Synthesis of New Bis-imidazole Derivatives

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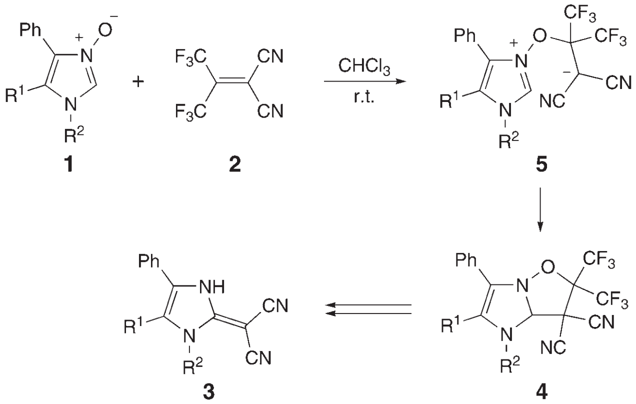
The reaction of aldimines with α-(hydroxyimino) ketones of type **10** (1,2-diketone monooximes) was used to prepare 2-unsubstituted imidazole 3-oxides **11** bearing an alkanol chain at N(1) (*Scheme 2*, *Table 1*). These products were transformed into the corresponding 2*H*-imidazol-2-ones **13** and 2*H*-imidazole-2-thiones **14** by treatment with Ac_2O and 2,2,4,4-tetramethylcyclobutane-1,3-dithione, respectively (*Scheme 3*). The three-component reaction of **10**, formaldehyde, and an alkane-1,ω-diamine **15** gave the bis[1*H*-imidazole 3-oxides] **16** (*Scheme 4*, *Table 2*). With Ac_2O, 2,2,4,4-tetramethylcyclobutane-1,3-dithione or *Raney*-Ni, the latter reacted to give the corresponding bis[2*H*-imidazol-2-ones] **19** and **20**, bis[2*H*-imidazol-2-thione] **21**, and bis[imidazole] **22**, respectively (*Schemes 5* and *6*). The structures of **11a** and **16b** were established by X-ray crystallography.

1. Introduction. – The importance of imidazole and benzimidazole derivatives both in the field of biologically active compounds and in organic synthesis is well documented (see, *e.g.*, [1–9]). Complexes of imidazoles [10] and imidazole-derived carbenes [11] with diverse metal cations have also been studied extensively. In a series of recent papers, the synthesis of 2-unsubstituted imidazole *N*-oxides was reported [12–15]. These derivatives were shown to be useful starting materials for the preparation of other imidazoles, such as imidazole-2-thiones, imidazole-2-carbonitriles, imidazol-2-ones, and *N*-alkyl- or *N*-arylimidazol-2-amines. An important feature of the structure of imidazole *N*-oxides **1** is their similarity with nitrones, which are well known 1,3-dipoles applied for the synthesis of N,O-containing five-membered heterocycles [16]. In the case of the electron-deficient 2,2-bis(trifluoromethyl)ethene-1,1-dicarbonitrile (=2-[2,2,2-trifluoro-1-(trifluoromethyl)ethylidene]propanedinitrile; **2**), the reaction with 2-unsubstituted 1*H*-imidazole 3-oxides **1** led to (1,3-dihydro-2*H*-imidazol-2-ylidene)propanedinitriles **3** and hexafluoroacetone. The formation of these products occurred *via* a regioselective [2+3]-cycloaddition to give **4** and subsequent fragmentation to produce **3** (*Scheme 1*). The reaction was proposed to proceed stepwise *via* a

[1]) Part of the planned Ph.D. thesis of *M. J.*, University of Łódź.
[2]) Part of the planned Ph.D. thesis of *P.M.*, University of Łódź.

Scheme 1

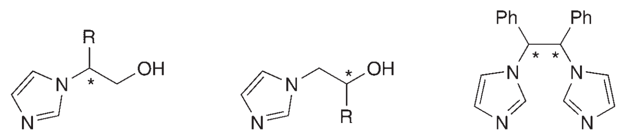


zwitterionic intermediate **5**, which, in the presence of H_2O, underwent the conversion to a 2*H*-imidazol-2-one [15].

A similar reaction pattern was observed when perfluoropropene was used as a dipolarophile. After elimination of carbonic difluoride ($F_2C{=}O$), the labile cycloadduct of type **4** gave the corresponding 2-(1,2,2,2-tetrafluoroethylidene)-2*H*-imidazole [17].

Recently, new approaches for the synthesis of both imidazoles and imidazole *N*-oxides were published [18][19]. Taking into account that imidazole *N*-oxides can easily be deoxygenated, the second approach opens access to a larger number of differently functionalized derivatives. Considering the type of starting materials applied in the syntheses of imidazole *N*-oxides, oximes and monooximes of 1,2-dicarbonyl compounds (=α-(hydroxyimino) ketones) are of special interest. In the latter case, the synthesis can be performed with an aldimine or, alternatively, in a three-component reaction with a primary amine and an aldehyde. However, it has been reported that in the three-component reaction with formaldehyde, isomerization of the initially formed imidazole *N*-oxide to the corresponding 1,3-dihydro-2*H*-imidazol-2-one already takes place in the reaction mixture [20].

As a continuation of our studies on imidazoles and imidazole *N*-oxides, the preparation of imidazole *N*-oxides bearing functionalized side chains should be elaborated. The only report on optically active imidazole *N*-oxides presented a method based on the use of α-amino acids as the amino component in the three-component reaction [21]. However, racemization during the formation of the imidazole ring was a serious problem, and in some cases, only completely racemized products were obtained. In a very recent paper, chiral β-amino alcohols with the stereogenic center in the α- or β-position were treated with glyoxal (=ethanedial), formaldehyde, and ammonia to



6 **7** **8**

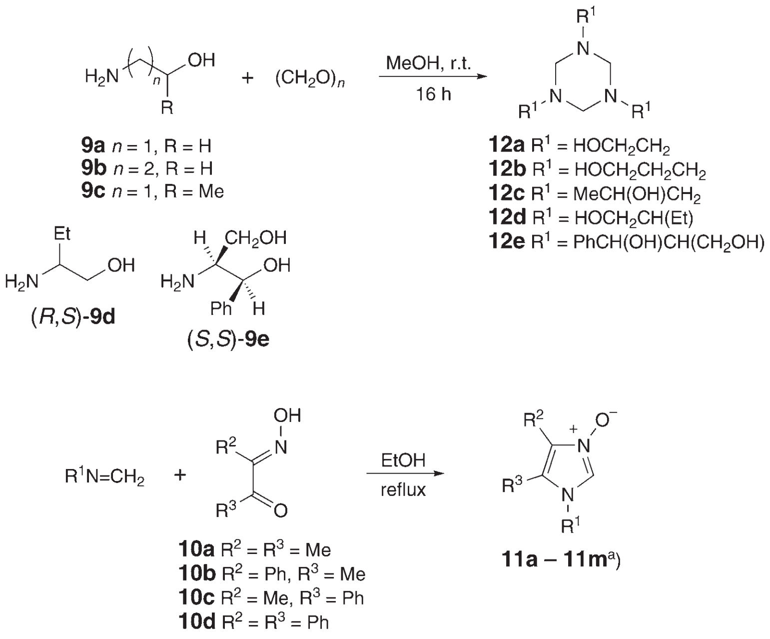
give optically active imidazoles of type **6** and **7** [9]. In another paper, the same method was reported for the synthesis of bis-imidazole **8**. The authors claimed that by using (*R,R*)- and (*S,S*)-1,2-diphenylethane-1,2-diamine, the (*R,R*) and (*S,S*) enantiomer of **8**, respectively, was obtained. However, no data regarding their optical activity or e.e. values were given [18].

To the best of our knowledge, there are no known reports on the preparation of imidazoles and bis[imidazole *N*-oxides] by using amino alcohols and diamines, respectively, in reactions with α-(hydroxyimino) ketones. In the present paper, we describe first results of this approach.

2. Results and Discussion. – 2.1. *Preparation of 1*H*-Imidazole-1-alkanol 3-Oxides.* In analogy to the already described preparations of 1,3,5-triazine 1,3,5(2*H*,4*H*,6*H*)-triethanol (**12a**) and -tripropanol (**12b**) [22], compounds **12c**–**e** were obtained by treatment of the corresponding amino alcohols **9** with paraformaldehyde in MeOH (*Scheme 2*). The crude products were used for the condensation with α-(hydroxy-imino) ketones **10** in refluxing EtOH (*Scheme 2*). Under these conditions, triazine-triethanols and -tripropanols **12** are known to undergo dissociation [12], and the monomeric formaldehyde imines (= *N*-methyleneamines) reacted with **10** to give 1*H*-imidazole 3-oxides **11** (*Table 1*) according to the known mechanism (*cf.* [23]).

All 1*H*-imidazole 3-oxides **11** were characterized by their spectroscopic and analytical data. In most cases, the crystalline products contained variable amounts of H_2O. The ^{1}H-NMR spectra show a characteristic down-field shifted signal for H–C(2)

Scheme 2



a) For R^1, R^2, and R^3, see *Table 1*.

Table 1. *1*H-*Imidazole-1-alkanol 3-Oxides* **11** *Prepared from* **10** *and* **12**

11	R^1	R^2	R^3	Yield [%]	M.p. [°]
a	$HOCH_2CH_2$	Me	Me	88	106–107
b	$HOCH_2CH_2$	Ph	Me	81	186–188
c	$HOCH_2CH_2$	Ph	Ph	89	197–198
d	$HOCH_2CH_2$	Me	Ph	55	165–167
e	$HOCH_2CH_2CH_2$	Ph	Me	94	140–142
f	$HOCH_2CH_2CH_2$	Ph	Ph	47	191–193
g	$HOCH_2CH_2CH_2$	Me	Ph	66	139–140
h	$MeCH(OH)CH_2$	Ph	Me	90	143–145
i	$MeCH(OH)CH_2$	Ph	Ph	92	182–184
j	(*S*)-$MeCH(OH)CH_2$	Me	Me	82	119–120
k	$HOCH_2CH(Et)$	Ph	Me	86	171–174
l	$HOCH_2CH(Et)$	Ph	Ph	71	199–200
m	(*S*,*S*)-$PhCH(OH)CH(CH_2OH)$	Ph	Me	52	177–178

(δ 8.2–8.5). Furthermore, the structure of **11a** was established by X-ray crystallography (*Fig. 1*).

The asymmetric unit of the structure of **11a** contains one zwitterionic molecule and half of a H_2O molecule, which sits on a C_2 axis. The OH group forms an intermolecular H-bond with the oxide O-atom of a neighboring molecule and thereby links the molecules into extended chains which run in the [1 – 1 0] and [1 1 0] directions and can be described by a graph set motif [25] of C(8). Each H_2O molecule forms two intermolecular H-bonds with the oxide O-atoms of two C_2-related zwitterionic molecules, thereby cross-linking the two directions of the extended chains into two-dimensional networks, which lie parallel to the (001) plane.

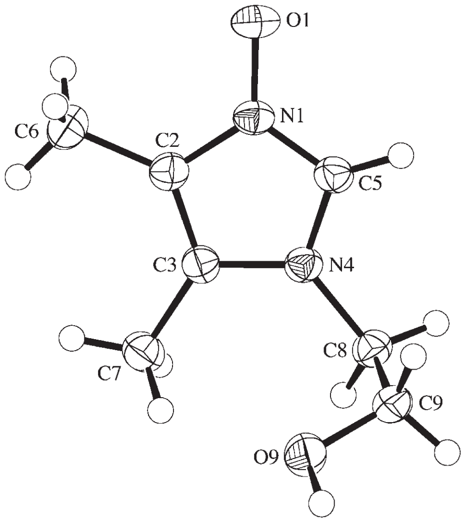
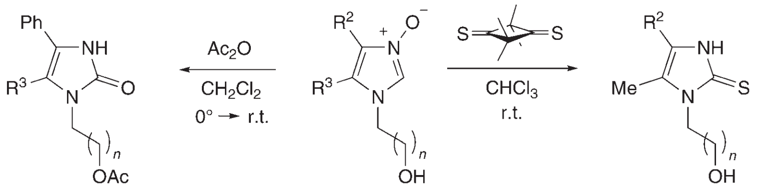


Fig. 1. *ORTEP Representation* [24] *of the molecular structure of* **11a** (arbitrary atom numbering, 50% probability ellipsoids; the H_2O molecule is not shown)

According to [14], treatment of 1*H*-imidazole 3-oxides of type **11** in CH_2Cl_2 with Ac_2O led to their isomerization to 2*H*-imidazol-2-ones, even at 0–5°. Heating of solutions of 2*H*-imidazol-2-ones in Ac_2O resulted in the acetylation of N(3) [14]. In the case of **11b**,**c**,**e**, the reaction with excess Ac_2O at 0° to room temperature resulted not only in the isomerization but also in acetylation of the OH group to yield the corresponding acetates **13a**–**c** (*Scheme 3*). In none of the cases was acetylation of N(3) observed. In the IR as well as in the ^{13}C-NMR spectra, the presence of an ester and a urea C=O group was evidenced by absorptions at *ca*. 1740 and 1670 cm^{-1} and δ 170 and 155, respectively.

Scheme 3



13a n = 1, R^3 = Me
13b n = 1, R^3 = Ph
13c n = 2, R^3 = Me

11

14a n = 1, R^2 = Me
14b n = 2, R^2 = Ph

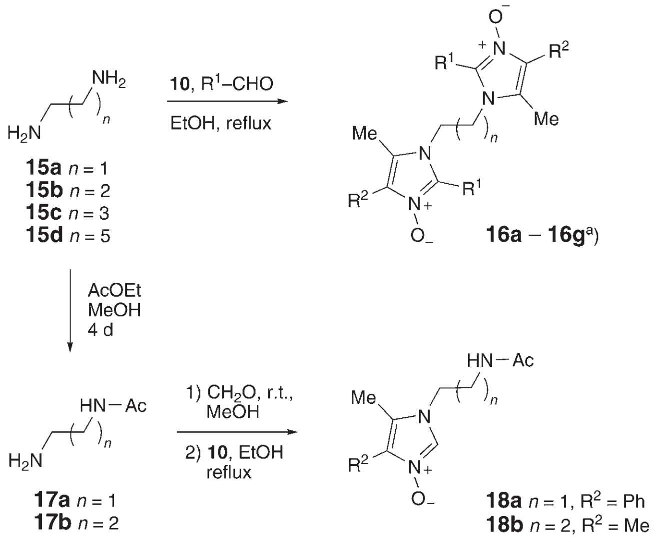
In analogy to previously reported transformations of 2-unsubstituted 1*H*-imidazole 3-oxides [12], compounds **11a** and **11e** reacted easily with 2,2,4,4-tetramethylcyclobutane-1,3-dithione to give the corresponding 2*H*-imidazole-2-thiones **14a** and **14b**, respectively, in high yield (*Scheme 3*).

Due to the fact that bis-imidazoles are of interest in the field of coordination chemistry [11], reactions of alkanediamines **15** with aldehydes and **10** were carried out in refluxing EtOH (*Scheme 4*). In the case of formaldehyde used in excess (2.5 equiv.), the three-component reaction yielded 2-unsubstituted products **16** with a variable length of the aliphatic chain which connects the two imidazole residues (*Table 2*). The reaction with ethane-1,2-diamine (**15a**), **10b**, and acetaldehyde gave the expected bis-[imidazole 3-oxide] **16c** with the Me group at C(2) of the imidazole.

The spectroscopic data confirm the structures of the bis[imidazole 3-oxides] **16**, and in the case of **16b**, the structure was established by X-ray crystallography (*Fig. 2*). The heterocyclic molecule has crystallographic C_2 symmetry. The asymmetric unit includes a H_2O molecule in a general position so that the ratio of heterocyclic molecules to H_2O is 1:2. The two oxide O-atoms in each bis-imidazole molecule are bridged by a pair of intermolecular H-bonds from each of two H_2O molecules. Thus, two H_2O molecules and the two oxide O-atoms from a single heterocyclic molecule combine to form a C_2-symmetric H-bonded loop with a graph-set motif of R_4^2 (8).

It is worth mentioning that the attempted synthesis of a 1*H*-imidazole-1-ethanamine 3-oxide from **15a**, formaldehyde, and **10a** in a ratio of 1:1:1 did not afford the expected product and, again, **16a** was obtained. As an alternative method, monoacetylated diamines **17a**,**b** were treated with formaldehyde, and the crude imines obtained thereby were heated together with **10** in EtOH. Under these conditions, 1*H*-

Scheme 4



a) For R[1] and R[2], see *Table 2.*

Table 2. *Prepared Bis[imidazole 3-oxides]* **16**

16	*n*	R1	R2	Yield [%]	M.p. [°]
a	1	H	Me	48	231–236
b	1	H	Ph	42	236–240
c	1	Me	Ph	35	234–237
d	2	H	Me	11	191–196
e	3	H	Me	47	151–155
f	5	H	Me	43	101–104
g	5	H	Ph	53	188–192

imidazole 3-oxides of type **18a**,**b** were formed and isolated as crystalline materials (*Scheme 4*).

The reactivity of bis[imidazole 3-oxides] of type **16** toward Ac_2O was tested with **16a**. The isomerization to give the bis[2*H*-imidazol-2-one] **19** was achieved by heating **16a** in $CHCl_3$/Ac_2O 1:1 under reflux for 3 h (*Scheme 5*). On the other hand, heating of **16a** in boiling Ac_2O resulted in complete acetylation of the rearranged product, and **20a** was obtained in fair yield (*Scheme 5*). The analogous reaction sequence was observed with **16e** and **16f** (→**20b** and **20c**, resp.).

The conversion of 2-unsubstituted 1*H*-imidazole 3-oxides to 2*H*-imidazole-2-thiones with 2,2,4,4-tetramethylcyclobutane-1,3-dithione (*cf.* *Scheme 3*) was applied efficiently in the case of **16e**. The reaction was carried out in $CHCl_3$ at room temperature, and the bis[2*H*-imidazole-2-thione] **21** precipitated from the solution (*Scheme 6*).

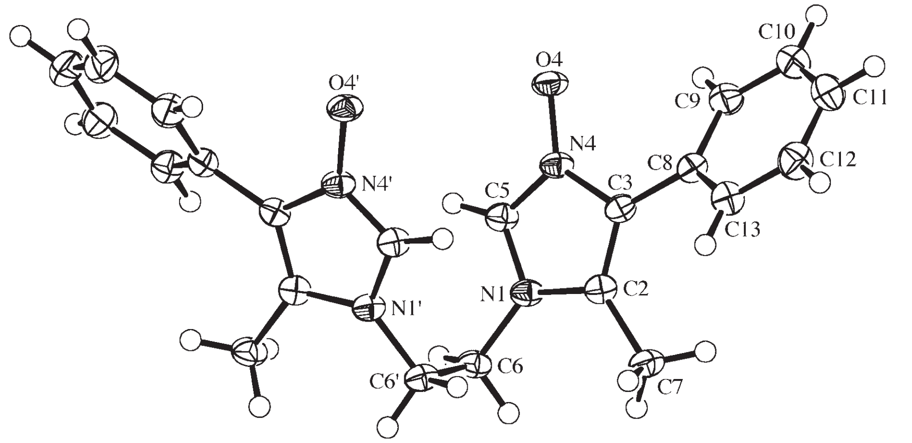
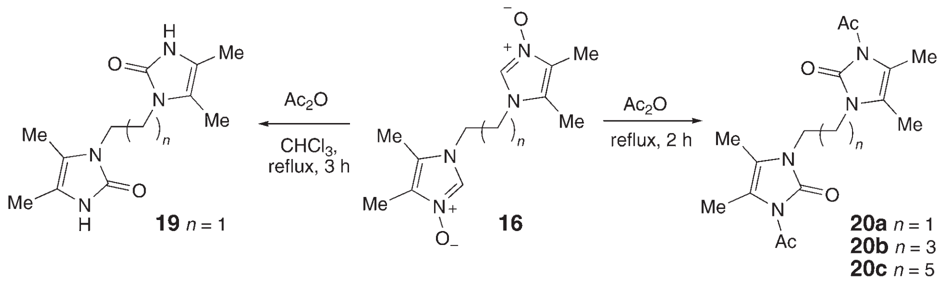
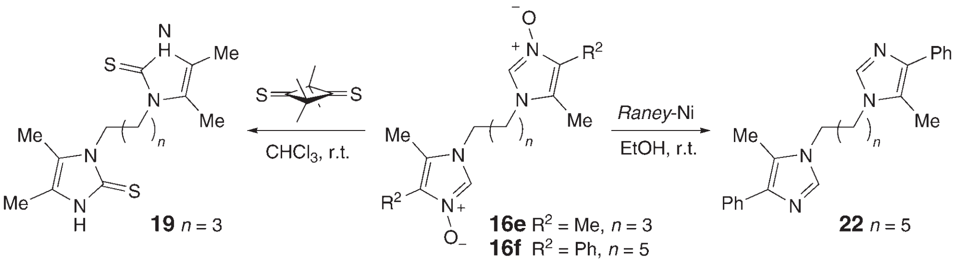


Fig. 2. *ORTEP Representation* [24] *of the molecular structure of* **16b** (arbitrary atom numbering; 50% probability ellipsoids; the H_2O molecule is not shown)

Scheme 5



Scheme 6



Finally, the deoxygenation of **16f** with *Raney*-Ni in EtOH led to the bis-imidazole derivative **22** (*Scheme 6*).

3. Conclusions. – The present study shows that the synthesis of 2-unsubstituted 1*H*-imidazole 3-oxides based on the three-component reaction of an α-(hydroxyimino) ketone, formaldehyde, and an amino component is a convenient and efficient access to new derivatives derived from amino alcohols and diamines. In the case of enantiomerically pure amino alcohols, optically active products are formed without any racemization. The readily available bis-imidazole derivatives obtained from aliphatic α,ω-diamines are attractive ligands for the preparation of new metal complexes.

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Experimental Part

1. *General.* Column chromatography = CC. M.p.: *Melt-Temp.-II* apparatus (*Aldrich*), in capillary; uncorrected. IR: *Nexus FT-IR* spectrophotometer, in KBr; in cm^{-1}. ^1H- and ^{13}C-NMR: *Tesla BS567A* (80 and 20 MHz, resp.) or *Bruker AC-300* instrument (300 and 75.5 MHz, resp.), in $CDCl_3$, CD_3OD, or $(D_6)DMSO$; $SiMe_4$ as an internal standard; δ in ppm, J in Hz; multiplicity of the ^{13}C-NMR signals from DEPT spectra. MS (EI, ESI or CI): *Finnigan MAT-90* or *Finnigan SSQ-700* instruments; in *m/z* (rel. %). Elemental analyses were performed in the Analytical Laboratory of the University of Zürich.

2. *Starting Materials.* α-(Hydroxyimino) ketones **10** were obtained according to known protocols: butane-2,3-dione monooxime (**10a**) [26a], 1-phenylpropane-1,2-dione 1-oxime (**10b**) [26b], and 1-phenylpropane-1,2-dione 2-oxime (**10c**) [26c] by nitrosation of the corresponding ketones with isoamyl nitrate (= 3-methylbutyl nitrate), 1,2-diphenylethane-1,2-dione monooxime (= benzil monooxime; **10d**) [26d] from dibenzoyl (= benzil = 1,2-diphenylethane-1,2-dione) and hydroxylamine hydrochloride.

3. *1,3,5-Triazine-1,3,5(2*H*,4*H*,6*H*)-trialkanols* **12**. *General Procedure 1.* Analogously to a known protocol [22], from the following amines: 2-aminoethan-1-ol (**9a**), 3-aminopropan-1-ol (**9b**), 1-aminopropan-2-ol (**9c**), 2-aminobutan-1-ol ((*RS*)-**9d**), (+)-(*S*)-1-aminopropan-2-ol ((*S*)-**9c**), and (+)-(1*S*,2*S*)-2-amino-1-phenylpropane-1,3-diol ((*S,S*)-**9e**), respectively. According to the *General Procedure 1*, paraformaldehyde (0.11 mol) was added to the soln. of the corresponding amino alcohol (0.10 mol) in MeOH (100 ml), and the resulting suspension was stirred overnight. Then, the excess of paraformaldehyde was filtered, and the filtrate was concentrated: **12** (quant.) as a colorless or pale yellow oil. The crude products **12** were used in the next step without purification.

4. *1*H*-Imidazole-1-alkanol 3-Oxides* **11**. *General Procedure 2.* A soln. of a dione monooxime **10a**–**d** (10 mmol) and the corresponding **12** (12 mmol) in abs. EtOH was heated for 3 h. After evaporation, the resulting oil was washed twice with Et_2O, treated with acetone, and cooled. The product was obtained as a white solid, usually as a hydrate with a variable amount of H_2O. Samples for analysis were recrystallized from appropriate solvents. In the case of **11e**,**g**,**l**, the resulting mixtures were purified by CC.

*4,5-Dimethyl-1*H*-imidazole-1-ethanol 3-Oxide* (**11a**). Yield[3]) 145 mg (88%). Colorless solid. M.p. 106–107° ($CHCl_3$/hexane). IR: 3470–2700*vs* (br.), 1626*m*, 1447*m*, 1404*s*, 1386*m*, 1346*s*, 1324*s*, 1194*m*, 1149*m*, 1092*s*, 1075*s*, 830*m*, 755*m*, 630*s*, 607*s*. ^1H-NMR ($CDCl_3$): 7.95 (*s*, H–C(2)); 3.88, 3.85 (2*t*, 2 CH_2); 2.14, 2.11 (2*s*, 2 Me). ^{13}C-NMR ($CDCl_3$): 125.9, 121.6 (2*s*, C(4), C(5)); 125.8 (*d*, C(2)); 60.3, 48.5 (2*t*, 2 CH_2); 8.7, 7.1 (2*q*, 2 Me). CI-MS: 157 (17, $[M+1]^+$), 141 (100). Anal. calc. for $C_7H_{12}N_2O_2 \cdot 0.5\ H_2O$ (165.20): C 50.90, H 7.93, N 16.96; found: C 50.88, H 7.50, N 17.08.

Suitable crystals for an X-ray crystal structure determination were grown from $CHCl_3$/hexane by slow evaporation of the solvent at r.t.

*5-Methyl-4-phenyl-1*H*-imidazole-1-ethanol 3-Oxide* (**11b**). Yield[3]) 177 mg (81%). Colorless crystals. M.p. 186–188° ($CHCl_3$/hexane). IR: 3350–2800*vs* (br.), 1614*m*, 1442*m*, 1389*m*, 1382*m*, 1353*s*, 1249*m*, 1213*m*, 1055*vs*, 770*s*, 716*s*, 699*s*, 608*s*. ^1H-NMR ($CDCl_3$): 8.27 (*s*, H–C(2)); 7.55–7.34 (*m*, 5 arom. H); 4.05, 3.84 (2*t*, 2 CH_2); 2.27 (*s*, Me). ^{13}C-NMR ($CDCl_3$): 129.7, 128.7, 128.3 (3*d*, 5 arom. CH); 129.4 (*s*, arom. C); 127.0, 126.2 (2*s*, C(4), C(5)); 123.4 (*d*, C(2)); 59.8, 48.5 (2*t*, 2 CH_2); 9.2 (*q*, Me). EI-MS: 218 (12,

[3]) Yield before crystallization.

$M^{+\bullet}$), 202 (100), 158 (46), 103 (56), 77 (27). Anal. calc. for $C_{12}H_{14}N_2O_2$ (218.26): C 66.04, H 6.47, N 12.84; found: C 66.15, H 6.35, N 12.42.

*4,5-Diphenyl-1*H*-imidazole-1-ethanol 3-Oxide* (**11c**). Yield[3]) 251 mg (89%). Colorless solid. M.p. 197 – 198° ($CHCl_3$/petroleum ether). IR: 3350 – 2600vs (br.), 1443*m*, 1393*m*, 1350*s*, 1200*m*, 1076*m*, 844*m*, 772*s*, 753v*s*, 694*s*, 658*m*. ^1H-NMR ($CDCl_3$): 8.46 (*s*, H – C(2)); 7.49 – 7.23 (*m*, 10 arom. H); 4.01, 3.71 (2*t*, 2 CH_2). ^{13}C-NMR ($CDCl_3$): 130.7, 129.7, 129.5, 129.0, 128.5, 128.0 (6*d*, 10 arom. CH); 129.8, 127.7, 126.4, 125.7 (4*s*, 2 arom. C, C(4), C(5)); 127.6 (*d*, C(2)); 59.9, 48.6 (2*t*, 2 CH_2). EI-MS: 280 (31, $M^{+\bullet}$), 264 (100), 219 (48), 165 (68), 103 (71), 77 (57). Anal. calc. for $C_{17}H_{16}N_2O_2 \cdot 0.1\ H_2O$ (282.13): C 72.37, H 5.79, N 9.93; found: C 72.34, H 5.71, N 9.64.

*4-Methyl-5-phenyl-1*H*-imidazole-1-ethanol 3-Oxide* (**11d**). Yield[3]) 120 mg (55%). Colorless solid. M.p. 165 – 167° (acetone). IR: 3250 – 2550vs (br.), 1501*m*, 1444*m*, 1395*s*, 1380*m*, 1337v*s*, 1165*s*, 1080*s*, 871*m*, 757*s*, 703*s*, 646*m*. ^1H-NMR ($CDCl_3$): 8.36 (*s*, H – C(2)); 7.56 – 7.42 (*m*, 5 arom. H); 4.02, 3.62 (2*t*, 2 CH_2); 2.15 (*s*, Me). ^{13}C-NMR ($CDCl_3$): 130.8, 129.6, 129.3 (3*d*, 5 arom. CH); 127.8, 127.4, 126.8 (3*s*, arom. C, C(4), C(5)); 60.5, 49.1 (2*t*, 2 CH_2); 7.6 (*q*, Me). EI-MS: 218 (76, $M^{+\bullet}$), 202 (100), 130 (63), 104 (72). Anal. calc. for $C_{12}H_{14}N_2O_2$ (218.26): C 66.04, H 6.47, N 12.84; found: C 66.38, H 6.43, N 12.46.

*5-Methyl-4-phenyl-1*H*-imidazole-1-propanol 3-Oxide* (**11e**). Yield after CC (R_f 0.59; SiO_2, AcOEt/MeOH 6 : 4): 218 mg (94%). Colorless solid. M.p. 140 – 142° (acetone). IR: 3350 – 2550vs (br.), 1497*m*, 1467*m*, 1400*m*, 1363*s*, 1344*s*, 1315*m*, 1253*s*, 1231*m*, 1064*s*, 930*m*, 766*s*, 712*s*, 702*s*, 695*s*, 608*s*. ^1H-NMR (CD_3OD): 8.31 (*s*, H – C(2)); 7.59 – 7.40 (*m*, 5 arom. H); 4.14, 3.59 (2*t*, 2 CH_2); 2.29 (*s*, Me); 1.99 (*m*, CH_2). ^{13}C-NMR (CD_3OD): 131.1, 129.8, 129.5 (3*d*, 5 arom. CH); 130.6, 128.2, 125.2 (3*s*, arom. C, C(4), C(5)); 127.8 (*d*, C(2)); 58.9, 44.0, 33.7 (3*t*, 3 CH_2); 9.2 (*q*, Me). EI-MS: 232 (5, $M^{+\bullet}$), 214 (100), 117 (47), 55 (49). Anal. calc. for $C_{13}H_{16}N_2O_2$ (232.28): C 67.22, H 6.94, N 12.06; found: C 67.46, H 7.06, N 11.70.

*4,5-Diphenyl-1*H*-imidazole-1-propanol 3-Oxide* (**11f**). Yield[3]) 140 mg (47%). Colorless solid. M.p. 191 – 193° (acetone). IR: 3350 – 2650vs (br.), 1445*m*, 1392*s*, 1345*s*, 1198*m*, 1078*s*, 769*s*, 756*s*, 698*s*, 657*m*. ^1H-NMR (CD_3OD): 8.51 (*s*, H – C(2)); 7.48 – 7.26 (*m*, 10 arom. H); 4.09, 3.48 (2*t*, 2 CH_2); 1.81 (*m*, CH_2). ^{13}C-NMR (CD_3OD): 132.1, 131.2, 130.9, 130.3, 129.7, 129.2, 128.9 (7*d*, 10 arom. CH, C(2)); 131.4, 129.3, 128.5, 127.8 (4*s*, 2 arom. C, C(4), C(5')); 59.0, 44.8, 33.8 (3*t*, 3 CH_2). EI-MS: 294 (7, $M^{+\bullet}$), 276 (75), 165 (19), 117 (100), 104 (19), 77 (22). Anal. calc. for $C_{18}H_{18}N_2O_2 \cdot 0.25\ H_2O$ (298.86): C 72.34, H 6.24, N 9.37; found: C 72.26, H 6.08, N 9.30.

*4-Methyl-5-phenyl-1*H*-imidazole-1-propanol 3-Oxide* (**11g**). Yield after CC (R_f 0.65, SiO_2, AcOEt/MeOH 1 : 1): 153 mg (66%). Colorless solid. M.p. 139 – 140° (CH_2Cl_2/petroleum ether). IR: 3250 – 2650vs (br.), 1463*m*, 1389*m*, 1379*m*, 1325*s*, 1165*s*, 1091*m*, 1076*m*, 942*w*, 773*s*, 705*m*, 643*m*. ^1H-NMR (CD_3OD): 8.37 (*s*, H – C(2)); 7.56 – 7.40 (*m*, 5 arom. H); 4.07, 3.43 (2*t*, 2 CH_2); 1.76 (*m*, CH_2). ^{13}C-NMR (CD_3OD): 131.5, 130.8, 130.3 (3*d*, 5 arom. CH); 128.5, 128.4, 127.4 (3*s*, arom. C, C(4), C(5)); 128.0 (*d*, C(2)); 58.9, 44.6, 33.8 (3*t*, 3 CH_2); 7.6 (*q*, Me). EI-MS: 232 (22, $M^{+\bullet}$), 214 (100), 171 (52), 117 (76), 104 (29), 55 (29). Anal. calc. for $C_{13}H_{16}N_2O_2$ (232.28): C 67.22, H 6.94, N 12.06; found: C 67.37, H 7.05, N 12.01.

*α,5-Dimethyl-4-phenyl-1*H*-imidazole-1-ethanol 3-Oxide* (**11h**). Yield[3]) 211 mg (90%). Colorless solid. M.p. 143 – 145° (acetone). IR: 3400 – 2600vs (br.), 1610*m*, 1497*m*, 1444*m*, 1377*s*, 1349*s*, 1260*m*, 1218*m*, 1136*m*, 1079*m*, 1029*m*, 767*s*, 720*m*, 700*s*, 678*m*, 608*m*. ^1H-NMR (CD_3OD): 8.25 (*s*, H – C(2)); 7.58 – 7.37 (*m*, 5 arom. H); 4.07 – 4.01 (*m*, CH_2); 3.87 – 3.82 (*m*, C*H*(OH)); 2.28 (*s*, Me); 1.22 (*d*, $J = 4.6$, Me). ^{13}C-NMR (CD_3OD): 131.2, 129.7, 129.5 (3*d*, 5 arom. CH); 130.4, 128.3, 125.7 (3*s*, arom. C, C(4), C(5)); 128.4 (*d*, C(2)); 67.3 (*d*, CH); 53.8 (*t*, CH_2); 20.7, 9.5 (2*q*, 2 Me). EI-MS: 232 (62, $M^{+\bullet}$), 216 (100), 174 (64), 159 (72), 130 (40), 103 (58). Anal. calc. for $C_{13}H_{16}N_2O_2 \cdot 0.125\ H_2O$ (234.53): C 66.58, H 6.98, N 11.94; found: C 66.89, H 6.98, N 11.82.

*α-Methyl-4,5-diphenyl-1*H*-imidazole-1-ethanol 3-Oxide* (**11i**). Yield[3]) 274 mg (92%). Colorless solid. M.p. 182 – 184° (CH_2Cl_2/petroleum ether). IR: 3350 – 2550vs (br.), 1486*m*, 1445*m*, 1398*m*, 1353*s*, 1265*m*, 1187*m*, 1138*m*, 763*s*, 701*s*, 656*m*. ^1H-NMR (CD_3OD): 8.48 (*s*, H – C(2)); 7.45 – 7.28 (*m*, 10 arom. H); 3.99 – 3.77 (*m*, CH_2, CH); 1.04 (*d*, $J = 4.2$, Me). ^{13}C-NMR (CD_3OD): 132.3, 131.2, 130.9, 130.2, 129.7, 129.1 (6*d*, 10 arom. CH); 131.0, 129.2, 128.4, 127.8 (4*s*, 2 arom. C, C(4), C(5)); 129.3 (*d*, C(2)); 66.8 (*d*, CH); 54.2 (*t*, CH_2); 20.7 (*q*, Me). EI-MS: 294 (2, $M^{+\bullet}$), 278 (11), 105 (100), 77 (35), 43 (46). Anal. calc. for $C_{18}H_{18}N_2O_2 \cdot 0.25\ H_2O$ (298.86): C 72.34, H 6.24, N 9.37; found: C 72.29, H 6.24, N 8.98.

*(αS)-α,4,5-Trimethyl-1*H*-imidazole-1-ethanol 3-Oxide* (**11j**). Yield after CC (R_f 0.59; SiO_2, AcOEt/MeOH 6 : 4): 141 mg (82%). Colorless solid. M.p. 119 – 120° (acetone). $[\alpha]_D^{17} + 42$ (c = 1, MeOH). IR:

3350–2600v*s* (br.), 1629*m*, 1446*m*, 1430*m*, 1398*s*, 1380*m*, 1340*s*, 1331*s*, 1303*m*, 1190*m*, 1139*s*, 1116*m*, 1081*m*, 864*m*, 839*m*, 684*m*. ^{1}H-NMR ($CDCl_3$): 7.84 (*s*, H–C(2)); 4.20–3.68 (*m*, CH); 3.75 (*d*, J = 2.9, CH_2); 2.13, 2.09 (2*s*, 2 Me); 1.21 (*d*, J = 6.1, Me). ^{13}C-NMR (CD_3OD): 127.4 (*d*, C(2)); 126.4, 124.1 (2*s*, C(4), C(5)); 67.2 (*d*, CH); 53.5 (*t*, CH_2); 20.7, 8.7, 7.1 (3*q*, 3 Me). CI-MS: 171 (14, $[M+1]^+$), 155 (100), 153 (13). Anal. calc. for $C_8H_{14}N_2O_2 \cdot 0.125\,H_2O$ (172.46): C 55.72, H 8.33, N 16.24; found: C 55.60, H 8.33, N 16.44.

*β-Ethyl-5-methyl-4-phenyl-1*H*-imidazole-1-ethanol 3-Oxide* (**11k**). Yield[3]) 212 mg (86%). Colorless solid. M.p. 171–174° (CH_2Cl_2/petroleum ether). IR: 3250–2550v*s* (br.), 1496*m*, 1443*m*, 1419*m*, 1351*s*, 1327*m*, 1227*s*, 1082*m*, 765*s*, 700*s*. ^{1}H-NMR ($CDCl_3$): 8.38 (*s*, H–C(2)); 7.59–7.42 (*m*, 5 arom. H); 4.28–4.16 (*m*, CH); 3.80 (*d*, J = 4.0, C*H*$_2$OH); 2.30 (*s*, Me); 1.94–1.85 (*m*, CH_2); 0.94 (*t*, J = 5.5, Me). ^{13}C-NMR (CD_3OD): 131.3, 129.7, 129.5 (3*d*, 5 arom. CH); 130.1, 128.2, 126.0 (3*s*, arom. C, C(4), C(5)); 126.1 (*d*, C(2)); 64.8, 25.4 (2*t*, 2 CH_2); 62.0 (*d*, CH); 10.7, 9.7 (2*q*, 2 Me). EI-MS: 246 (22, $M^{+\bullet}$), 215 (15), 174 (100), 130 (16), 104 (19), 77(16). Anal. calc. for $C_{14}H_{18}N_2O_2$ (246.31): C 68.27, H 7.37, N 11.37; found: C 68.00, 7.38, 11.50.

*β-Ethyl-4,5-diphenyl-1*H*-imidazole-1-ethanol 3-Oxide* (**11l**). Yield[3]) 219 mg (71%). Colorless solid. M.p. 199–200° (acetone). IR: 3300–2600v*s* (br.), 1604*m*, 1506*m*, 1486*m*, 1445*m*, 1410*m*, 1350*s*, 1239*m*, 1079*m*, 1064*m*, 759*s*, 696*s*, 655*m*, 645*m*. ^{1}H-NMR ($CDCl_3$): 8.34 (*s*, H–C(2)); 7.58–7.05 (*m*, 10 arom. H); 4.08–3.61 (*m*, CH); 3.67 (*d*, J = 4.8, C*H*$_2$OH); 1.91–1.47 (*m*, CH_2); 0.68 (*t*, J = 7.2, Me). ^{13}C-NMR (CD_3OD): 132.7, 131.1, 130.9, 130.1, 129.6, 129.1 (6*d*, 10 arom. CH); 130.7, 130.4, 128.5, 127.8 (4*s*, 2 arom. C, C(4), C(5)); 126.8 (*d*, C(2)); 64.7, 25.8 (2*t*, 2 CH_2); 62.2 (*d*, CH); 10.7 (*q*, Me). EI-MS: 308 (29, $M^{+\bullet}$), 292 (25), 236 (100), 165 (22), 104 (37).

*(1*S*,2*S*)-2-(5-Methyl-3-oxido-4-phenyl-1*H*-imidazol-1-yl)-1-phenylpropane-1,3-diol* (**11m**). Yield after CC (R_f 0.7, SiO_2, MeOH): 168 mg (52%). Colorless solid. M.p. 177–178° (CH_2Cl_2/petroleum ether). $[\alpha]_D^{17}$ +137 (c=0.38, MeOH). IR: 3450–2450v*s* (br.), 1625*m*, 1497*m*, 1452*m*, 1412*m*, 1356*s*, 1232*m*, 1093*m*, 1066*m*, 1047*m*, 1029*m*, 764*m*, 739*m*, 699*s*. ^{1}H-NMR (CD_3OD): 8.48 (*s*, H–C(2)); 7.46–7.25 (*m*, 10 arom. H); 5.16, 5.15 (*d*, C*H*OH); 4.39–4.36 (*m*, CH); 4.02, 4.01 (*d*, CH_2); 1.69 (*s*, Me). ^{13}C-NMR (CD_3OD): 131.2, 129.7, 129.6, 129.4, 129.1, 127.1 (6*d*, 10 arom. CH); 142.8, 128.1, 127.2, 126.7 (4*s*, 2 arom. C, C(4), C(5)); 127.3 (*d*, C(2)); 72.9, 65.9 (2*d*, 2 CH); 63.2 (*t*, CH_2); 9.1 (*q*, Me). EI-MS: 324 (2, $M^{+\bullet}$), 200 (100), 104 (21), 77 (22). Anal. calc. for $C_{19}H_{20}N_2O_3$ (324.38): C 70.35, H 6.21, N 8.64; found: C 70.51, H 6.25, N 8.74.

5. *1-[ω-(Acetyloxy)alkyl]-1,3-dihydro-2*H*-imidazol-2-ones* **13**. *General Procedure 3*. To a soln. of 1*H*-imidazole-1-alkanol 3-oxide **11** (1 mmol) in abs. CH_2Cl_2 (2 ml) in an H_2O/ice cooling bath, a soln. of freshly distilled Ac_2O (0.61 g, 6 mmol) in abs. CH_2Cl_2 (2 ml) was added portionwise. The mixture was allowed to warm up to r.t., and stirring was continued until **11** was consumed (TLC monitoring). Then, the mixture was diluted with MeOH (5 ml). After stirring for another 30 min, the solvents were evaporated, H_2O (5 ml) was added, and the white precipitate of the corresponding acetate **13** was filtered. Anal. pure products were obtained by recrystallization.

*1-[2-(Acetyloxy)ethyl]-1,3-dihydro-5-methyl-4-phenyl-2*H*-imidazol-2-one* (**13a**). Reaction time 2 h. Yield 185 mg (71%). Colorless solid. M.p. 135–137° (EtOH/H_2O). IR: 3150–2750*s* (br., NH), 1745v*s* (C=O(Ac)), 1672v*s* (br., C=O), 1456*m*, 1429*m*, 1403*m*, 1388*m*, 1367*m*, 1255*s*, 1240*s*, 1070*m*, 769*m*, 750*m*, 702*m*. ^{1}H-NMR ($CDCl_3$): 10.89 (br. *s*, NH); 7.44–7.21 (*m*, 5 arom. H); 4.30, 3.93 (2*t*, 2 CH_2); 2.25, 2.01 (2*s*, 2 Me). ^{13}C-NMR ($CDCl_3$): 170.7 (*s*, Me*C*=O); 154.6 (*s*, C(2)=O); 130.5, 118.2, 115.6 (3*s*, arom. C, C(4), C(5)); 128.8, 126.7, 126.3 (3*d*, 5 arom. CH); 62.5, 39.7 (2*t*, 2 CH_2); 20.8, 9.8 (2*q*, 2 Me). CI-MS: 261 (100, $[M+1]^+$). Anal. calc. for $C_{14}H_{16}N_2O_3$ (260.30): C 64.60, H 6.20, N 10.76; found: C 64.27, H 5.98, N 10.51.

*1-[2-(Acetyloxy)ethyl]-1,3-dihydro-4,5-diphenyl-2*H*-imidazol-2-one* (**13b**). Reaction time 2 h. Yield 303 mg (94%). Colorless solid. M.p. 187–190° (EtOH). IR: 3200–2750*s* (br., NH), 1739*s* (C=O(Ac)), 1686v*s* (br., C=O), 1602*m*, 1506*m*, 1454*m*, 1444*m*, 1432*m*, 1395*m*, 1370*m*, 1234*s*, 1045*m*, 768*m*, 753*m*, 701*m*, 667*m*. ^{1}H-NMR ($CDCl_3$): 11.69 (br. *s*, NH); 7.47–7.11 (*m*, 10 arom. H); 4.18, 3.88 (2*t*, 2 CH_2); 1.89 (*s*, Me). ^{13}C-NMR ($CDCl_3$): 170.6 (*s*, Me*C*=O); 154.7 (*s*, C(2)=O); 131.2, 129.2, 129.0, 128.5, 126.8, 125.7 (6*d*, 10 arom. CH); 129.7, 129.6, 120.7, 119.2 (4*s*, 2 arom. C, C(4), C(5)); 62.1, 40.1 (2*t*, 2 CH_2); 20.8 (*q*, Me). CI-MS: 323 (100, $[M+1]^+$), 263 (5). Anal. calc. for $C_{19}H_{18}N_2O_3$ (322.37): C 70.79, H 5.63, N 8.69; found: C 70.80, H 5.76, N 8.72.

*1-[3-(Acetyloxy)propyl]-1,3-dihydro-5-methyl-4-phenyl-2*H*-imidazol-2-one* (**13c**). Reaction time 3 h. Yield 200 mg (73%). Colorless solid. M.p. 153–154° (EtOH). IR: 3200–2850*s* (br., NH), 1734v*s* (C=O(Ac)), 1675v*s* (br., C=O), 1603*m*, 1503*w*, 1465*m*, 1404*m*, 1388*m*, 1364*m*, 1254*s*, 1042*m*, 767*m*, 747*m*, 699*m*. ^{1}H-NMR ($CDCl_3$): 10.64 (br. *s*, NH); 7.29–7.10 (*m*, 5 arom. H); 3.99, 3.64 (2*t*, 2 CH_2); 2.10, 1.90 (2*s*, 2 Me); 1.88 (*m*, CH_2). ^{13}C-NMR ($CDCl_3$): 170.9 (*s*, MeC=O); 154.0 (*s*, C(2)=O); 130.2, 118.3, 115.5 (3*s*, arom. C, C(4), C(5)); 128.7, 126.8, 126.3 (3*d*, 5 arom. CH); 61.8, 38.0, 28.5 (3*t*, 3 CH_2); 20.8, 9.6 (2*q*, 2 Me). EI-MS: 275 (16, $[M+1]^+$), 274 (100, $M^{+\bullet}$), 215 (66), 174 (36), 101 (63), 77 (18). Anal. calc. for $C_{15}H_{18}N_2O_3$ (274.32): C 65.68, H 6.61, N 10.21; found: C 66.08, H 6.63, N 10.01.

6. *1,3-Dihydro-2*H*-imidazole-2-thiones* **14**: *General Procedure 4.* To a soln. of a 1*H*-imidazole-1-alkanol 3-oxide **11** (1 mmol) in MeOH (2 ml), a soln. of 2,2,4,4-tetramethylcyclobutane-1,3-dithione (95 mg, 0.55 mmol) in $CHCl_3$ (2 ml) was added dropwise at 0°, and magnetic stirring was continued for 30 min. Then, the solvents were evaporated, the resulting solid was washed with Et_2O, and the colorless product was filtered and dried *i.v.* Anal. pure samples were obtained by recrystallization from an appropriate solvent.

*1,3-Dihydro-1-(2-hydroxyethyl)-4,5-dimethyl-2*H*-imidazole-2-thione* (**14a**). Yield 148 mg (86%). Colorless crystals. M.p. 179–180° (MeOH). IR: 3350–2750v*s* (br., NH), 1659*m*, 1506*m*, 1444*m*, 1402*s*, 1363*m*, 1224*w*, 1186*w*, 1058*s*, 870*w*. ^{1}H-NMR ((D_6)DMSO): 3.92, 3.61 (2*t*, 2 CH_2); 2.06, 1.96 (2*s*, 2 Me). ^{13}C-NMR ((D_6)DMSO): 168.3 (*s*, C=S); 131.3, 127.8 (2*s*, C(4), C(5)); 68.1, 55.6 (2*t*, 2 CH_2); 18.1, 18.0 (2*q*, 2 Me). EI-MS: 172 (92, $M^{+\bullet}$), 128 (100), 95 (39). Anal. calc. for $C_7H_{12}N_2OS$ (127.25): C 48.81, H 7.02, N 16.26; found: C 49.11, H 7.06, N 15.70.

*1,3-Dihydro-1-(3-hydroxypropyl)-5-methyl-4-phenyl-2*H*-imidazole-2-thione* (**14b**). Yield: 231 mg (93%). Colorless crystals. M.p. 172–174° (CH_2Cl_2/petroleum ether). IR: 3350–2750v*s* (br., NH), 1497*s*, 1459*m*, 1407*s*, 1376*m*, 1282*m*, 1213*m*, 1196*m*, 1174*s*, 1087*m*, 1068*s*, 985*m*, 933*m*, 769*s*, 708*m*, 699*s*. ^{1}H-NMR ((D_6)DMSO): 12.42 (br. *s*, NH); 7.48–7.31 (*m*, 5 arom. H); 4.08, 3.46 (2*t*, 2 CH_2); 2.31 (*s*, Me); 1.83 (*m*, CH_2). ^{13}C-NMR ((D_6)DMSO): 169.9 (*s*, C=S); 138.4 (*s*, arom. C); 138.3, 136.9, 136.4 (3*d*, 5 arom. CH); 133.0, 132.1 (2*s*, C(4), C(5)); 67.4, 50.6, 40.9 (3*t*, 3 CH_2); 19.2 (*q*, Me). EI-MS: 248 (41, $M^{+\bullet}$), 230 (59), 215 (100), 204 (27). Anal. calc. for $C_{13}H_{16}N_2OS$ (248.35): C 62.87, H 6.49, N 11.28; found: C 62.90, H 6.48, N 11.10.

7. *1,1′-(Alkane-1,ω-diyl)bis[1*H*-imidazole] 3,3′-Dioxides* **16**: *General Procedure 5.* A soln. of a diamine **15** (1 mmol), paraformaldehyde (75 mg, 2.5 mmol) or acetaldehyde (110 mg, 2.5 mmol), and **10** (2 mmol) in EtOH was heated to reflux for 3 h. Then, the solvent was evaporated. To the resulting oil, acetone (10 ml) was added, the soln. was heated to reflux, and after cooling, the colorless precipitate was collected as highly pure product.

*1,1′-(Ethane-1,2-diyl)bis[4,5-dimethyl-1*H*-imidazole] 3,3′-Dioxide* (**16a**). Yield 137 mg (48%). Colorless solid. M.p. (dec.) 231–236° (EtOH/Et_2O). IR: 3650–2800v*s* (br.), 1629*m*, 1451*m*, 1400*s*, 1386*s*, 1358*m*, 1336*s*, 1154*m*, 834*m*, 790*m*, 620*m*, 603*m*. ^{1}H-NMR ($CDCl_3$): 8.15 (*s*, H−C(2), H−C(2′)); 4.33 (*s*, 2 CH_2); 2.13, 1.99 (2*s*, 4 Me). ^{13}C-NMR ($CDCl_3$): 127.5, 124.1 (2*s*, C(4), C(4′), C(5), C(5′)); 127.1 (*d*, C(2), C(2′)); 46.7 (*t*, 2 CH_2); 7.9, 7.1 (2*q*, 4 Me). ESI-MS: 273 (100, $[M+Na]^+$), 251 (2, $[M+1]^+$). Anal. calc. for $C_{12}H_{18}N_4O_2 \cdot 2\ H_2O$ (286.34): C 50.34, H 7.74, N 19.57; found: C 50.05, H 8.34, N 19.68.

*1,1′-(Ethane-1,2-diyl)bis[5-methyl-4-phenyl-1*H*-imidazole] 3,3′-Dioxide* (**16b**). Yield 172 mg (42%). Colorless crystals. M.p. (dec.) 236–240° (MeOH/EtOH). IR: 3550–2700v*s* (br.), 1679*m*, 1498*m*, 1399*s*, 1361*m*, 1344*m*, 1268*m*, 1228*m*, 764*s*, 707*m*, 697*m*, 628*m*, 601*m*. ^{1}H-NMR (CD_3OD): 8.68 (*s*, H−C(2), H−C(2′)); 7.85–7.67 (*m*, 10 arom. H); 4.73 (*s*, 2 CH_2); 2.37 (*s*, 2 Me). ^{13}C-NMR (CD_3OD): 131.3, 127.2, 125.4 (3*s*, 2 arom. C, C(4), C(4′), C(5), C(5′)); 131.1, 130.1, 129.6 (3*d*, 10 arom. CH); 127.9 (*d*, C(2), C(2′)); 46.9 (*t*, 2 CH_2); 8.9 (*q*, 2 Me). ESI-MS: 397 (100, $[M+Na]^+$), 375 (6, $[M+1]^+$). Anal. calc. for $C_{22}H_{22}N_4O_2 \cdot 2\ H_2O$ (410.49): C 64.38, H 6.38, N 13.65; found: C 64.32, H 6.33, N 13.60.

Suitable crystals for the X-ray crystal-structure determination were grown from EtOH by slow evaporation of the solvent at r.t.

*1,1′-(Ethane-1,2-diyl)bis[2,5-dimethyl-4-phenyl-1*H*-imidazole] 3,3′-Dioxide* (**16c**). Yield 153 mg (35%). Colorless solid. M.p. (dec.) 234–237° (acetone). IR: 3450–2850v*s* (br.), 1626*m*, 1516*m*, 1490*m*, 1462*m*, 1445*m*, 1414*m*, 1382*m*, 1348*s*, 1318*m*, 1274*s*, 1224*m*, 769*s*, 703*s*, 656*m*, 597*s*. ^{1}H-NMR (CD_3OD): 7.52–7.38 (*m*, 10 arom. H); 4.35 (*s*, 2 CH_2); 2.48, 2.05 (2*s*, 4 Me). ^{13}C-NMR (CD_3OD): 134.5, 130.0, 126.7, 121.9 (4*s*, 2 arom. C, C(2), C(2′), C(4), C(4′), C(5), C(5′)); 130.2, 129.4, 128.9 (3*d*, 6 arom.

CH); 44.2 (*t*, CH_2); 8.7, 7.9 (2*q*, 4 Me). EI-MS: 402 (22, $M^{+\bullet}$), 386 (36), 355 (100), 213 (33), 172 (56), 103 (52). Anal. calc. for $C_{24}H_{26}N_4O_2 \cdot 2\ H_2O$ (438.54): C 65.73, H 6.90, N 12.78; found: C 66.23, H 6.89, N 12.53.

*1,1′-(Propane-1,3-diyl)bis[4,5-dimethyl-1*H*-imidazole] 3,3′-Dioxide* (**16d**). Yield 33 mg (11%). Colorless solid. M.p. (dec.) 191 – 196°. IR: 3550 – 2800v*s* (br.), 1686*m*, 1626*m*, 1472*m*, 1403*m*, 1380*s*, 1345*s*, 1200*m*, 1149*m*, 1077*m*, 695*m*, 618*m*, 582*m*. ^{1}H-NMR (CD_3OD): 8.22 (*s*, H–C(2), H–C(2′)); 4.02 (*t*, 2 CH_2); 2.23 (*m*, CH_2); 2.20, 2.14 (2*s*, 4 Me). ^{13}C-NMR (CD_3OD): 127.2, 126.8 (2*s*, C(4), C(4′), C(5), C(5′)); 123.7 (*d*, C(2), C(2′)); 43.8, 31.7 (2*t*, 3 CH_2); 8.3, 7.0 (2*q*, 4 Me). EI-MS: 264 (3, $M^{+\bullet}$), 232 (26), 137 (51), 123 (100), 110 (93), 96 (57). Anal. calc. for $C_{13}H_{20}N_4O_2 \cdot 2\ H_2O$ (300.37): C 51.99, H 8.05, N 18.65; found: C 51.70, H 8.12, N 17.75.

*1,1′-(Butane-1,4-diyl)bis[4,5-dimethyl-1*H*-imidazole] 3,3′-Dioxide* (**16e**). Yield 156 mg (47%). Colorless solid. M.p. (dec.) 151 – 155° (EtOH). IR (KBr): 3550 – 2850v*s* (br.), 1625*m*, 1401*m*, 1377*m*, 1341*s*, 1228*m*, 1160*m*, 1142*m*, 682*m*, 625*m*. ^{1}H-NMR (CD_3OD): 8.19 (*s*, H–C(2), H–C(2′)); 4.00 (*t*, 2 CH_2); 2.20, 2.14 (2*s*, 4 Me); 1.81 – 1.75 (*m*, 2 CH_2). ^{13}C-NMR (CD_3OD): 127.0, 123.6 (2*s*, C(4), C(4′), C(5), C(5′)); 126.7 (*d*, C(2), C(2′)); 46.2, 28.1 (2*t*, 4 CH_2); 8.4, 7.1 (2*q*, 4 Me). ESI-MS: 279 (100, $[M+1]^+$). Anal. calc. for $C_{14}H_{22}N_4O_2 \cdot 3\ H_2O$ (332.42): C 50.59, H 8.49, N 16.86; found: C 50.40, H 8.18, N 16.50.

*1,1′-(Hexane-1,6-diyl)bis[4,5-dimethyl-1*H*-imidazole] 3,3′-Dioxide* (**16f**). Yield 162 mg (43%). Colorless solid. M.p. (dec.) 101 – 104° (EtOH/Et_2O). IR: 3500 – 2950v*s* (br.), 1627*m*, 1481*m*, 1413*m*, 1381*m*, 1336*m*, 1193*m*, 1144*m*, 1088*m*, 738*m*, 589*m*. ^{1}H-NMR ($CDCl_3$): 7.89 (*s*, H–C(2), H–C(2′)); 3.84 (*t*, 2 CH_2); 2.15 (br. *s*, 4 Me); 1.82 – 1.66, 1.40 – 1.29 (2*m*, 4 CH_2). ^{13}C-NMR ($CDCl_3$): 127.1 (*d*, C(2), C(2′)); 126.0, 121.2 (2*s*, C(4), C(4′), C(5), C(5′)); 45.4, 29.8, 25.6 (3*t*, 6 CH_2); 8.2, 6.3 (2*q*, 4 Me). EI-MS: 306 (21, $M^{+\bullet}$), 290 (47), 273 (51), 179 (59), 165 (100), 151 (66), 137 (56), 110 (70). Anal. calc. for $C_{16}H_{26}N_4O_2 \cdot 4\ H_2O$ (378.49): C 50.78, H 9.06, N 14.80; found: C 50.39, H 9.15, N 14.40.

*1,1′-(Hexane-1,6-diyl)bis[5-methyl-4-phenyl-1*H*-imidazole] 3,3′-Dioxide* (**16g**). Yield 247 mg (53%). Colorless solid. M.p. (dec.) 188 – 192° (EtOH/Et_2O). IR: 3600 – 2750v*s* (br.), 1646*m*, 1497*m*, 1470*m*, 1429*m*, 1390*s*, 1365*s*, 1347*s*, 1250*m*, 1216*m*, 835*m*, 762*s*, 699*s*, 598*s*. ^{1}H-NMR (CD_3OD): 8.34 (*s*, H–C(2), H–C(2′)); 7.60 – 7.37 (*m*, 10 arom. H); 4.04 (*t*, 2 CH_2); 2.28 (*s*, 2 Me); 1.84 (*t*, 2 CH_2); 1.49 – 1.44 (*m*, 2 CH_2). ^{13}C-NMR (CD_3OD): 131.1, 129.7, 129.4, 127.7 (4*d*, 10 arom. CH, C(2), C(2′)); 130.6, 128.1, 125.0 (3*s*, 2 arom. C, C(4), C(4′), C(5), C(5′)); 47.0, 31.0, 26.9 (3*t*, 6 CH_2); 9.3 (*q*, 2 Me). ESI-MS: 431 (17, $[M+1]^+$). Anal. calc. for $C_{26}H_{30}N_4O_2 \cdot 2\ H_2O$ (466.59): C 66.93, H 7.35, N 12.01; found: C 67.31, H 7.48, N 12.04.

8. N*-[(3-Oxido-1*H*-imidazol-1-yl)alkyl]acetamides* **18a**,**b**. AcOEt (0.88 g, 10 mmol) was added to a fourfold excess of a diamine **15a**,**b** in MeOH (25 ml), and the resulting soln. was allowed to stand at r.t. for 4 d. Then, solvent, by-product EtOH, excess AcOEt, and diamine were removed *i.v.* to give the corresponding *N*-acetyldiamine **17a**,**b** as a colorless oily product.

To a soln. of an *N*-acetyldiamine **17a**,**b** in MeOH (5 ml), paraformaldehyde (0.156 g, 5.2 mmol) was added at r.t., and the mixture was stirred for 24 h. Then, the soln. was filtered and the solvent removed *i.v.* to give the corresponding imine as a yellow oil in almost quant. yield. The crude product was used in the next step without purification.

A soln. of the corresponding dione monoxime **10** (1 mmol) and the imine (from **17a**,**b** + CH_2O; 1.2 mmol) in EtOH (10 ml) was refluxed for 3 h. After evaporation of the solvent, the resulting oil was treated with acetone, warmed, and cooled again. The white precipitate of **18a**,**b** was collected and recrystallized from an appropriate solvent.

N*-[2-(5-Methyl-3-oxido-4-phenyl-1*H*-imidazol-1-yl)ethyl]acetamide* (**18a**). Yield 161 mg (58%). Colorless solid. M.p. 174 – 175° (acetone). IR: 3500 – 2850v*s* (br.), 1647v*s* (C=O), 1560*m*, 1444*m*, 1397*m*, 1382*m*, 1348*m*, 1308*m*, 1284*m*, 1258*m*, 1213*m*, 769*m*, 700*m*, 601*m*. ^{1}H-NMR ($CDCl_3$): 8.66 (br. *t*, NH); 8.35 (*s*, H–C(2′)); 7.56 – 7.29 (*m*, 5 arom. H); 3.89 (*t*, CH_2); 3.31 – 3.24 (*m*, CH_2); 2.19, 1.75 (2*s*, 2 Me). ^{13}C-NMR ($CDCl_3$): 171.7 (*s*, C=O); 129.7, 128.6, 128.4, 125.9 (4*d*, 5 arom. CH, H–C(2′)); 129.3, 127.2, 123.2 (3*s*, arom. C, C(4′), C(5′)); 44.9, 39.0 (2*t*, 2 CH_2); 22.5, 9.3 (2*q*, 2 Me). CI-MS: 260 (56, $[M+1]^+$), 244 (100), 232 (9), 230 (10), 159 (6). Anal. calc. for $C_{14}H_{17}N_3O_2 \cdot H_2O$ (277.33): C 60.63, H 6.91, N 15.15, found: C 60.54, H 6.39, N 15.06.

N*-[3-(4,5-Dimethyl-3-oxido-1*H*-imidazol-1-yl)propyl]acetamide* (**18b**). Yield 165 mg (78%). Colorless needles. M.p. 170 – 171° (CH_2Cl_2/petroleum ether). IR: 3350 – 2850v*s* (br.), 1667v*s* (C=O), 1559*m*, 1446*m*, 1400*m*, 1383*m*, 1371*m*, 1338*m*, 1293*m*, 609*m*. ^{1}H-NMR ($CDCl_3$): 8.23 (*s*, H–C(2)); 3.98, 3.20 (2*t*, 2 CH_2); 2.20, 2.14, 1.94 (3*s*, 3 Me); 1.93 (*m*, CH_2). ^{13}C-NMR ($CDCl_3$): 173.4 (*s*, C=O); 127.0, 123.6 (2*s*, C(4'), C(5')); 126.9 (*d*, C(2')); 44.5, 37.3, 31.1 (3*t*, 3 CH_2); 22.6, 8.3, 7.1 (3*q*, 3 Me). EI-MS: 211 (38, $M^{+\bullet}$), 110 (80), 100 (100), 97 (28), 72 (27). Anal. calc. for $C_{10}H_{17}N_3O_2 \cdot 0.25\ H_2O$ (215.77): C 55.67, H 8.18, N 19.47, found: C 55.76, H 8.27, N 18.59.

9. *1,1'-(Ethane-1,2-diyl)bis[1,3-dihydro-4,5-dimethyl-2*H*-imidazol-2-one]* (**19**). To a soln. of **16a** (286 mg, 1 mmol) in $CHCl_3$ (10 ml), a soln. of Ac_2O (2 ml) in $CHCl_3$ (2 ml) was added, and the mixture was heated to reflux for 3 h. After cooling, MeOH (5 ml) was added carefully, and stirring was continued for 30 min. Then, the solvent was removed, H_2O (5 ml) was added, and the colorless **19**, containing small amounts of *N*-acetylated derivatives, was filtered and purified by crystallization from aq. MeOH: **19** (140 mg; 43%). Colorless solid. M.p. 218–223° (MeOH/H_2O). IR: 3450–2750v*s* (br.), 1671v*s* (C=O), 1460*m*, 1407*s*, 1373*m*, 1315*w*, 1114*w*, 747*m*, 627*m*, 558*m*. ^{1}H-NMR ($CDCl_3$): 3.78 (*s*, 2 CH_2); 1.92, 1.75 (2 br. *s*, 4 Me). ^{13}C-NMR ($CDCl_3$): 155.2 (*s*, 2 C=O); 115.9, 113.7 (2*s*, C(4), C(4'), C(5), C(5')); 41.1 (*t*, 2 CH_2); 9.0, 7.7 (2*q*, 4 Me). CI-MS: 251 (100, $[M+1]^+$), 138 (11). Anal. calc. for $C_{12}H_{18}N_4O_2 \cdot 4\ H_2O$ (322.38): C 44.71, H 8.13, N 17.38; found: C 44.69, H 7.94, N 17.04.

10. *1,1'-(Alkane-1,ω-diyl)bis[3-acetyl-1,3-dihydro-2*H*-imidazol-2-one]* **20**: *General Procedure 6*. A soln. of an 3,3'-dioxide **16** (1 mmol) in freshly distilled Ac_2O (2 ml) was heated to reflux for 2 h. The mixture was cooled, and excess MeOH (10 ml) was added. After evaporation of the solvents, H_2O (10 ml) was added, and the crude product was filtered and recrystallized.

*1,1'-(Ethane-1,2-diyl)bis[3-acetyl-1,3-dihydro-4,5-dimethyl-2*H*-imidazol-2-one]* (**20a**). Yield 140 mg (42%). Colorless solid. M.p. (dec.) 232–238° (MeCN). IR: 1717v*s* (C=O(Ac)), 1675*s* (C=O), 1449*m*, 1403*s*, 1386*s*, 1370*s*, 1316*s*, 1178*m*, 1106*m*, 750*m*, 579*m*, 560*m*. ^{1}H-NMR ($CDCl_3$): 3.78 (*s*, 2 CH_2); 2.63 (*s*, 2 MeCO); 2.34, 1.92 (2 br. *s*, 4 Me). ^{13}C-NMR ($CDCl_3$): 170.7 (*s*, 2 Me*C*=O)); 152.5 (*s*, 2 C=O); 117.4, 114.0 (2*s*, C(4), C(4'), C(5), C(5')); 39.4 (*t*, 2 CH_2); 26.0 (*q*, 2 *Me*C=O); 11.8, 7.8 (2*q*, 4 Me). CI-MS: 336 (26), 335 (100, $[M+1]^+$), 293 (7). Anal. calc. for $C_{16}H_{22}N_4O_4$ (334.38): C 57.47, H 6.63, N 16.76; found: C 57.21, H 6.86, N 16.36.

*1,1'-(Butane-1,4-diyl)bis[3-acetyl-1,3-dihydro-4,5-dimethyl-2*H*-imidazol-2-one]* (**20b**). Yield 76 mg (21%). Colorless solid. M.p. 188–189° (MeOH/H_2O). IR: 1709v*s* (C=O(Ac)), 1673*s* (C=O), 1457*m*, 1438*m*, 1386*s*, 1370*s*, 1317*s*, 1173*w*, 1106*w*, 967*w*, 749*w*, 678*m*, 599*m*. ^{1}H-NMR ($CDCl_3$): 3.60 (*t*, 2 CH_2); 2.63 (*s*, 2 MeCO); 2.24, 1.97 (2 br. *s*, 4 Me); 1.68–1.65 (*m*, 2 CH_2). ^{13}C-NMR ($CDCl_3$): 170.9 (*s*, 2 Me*C*=O)); 152.5 (*s*, 2 C=O); 117.4, 113.8 (2*s*, C(4), C(4'), C(5), C(5')); 40.5, 26.7 (2*t*, 4 CH_2); 26.1 (*q*, 2 *Me*C=O); 11.8, 8.2 (2*q*, 4 Me). CI-MS: 364 (23), 363 (100, $[M+1]^+$), 321 (10). Anal. calc. for $C_{18}H_{26}N_4O_4$ (362.43): C 59.65, H 7.23, N 15.46; found: C 59.29, H 7.17, N 15.28.

*1,1'-(Hexane-1,6-diyl)bis[3-acetyl-1,3-dihydro-4,5-dimethyl-2*H*-imidazol-2-one]* (**20c**). Yield 101 mg (25%). Colorless solid. M.p. (dec.) 167–170° (MeOH). IR: 1710v*s* (C=O(Ac)), 1674*m* (C=O), 1448*w*, 1407*m*, 1390*m*, 1368*s*, 1312*s*, 1166*w*, 1106*w*, 1051*w*, 969*w*, 908w, 751*m*, 676*w*, 607*w*, 590*m*. ^{1}H-NMR ($CDCl_3$): 3.54 (*t*, 2 CH_2); 2.63 (*s*, 2 MeCO); 2.24, 1.96 (2 br. *s*, 4 Me); 1.63–1.59, 1.40–1.35 (2*m*, 4 CH_2). ^{13}C-NMR ($CDCl_3$): 171.0 (*s*, 2 Me*C*=O); 152.4 (*s*, 2 C=O); 117.5, 113.6 (2*s*, C(4), C(4'), C(5), C(5')); 40.5, 26.7, 26.4 (3*t*, 6 CH_2); 26.1 (*q*, 2 *Me*C=O); 11.8, 8.2 (2*q*, 4 Me). CI-MS: 392 (25), 391 (100, $[M+1]^+$), 349 (6), 306 (4). Anal. calc. for $C_{20}H_{30}N_4O_4 \cdot 0.5\ H_2O$ (399.50): C 60.13, H 7.82, N 14.02; found: C 60.46, H 7.17, N 13.88.

11. *1,1'-(Butane-1,4-diyl)bis[1,3-dihydro-4,5-dimethyl-2*H*-imidazol-2-thione]* (**21**). To a soln. of **16e** (332 mg of trihydrate, 1 mmol), a soln. of 2,2,4,4-tetramethylcyclobutane-1,3-dithione (95 mg, 0.55 mmol) in $CHCl_3$ (2 ml) was added dropwise, and the mixture was stirred overnight at r.t. The precipitate was filtered, washed with cold EtOH and Et_2O, and the obtained solid was analyzed without further purification: **21** (196 mg, 63%). Colorless solid. M.p. (dec.) 271–277°. IR: 3450–2700v*s* (br.), 1659*m*, 1495*s*, 1441*m*, 1406*m*, 1369*m*, 1319*m*, 1250*m*, 1166*m*, 780*m*, 684*m*. ^{1}H-NMR ((D_6)DMSO): 11.81 (br. *s*, 2 NH); 3.90 (*t*, 2 CH_2); 2.04, 1.95 (2*s*, 4 Me); 1.68–1.51 (*m*, 2 CH_2). ^{13}C-NMR ((D_6)DMSO): 158.8 (*s*, C=S); 120.5, 118.7 (2*s*, C(4), C(4'), C(5), C(5')); 43.0, 25.5 (2*t*, 4 CH_2); 8.6, 8.4 (2*q*, 4 Me). EI-MS: 310 (100, $M^{+\bullet}$), 183 (84), 149 (54), 128 (32). Anal. calc. for $C_{14}H_{22}N_4S_2$ (310.49): C 54.16, H 7.14, N 18.04; found: C 53.92, H 6.91, N 17.82.

12. *1,1'-(Hexane-1,6-diyl)bis[5-dimethyl-4-phenyl-1*H*-imidazole]* (**22**) *by Deoxygenation of* **16g**. To a soln. of **16g** (467 mg dihydrate, 1 mmol) in EtOH (2 ml), a suspension of freshly prepared *Raney*-Ni in

EtOH was added in small portions. When **16g** was completely reduced (TLC (MeOH/AcOEt 1:3) monitoring), the mixture was filtered, and the filtrate was concentrated. The crude product was purified by crystallization from EtOH: **22** (302 mg, 76%). Colorless crystals. M.p. 163–164°. IR: 3120–2850v*s* (br.), 1602*s*, 1510*s*, 1495*m*, 1445*m*, 1371*m*, 1277*m*, 1261*s*, 944*m*, 850*m*, 769*s*, 696v*s*, 636*m*. ^{1}H-NMR ($CDCl_3$): 7.67–7.21 (*m*, 10 arom. H); 7.48 (*s*, H–C(2), H–C(2′)); 3.87 (*t*, 2 CH_2); 2.38 (*s*, 2 Me); 1.81–1.73, 1.43–1.35 (2*m*, 4 CH_2). ^{13}C-NMR ($CDCl_3$): 138.1, 135.3, 123.0 (3*s*, 2 arom. C, C(4), C(4′), C(5), C(5′)); 135.9, 128.4, 127.0, 126.2 (4*d*, 10 arom. CH, C(2), C(2′)); 44.9, 30.6, 26.3 (3*t*, 6 CH_2); 9.9 (*q*, 2 Me). ESI-MS: 399 (100, $[M+1]^+$). Anal. calc. for $C_{26}H_{30}N_4$ (398.56): C 78.36, H 7.59, N 14.06; found: C 77.92, H 6.90, N 13.79.

13. *X-Ray Crystal-Structure Determination of* **11a** *and* **16b** (*Table* and *Figs. 1–2*)[4]). All measurements were performed on a *Nonius KappaCCD* diffractometer [27] by using graphite-monochromated

Table 3. *Crystallographic Data for Compounds* **11a** *and* **16b**

	11a	**16b**
Crystallized from	$CHCl_3$/hexane	EtOH
Empirical formula	$C_7H_{12}N_2O_2 \cdot 0.5\ H_2O$	$C_{22}H_{22}N_4O_2 \cdot 2\ H_2O$
M_r	165.19	410.47
Crystal color, habit	colorless, prism	colorless, plate
Crystal dimensions [mm]	0.25 × 0.25 × 0.25	0.05 × 0.17 × 0.22
Temperature [K]	160(1)	160(1)
Crystal system	monoclinic	orthorhombic
Space group	*C*2/*c*	*Aba*2
Z	8	4
Reflections for cell determination	2566	1341
2θ Range for cell determination [°]	4–60	4–55
Unit cell parameters a [Å]	11.1258(2)	24.0599(8)
b [Å]	11.8321(3)	10.8504(3)
c [Å]	12.9472(3)	7.7711(3)
β [°]	99.040(2)	90
V [Å^3]	1683.22(7)	2028.7(1)
D_x [g cm^{-3}]	1.304	1.344
$\mu(MoK_\alpha)$ [mm^{-1}]	0.0993	0.0941
Scan type	ϕ and ω	ϕ and ω
$2\theta_{max}$ [°]	60	55
Total reflections measured	21719	13330
Symmetry-independent-reflections	2460	1248
Reflections with $I > 2\sigma(I)$	2006	1127
Reflections used in refinement	2459	1248
Parameters refined; restraints	116; 0	145; 1
Final $R(F)$ ($I > 2\sigma(I)$ reflections)	0.0423	0.0374
$wR(F^2)$ (all data)	0.1154	0.0945
Weighting parameters [a; b][a])	0.0542; 0.7192	0.0445; 1.0001
Goodness of fit	1.057	1.122
Secondary extinction coefficient	0.009(2)	–
Final Δ_{max}/σ	0.001	0.001
$\Delta\rho$ (max; min) [e Å^{-3}]	0.21; –0.25	0.16; –0.20

a) $w^{-1} = \sigma^2(F_o^2) + (aP)^2 + bP$, where $P = (F_o^2 + 2F_c^2)/3$.

[4]) CCDC-646512 and -646513 contain the supplementary crystallographic data for this paper. These data can be obtained free of charge from the *Cambridge Crystallographic Data Centre*, *via* www.ccdc.cam.ac.uk/data_request/cif.

MoK_α radiation (λ 0.71073 Å) and an *Oxford-Cryosystems Cryostream 700* cooler. The data collection and refinement parameters are given in *Table 3*, and views of the molecules are shown in *Figs. 1* and *2*. Data reduction was performed with HKL Denzo and Scalepack [28]. The intensities were corrected for *Lorentz* and polarization effects but not for absorption. Equivalent reflections were merged. The structures were solved by direct methods by using SIR92 [29], which revealed the positions of all non-H-atoms. The asymmetric unit of **11a** contains one zwitterionic molecule and half of a H_2O molecule, which sits on a C_2 axis, while that of **16b** contains one half of the heterocyclic molecule, which sits across a C_2-axis, plus one H_2O molecule in a general position. The non-H-atoms of **11a** and **16b** were refined anisotropically. The H-atoms of the OH group and the H_2O molecule of **11a** and the H-atoms of the H_2O molecule of **16b** were placed in the positions indicated by a difference electron density map, and their positions were allowed to refine with individual isotropic displacement parameters. All remaining H-atoms were placed in geometrically calculated positions and refined by using a riding model where each H-atom was assigned a fixed isotropic displacement parameter with a value equal to 1.2 U_{eq} of its parent C-atom (1.5 U_{eq} for the Me groups). The refinement of each structure was carried out on F^2 by full-matrix least-squares procedures, which minimized the function $\Sigma w(F_o^2 - F_c^2)^2$. In the case of **11a**, a correction for secondary extinction was applied, and one reflection, whose intensity was considered to be an extreme outlier, was omitted from the final refinement. Neutral-atom scattering factors for non-H-atoms were taken from [30a], and the scattering factors for H-atoms were taken from [31]. Anomalous dispersion effects were included in F_c [32]; the values for f' and f'' were those of [30b]. The values of the mass attenuation coefficients are those of [30c]. All calculations were performed with the SHELXL97 [33] program.

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