320*s*, 3080*w*, 3050*w*, 3000*w*, 2940*w*, 1665*s*, 1550*s*, 1475*m*, 1465*m*, 1450*m*, 1405*w*, 1395*w*, 1370*w*, 1340*s*, 1300*s*, 1290*s*, 1260*m*, 1195*m*, 1180*m*, 1160*s*, 1135*s*, 1115*m*, 1100*w*, 1070*m*, 1030*m*, 985*m*, 910*w*, 840*w*, 805*s*, 770*s*, 760*m*, 735*s*, 700*s*, 660*m*, 630*m*. ^1H-NMR: 8.35 (*d*, $J = 8$, 1 H); 7.95–7.4 (*m*, 9 H); 4.2–4.1 (*m*, 1 H); 3.32 (*s*, CH_3N); 0.37 (*d*, $J = 8$, CH_3). CI-MS: (100, $[M + 1]^+$). Anal. calc. for $C_{17}H_{17}N_3SO_3$ (343.39): C 59.46, H 4.98, N 12.23, S 9.33; found: C 59.52, H 4.71, N 11.94, S 9.31.

1.3. *4-Ethyl-4,5-dihydro-3-(*N*-methyl-*N*-phenylamino)benzo[*g*][1,2,5]thiadiazocin-6-one 1,1-Dioxide* (**6c**): 500 mg (70%). Colorless powder. M.p. 239.5–240° (dec.). IR: 3300*s*, 3060*w*, 2970*m*, 2940*w*, 2880*w*, 1660*s*, 1565*s*,

1550*s*, 1535*s*, 1495*m*, 1470*m*, 1440*m*, 1415*w*, 1390*m*, 1350*s*, 1300*s*, 1290*s*, 1275*s*, 1260*s*, 1195*m*, 1180*m*, 1160*s*, 1130*s*, 1105*m*, 1070*m*, 1055*m*, 1040*m*, 1010*m*, 990*m*, 930*w*, 890*m*, 840*m*, 780*s*, 730*m*, 705*s*, 685*m*, 670*w*, 630*s*. ^{1}H-NMR: 8.19 (*d*, *J* = 8, 1 H); 7.9–7.45 (*m*, 9 H); 3.9–3.85 (*m*, 1 H); 3.31 (*s*, CH_3N); 1.15–1.1 (*m*, CH_3CH_2); 0.21 (*t*, *J* = 7, CH_3CH_2). ^{13}C-NMR: 169.6 (*s*, C=N); 163.9 (*s*, C=O); 141.6, 139.8, 135.1 (3*s*, 3 arom. C); 129.9, 129.0, 127.8, 127.4, 127.1 (5*d*, 7 arom. CH); 54.2 (*q*, CH_3N); 41.5 (*d*, C(4)); 22.3 (*t*, CH_3CH_2); 10.2 (*q*, CH_3CH_2). CI-MS: 358 (100, $[M+1]^+$). Anal. calc. for $C_{18}H_{19}N_3SO_3$ (357.42): C 60.48, H 5.35, N 11.75, S 8.96; found: C 60.61, H 5.59, N 11.82, S 8.68.

1.4. *4-(*tert*-Butyl)-4,5-dihydro-3-(*N*-methyl-*N*-phenylamino)benzo[g][1,2,5]thiadiazocin-6-one 1,1-Dioxide* (**6d**): 500 mg (65%). Colorless microcrystals. M.p. 237.0–238.0°. IR: 3380*w*, 3360*w*, 3270*w*, 3060*w*, 2960*m*, 1690*s*, 1640*w*, 1610*w*, 1590*w*, 1570*w*, 1515*s*, 1505*s*, 1460*s*, 1430*m*, 1395*s*, 1375*w*, 1330*m*, 1305*s*, 1290*s*, 1240*s*, 1170*w*, 1140*s*, 1115*s*, 1100*m*, 1055*m*, 1020*w*, 990*m*, 950*m*, 885*w*, 865*w*, 819*m*, 780*s*, 750*s*, 700*s*, 650*m*, 630*m*, 615*m*. ^{1}H-NMR: 8.15–8.1 (*m*, 1 H); 7.90 (*d*, *J* = 10, 1 H); 7.8–7.4 (*m*, 8 arom. H); 5.26 (*d*, *J* = 10, 1 H); 3.31 (*s*, CH_3N); 0.80 (*s*, $(CH_3)_3C$). ^{13}C-NMR: 173.1 (*s*, C=N); 170.5 (*s*, C=O); 144.0, 143.1, 133.6 (3*s*, 3 arom. C); 132.4, 131.9, 129.9, 128.8, 127.8, 127.0 (6*d*, 9 arom. CH); 62.7 (*q*, CH_3N); 44.0 (*d*, C(4)); 33.6 (*s*, $(CH_3)_3C$); 28.8 (*q*, $(CH_3)_3C$). CI-MS: 386 (100, $[M+1]^+$). Anal. calc. for $C_{20}H_{23}N_3SO_3$ (386.48): C 62.15, H 6.25, N 10.87, S 8.29; found: C 62.00, H 6.30, N 10.80, S 8.46.

2. *Reaction of* **2** *with 5-(Methylsulfonyl)-1,3,4-thiadiazole-2(3*H*)-one* (**7**). *General Procedure.* To a soln. of 73 mg (0.40 mmol) of **7** in 2 ml of i-PrOH, a soln. of 0.45 mmol of **2** in 0.5 ml of CH_2Cl_2 was added. The mixture was then stirred at r.t. under N_2. After 1 h, hexane was added, and the precipitated solid was collected by filtration, washed with hexane, and dried in high vacuum.

2.1. *N-{2,3-Dihydro-5-(*N*-methyl-*N*-phenylamino)-2-oxo-4-phenylimidazol-1-yl}-1-(methylsulfonyl)thioformamide* (**9a**): 136 mg (84%). Colorless powder. M.p. 148°. IR: 3320*m*, 3040*w*, 2930*w*, 1800*s*, 1650*s*, 1590*m*, 1490*m*, 1460*m*, 1430*s*, 1410*w*, 1350*w*, 1315*m*, 1300*s*, 1220*w*, 1195*w*, 1135*s*, 1110*w*, 1090*m*, 1030*w*, 1010*w*, 945*m*, 915*w*, 845*w*, 820*w*, 795*m*, 770*m*, 760*m*, 745*m*, 700*s*, 645*w*, 620*w*. ^{1}H-NMR: 9.72 (*s*, NH); 7.75–6.8 (*m*, 10 H); 6.75–6.7 (*m*, 1 H); 3.7–3.4 (br. *s*, CH_3N, CH_3SO_2). ^{13}C-NMR: 191.6 (*s*, C=S); 167.4 (*s*, C=O); 148.2, 146.0 (2*s*, 2 arom. C); 129.4, 129.3, 129.0, 128.8, 124.3, 124.1 (6*d*, 6 arom. CH); 122.0 (*s*, C(5)); 118.8, 117.5 (2*d*, 2 arom. CH); 115.9 (*s*, C(4)); 113.4, 113.0 (2*d*, 2 arom. CH); 40.8 (*q*, CH_3SO_2); 39.1 (*q*, CH_3N). EI-MS: 402 (< 1, $M^{+\cdot}$), 264 (14), 263 (35), 262 (27), 180 (29), 133 (20), 132 (100), 131 (15), 118 (13), 117 (11), 106 (13), 105 (12), 104 (25), 103 (13), 91 (30), 80 (20), 79 (19), 78 (17), 77 (94), 76 (18), 65 (80), 64 (16), 63 (44). Anal. calc. for $C_{18}H_{18}N_4S_2O_3$ (402.49): C 53.71, H 4.51, N 13.92; found: C 53.60, H 4.73, N 13.65.

2.2. *N-{2,3-Dihydro-4-methyl-5-(*N*-methyl-*N*-phenylamino)-2-oxoimidazol-1-yl}-1-(methylsulfonyl)thioformamide* (**9b**): 161 mg (95%). Colorless powder. M.p. 108°. Very hygroscopic substance, only soluble in DMSO where it decomposes. IR: 3480*m*, 3120*m*, 3010*w*, 2970*m*, 2930*m*, 1775*s*, 1660*s*, 1590*m*, 1560*w*, 1490*m*, 1425*m*, 1380*w*, 1345*m*, 1320*w*, 1295*s*, 1260*m*, 1220*m*, 1145*s*, 1080*m*, 1015*m*, 955*m*, 810*w*, 770*w*, 750*m*, 695*m*, 665*w*, 635*w*. EI-MS: 340 (< 1, $M^{+\cdot}$), 106 (6), 85 (12), 57 (100).

2.3. *4-Ethyl-N-{2,3-dihydro-5-(*N*-methyl-*N*-phenylamino)-2-oxoimidazol-1-yl}-1-(methylsulfonyl)thioformamide* (**9c**): 92 mg (65%). Colorless powder. M.p. 117°. Substance only soluble in DMSO where it decomposes. IR: 3420*m*, 3300*m*, 2980*w*, 2930*w*, 1800*s*, 1650*s*, 1590*m*, 1495*m*, 1425*s*, 1350*w*, 1300*s*, 1225*w*, 1140*s*, 1080*w*, 1030*w*, 1010*w*, 935*m*, 880*w*, 795*w*, 750*m*, 720*w*, 705*w*, 680*w*, 650*w*, 620*w*. EI-MS: 354 (< 1, $M^{+\cdot}$), 85 (12), 57 (100), 41 (18). Anal. calc. for $C_{14}H_{18}N_4S_2O_3$ (354.45): C 47.44, H 5.12, N 15.81, S 18.09; found: C 47.19, H 5.39, N 15.82, S 18.18.

3. *Reaction of* **2** *with 5-Methoxy-1,3,4-thiadiazole-2(3*H*)-one* (**8**). *General Procedure.* To a soln. of 66 mg (0.5 mmol) of **8** in 2 ml of i-PrOH, a soln. of 0.55 mmol of **2** in 0.5 ml of i-PrOH, was added. The mixture was stirred at 80° under N_2 for 2 h. After cooling to r.t., the precipitated solid was collected by filtration, washed with hexane/Et_2O, and dried in high vacuum.

3.1. *N-{2,3-Dihydro-5-(*N*-methyl-*N*-phenylamino)-2-oxo-4-phenylimidazol-1-yl}-1-methoxythioformamide* (**10a**): 145 mg (82%). Colorless powder. M.p. 207°. IR: 3420*m*, 3170*s*, 3000*s*, 1710*s*, 1660*s*, 1600*s*, 1520*m*, 1500*s*, 1450*s*, 1360*m*, 1335*s*, 1290*m*, 1245*s*, 1225*s*, 1150*m*, 1110*w*, 1060*m*, 1035*w*, 990*w*, 910*w*, 890*w*, 845*m*, 755*s*, 695*s*, 660*m*, 640*w*, 610*w*. ^{1}H-NMR: 10.82, 10.57 (2*s*, 2 NH); 7.5–7.1 (*m*, 7 arom. H); 6.85–6.70 (*m*, 3 arom. H); 3.84 (br. *s*, CH_3O); 3.18 (*s*, CH_3N). ^{13}C-NMR[3]): 192.8, 190.9 (2*s*, C=S); 149.5 (*s*, C=O); 146.5, 146.4 (2*s*, 1 arom. C); 128.8 (*d*, 4 arom. CH); 128.5, 128.4 (2*s*, 1 arom. C); 127.2 (*d*, 1 arom. CH); 124.1 (*d*, 2 arom. CH); 122.9, 122.6 (2*s*, C(5)); 118.6 (*d*, 1 arom. CH); 114.4, 113.4 (2*s*, C(4)); 113.0 (*d*, 2 arom. CH); 57.8 (br. *q*, CH_3O); 38.2, 37.8 (2*q*, CH_3N). EI-MS: 354 (41, $M^{+\cdot}$), 264 (42), 161 (26), 106 (23), 104 (82), 103 (16), 91 (16), 89 (15), 77 (100), 60 (31), 58 (20), 51

[3]) Doubling of some signals observed; two conformers.

(44), 47 (18), 43 (28), 42 (39), 41 (23). Anal. calc. for $C_{18}H_{18}N_4SO_2$ (354.43): C 61.00, H 5.12, N 15.81, S 9.05; found: C 60.87, H 5.33, N 15.67, S 9.22.

3.2. *N-[2,3-Dihydro-4-methyl-5-(*N*-methyl-*N*-phenylamino)-2-oxoimidazol-1-yl]-1-methoxythioformamide* (**10b**): 140 mg (96%). Colorless powder. M.p. 215°. IR: 3130*s*, 2920*s*, 2810*w*, 1715*s*, 1690*s*, 1600*s*, 1580*w*, 1560*w*, 1520*m*, 1500*s*, 1480*m*, 1445*m*, 1355*m*, 1320*s*, 1295*m*, 1230*s*, 1170*m*, 1120*w*, 1090*w*, 1065*w*, 1040*w*, 1030*w*, 995*w*, 955*m*, 890*w*, 850*w*, 800*w*, 750*s*, 720*w*, 690*m*, 645*m*. ^{1}H-NMR: 10.63, 9.67 (2*s*, 2 NH); 7.2–7.1 (*m*, 2 arom. H); 6.75–6.7 (*m*, 3 arom. H); 3.82 (*s*, CH_3O); 3.07 (*s*, CH_3N); 1.76 (*s*, CH_3). ^{13}C-NMR[3]): 194.0, 193.7 (2*s*, C=S); 149.7 (*s*, C=O); 148.0, 147.8 (2*s*, 1 arom. C); 128.9 (*d*, 2 arom. CH); 122.4, 122.1 (2*s*, C(5)); 118.2 (br. *d*, 1 arom. CH); 113.0 (*d*, 2 arom. CH); 111.5, 111.0 (2*s*, C(4)); 57.7 (*q*, CH_3O); 38.4 (*q*, CH_3N); 8.9 (*q*, CH_3). EI-MS: 292 (10, $M^{+\cdot}$), 202 (12), 104 (10), 75 (18), 55 (11), 44 (15), 43 (30), 42 (56), 41 (27), 40 (100). Anal. calc. for $C_{13}H_{16}N_4SO_2$ (292.36): C 53.41, H 5.52, N 19.16, S 10.97; found: C 53.61, H 5.57, N 18.95, S 11.23.

3.3. *4-Ethyl-*N*-[2,3-dihydro-5-(*N*-methyl-*N*-phenylamino)-2-oxoimidazol-1-yl]-1-methoxythioformamide* (**10c**): 108 mg (71%). Colorless powder. M.p. 178°. IR: 3140*s*, 2980*s*, 2920*s*, 2820*m*, 1710*s*, 1680*s*, 1600*s*, 1580*m*, 1560*w*, 1535*m*, 1500*s*, 1480*s*, 1450*s*, 1360*s*, 1320*s*, 1300*s*, 1230*s*, 1185*w*, 1170*m*, 1135*w*, 1090*m*, 1070*w*, 1045*w*, 1030*w*, 995*m*, 920*m*, 870*w*, 855*w*, 815*w*, 690*s*, 645*m*. ^{1}H-NMR: (two conformers): 11.13, 11.03, 10.24, 10.18 (4*s*, 2 NH); 7.2–7.1 (*m*, 2 arom. H); 6.75–6.65 (*m*, 3 arom. H); 3.90, 3.72 (2*s*, CH_3O); 3.05, 3.00 (2*s*, CH_3N); 2.10, 2.08 (2*q*, CH_3CH_2); 0.98, 0.96 (2*t*, CH_3CH_2). ^{13}C-NMR[3]): 192.1, 191.0 (2*s*, C=S); 149.6 (*s*, C=O); 148.0, 147.7 (2*s*, 1 arom. C); 128.7 (*d*, 2 arom. CH); 121.4, 121.2 (2*s*, C(5)); 118.0 (*d*, 1 arom. CH); 116.8, 116.2 (2*s*, C(4)); 112.8 (*d*, 2 arom. CH); 57.5 (*q*, CH_3O); 38.7 (*q*, CH_3N); 16.8 (*t*, CH_3CH_2); 12.2 (*q*, CH_3CH_2). EI-MS: 306 (100, $M^{+\cdot}$), 216 (40), 161 (23), 77 (12), 56 (12). Anal. calc. for $C_{14}H_{18}N_4SO_2$ (306.38): C 54.88, H 5.92, N 18.29, S 10.47; found: C 54.64, H 5.75, N 18.25, S 10.61.

4. *Reaction of* **2** *with Imidazolidine-2,4,5-trione* (**12**). *General Procedure*. To a soln. of 57 mg (0.5 mmol) of **12** in 2 ml of i-PrOH, a soln. of 0.5 mmol of **2** in 0.5 ml of CH_2Cl_2 was added at r.t. The mixture was stirred for 3–5 h, the resulting solid was filtered, washed with hexane/Et_2O, and dried in high vacuum.

4.1. *5-(*N*-Methyl-*N*-phenylamino)-4-phenylimidazole-2-carboxamide* (**13a**): 113 mg (78%). Colorless powder. M.p. 230°. IR: 3440*s*, 3300*s*, 3160*s*, 2880*m*, 2820*m*, 2440*w*, 1920*w*, 1750*w*, 1660*s*, 1590*s*, 1525*s*, 1495*s*, 1465*s*, 1440*s*, 1425*s*, 1365*s*, 1340*m*, 1330*m*, 1310*m*, 1295*m*, 1280*m*, 1260*w*, 1220*w*, 1195*m*, 1185*w*, 1160*w*, 1145*m*, 1130*w*, 1110*w*, 1100*m*, 1070*w*, 1035*w*, 1030*w*, 1015*w*, 1005*m*, 995*w*, 910*w*, 880*w*, 855*w*, 830*m*, 780*m*, 755*s*, 750*s*, 725*w*, 695*s*, 655*m*, 620*m*. ^{1}H-NMR: 13.33 (*s*, NH); 7.8–7.7 (*m*, 3 H); 7.47 (*s*, NH); 7.35–7.05 (*m*, 5 arom. H); 6.8–6.55 (*m*, 3 arom. H); 3.15 (*s*, CH_3N). ^{13}C-NMR: 159.9 (*s*, C=O); 148.5, 141.4. 138.6, 132.8, 126.4 (5*s*, 2 arom. C, C(2), C(4), C(5)); 128.9, 128.3, 127.4, 125.6, 117.3, 113.1 (6*d*, 10 arom. CH); 38.4 (*q*, CH_3N). CI-MS: 293 (100, $[M + 1]^+$). Anal. calc. for $C_{17}H_{16}N_4O$ (292.33): C 69.84, H 5.52, N 19.16; found: C 69.79, H 5.31, N 19.07.

4.2. *4-Methyl-5-(*N*-methyl-*N*-phenylamino)-imidazole-2-carboxamide* (**13b**): 73 mg (63%). Colorless powder. M.p. 231°. IR: 3340*s*, 3180*s*, 1750*w*, 1675*s*, 1650*s*, 1600*s*, 1500*s*, 1480*m*, 1450*s*, 1390*w*, 1355*m*, 1330*m*, 1300*w*, 1270*w*, 1220*w*, 1185*w*, 1130*w*, 1095*m*, 1030*w*, 1010*w*, 990*w*, 860*w*, 830*w*, 750*m*, 690*m*, 670*w*, 625*w*. ^{1}H-NMR: 12.78, 7.62, 7.29 (3*s*, 3 NH); 7.15–7.1 (*m*, 2 arom. H); 6.8–6.4 (*m*, 3 arom. H); 3.12 (*s*, CH_3N); 2.00 (*s*, CH_3). ^{13}C-NMR: 160.3 (*s*, C=O); 149.0, 141.4, 136.7, 123.3 (4*s*, 1 arom. C, C(2), C(4), C(5)); 129.0, 117.3, 113.0 (3*d*, 5 arom. CH); 39.7 (*q*, CH_3N); 9.2 (*q*, CH_3). EI-MS: 230 (40, $M^{+\cdot}$), 213 (25), 184 (26), 118 (36), 106 (10), 104 (15), 91 (10), 77 (39), 67 (12), 51 (36), 44 (25), 43 (18), 42 (100), 41 (31), 40 (12). Anal. calc. for $C_{12}H_{14}N_4O$ (230.26): C 62.59, H 6.13, N 24.33; found: C 62.70, H 6.15, N 24.04.

4.3. *4-Ethyl-5-(*N*-methyl-*N*-phenylamino)imidazole-2-carboxamide* (**13c**): 69 mg (57%). Colorless powder. M.p. 197°. IR: 3360*s*, 3180*s*, 2980*m*, 2940*m*, 2900*w*, 2810*w*, 1645*s*, 1600*s*, 1585*s*, 1515*s*, 1500*s*, 1435*m*, 1380*m*, 1360*m*, 1315*w*, 1300*w*, 1280*w*, 1245*w*, 1215*w*, 1185*w*, 1155*w*, 1135*w*, 1100*w*, 1075*w*, 1050*w*, 1030*w*, 1005*w*, 995*w*, 965*w*, 865*w*, 785*w*, 750*m*, 695*m*, 670*w*, 635*w*, 610*w*. ^{1}H-NMR: 12.80, 7.64, 7.30 (3*s*, 3 NH); 7.15–7.05 (*m*, 2 arom. H); 6.65–6.5 (*m*, 3 arom. H); 3.11 (*s*, CH_3N); 2.35 (*q*, $J = 7$, CH_3CH_2); 1.04 (*t*, $J = 7$, CH_3CH_2). ^{13}C-NMR: 160.2 (*s*, C=O); 149.0, 140.5, 136.8, 129.3 (4*s*, 1 arom. C, C(2), C(4), C(5)); 128.6, 116.8, 112.5 (3*d*, 5 arom. CH); 38.2 (*q*, CH_3N); 17.0 (*t*, CH_3CH_2); 13.3 (*q*, CH_3CH_2). EI-MS: 244 (100, $M^{+\cdot}$), 229 (11), 227 (63), 212 (25), 198 (29), 91 (15), 77 (33).

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