Reduction of α,α-dialkoxy-substituted nitroxides: the synthesis of α-alkoxynitrones and acetals of *N*-hydroxyamides

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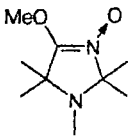
Reduction of stable nitroxides derived from tetrahydrooxazole, tetrahydroimidazole, 2,5-dihydroimidazole, and 2,5-dihydroimidazole 3-oxide containing alkoxy groups in α-position to the nitroxyl group affords α-alkoxynitrones, acetals of *N*-hydroxyamides, or their equilibrium mixtures.

Key words: nitroxides, α-alkoxynitrones, α-methoxynitrones, 2,5-dihydroimidazoles, 2,5-dihydroimidazole 3-oxides, 2*H*-imidazole *N*-oxides, 4*H*-imidazole *N*-oxides, 4,5-dihydrooxazole 3-oxides, ring-chain tautomerism.

Earlier,[1–5] we proposed a method for the synthesis of stable nitroxyl radicals (SNRs) bearing alkoxy groups at the nitroxyl α-carbon atom by oxidation of nitrones in methanol and other alcohols (oxidative alkoxylation). It was determined that this transformation proceeds *via* intermediate α-alkoxynitrones, not easily available compounds, which are interesting because of their high reactivity, especially in reactions of nucleophilic substitution and 1,3-dipolar cycloaddition.[6–8] A possible preparative application of oxidative alkoxylation of alkoxynitrones was shown with the synthesis of 4-methoxy-1,2,2,5,5-pentamethyl-2,5-dihydroimidazole 3-oxide (**1**) as an example.[1]



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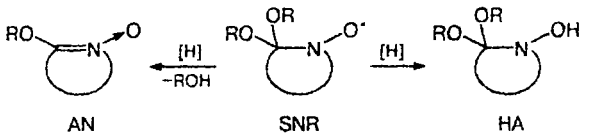
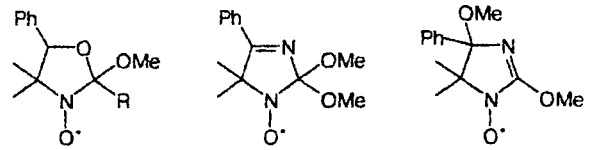
However, in other cases, the reaction cannot be stopped at the stage of formation of α-alkoxynitrones and results in SNRs or destruction products. For example, the oxidation of *N*-(2-hydroxyethyl-1,1-dimethyl-2-phenylethyl)-α-(3-nitrophenyl)nitrone in aprotic solvents yields a mixture of benzaldehyde, 3-nitrobenzaldehyde, and acetone instead of the expected cyclic α-alkoxynitrone, 4,4-dimethyl-2-(3-nitrophenyl)-5-phenyl-4,5-dihydrooxazole 3-oxide (**2a**), while the oxidation in methanol affords only 2-methoxy-4,4-dimethyl-2-(3-nitrophenyl)-5-phenyl-2,3,4,5-tetrahydrooxazole-3-oxyl (**3a**).

Compound **2a** was obtained[3] in high yield by reducing SNR **3a**. One could expect that reduction of other SNRs containing alkoxy groups at the nitroxyl α-carbon atom would also result in α-alkoxynitrones (AN). However, the reduction of 2,2-dialkoxy-2,5-dihydroimidazole-1-oxyl 3-oxides is not accompanied by elimination of an alcohol molecule, giving stable hydroxylamines (HA), 2,2-dialkoxy-1-hydroxy-2,5-dihydroimidazole 3-oxides.

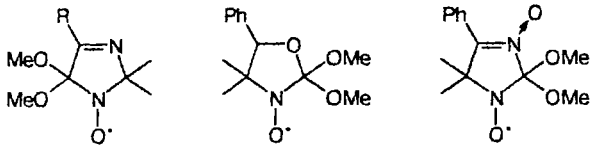


AN SNR HA

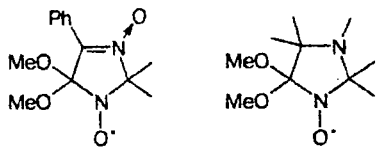
To clear up just how far these two possible reaction pathways are general, we studied the reduction of various SNR with alkoxy groups at the nitroxyl α-carbon atom. SNRs **3**—**10** were used as substrates and hydroxylamine and zinc in the presence of ammonium chloride as reducing agents.



3 **4** **5**



6 **7** **8**



9 **10**

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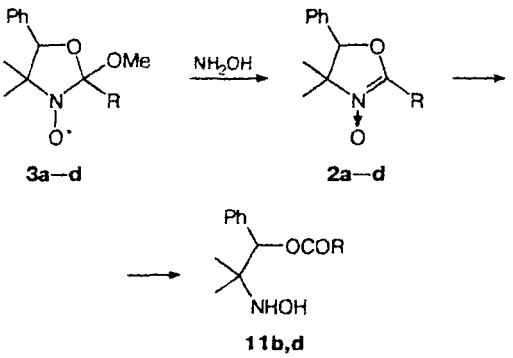
Like the previously described reduction of SNR **3a**,[3] the reduction of SNRs **3b—d** with hydroxylamine in methanol yields the corresponding 4,5-dihydrooxazole 3-oxides **2b—d**, compounds **2b,d** being easily hydrolyzable in air to give *N*-(2-aroyloxy-1,1-dimethyl-2-phenylethyl)hydroxylamines (**11b,d**). The reduction of SNRs **3b,d** with zinc in the presence of ammonium chloride immediately results in compounds **11b,d**.

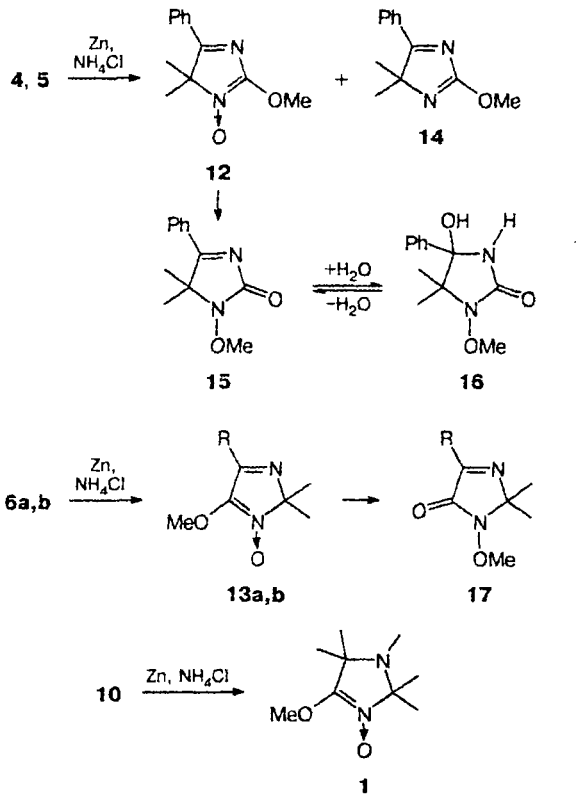


R = 3-$O_2NC_6H_4$ (**a**), Ph (**b**), 4-Py (**c**), 4-$MeOC_6H_4$ (**d**)

The reduction of SNRs **4**, **6a,b**, and **10** is also accompanied by elimination of a methanol molecule and gives the corresponding methoxynitrones **12**, **13a,b**, and **1**, irrespective of the method of reduction (Scheme 1). The highest yields were reached with zinc and ammonium chloride as reducing agents. The reduction of the iminonitroxyl radical **5** also affords 2-methoxy-4,4-dimethyl-5-phenyl-4*H*-imidazole 3-oxide (**12**), which allows mixtures of radicals **4** and **5** (formed in the oxidative methoxylation of 4,4-dimethyl-5-phenyl-4*H*-imidazole 3-oxide[2]) to be used without separation for preparative synthesis of compound **12**. Compound **14** was isolated from the reaction mixture as a by-product. Its yield increases (up to 10—50%) as the reaction temperature increases. The ^1H and ^{13}C NMR spectra of this compound show signals for a methoxy group at δ 3.90 and 55.92, respectively; in addition, its ^{13}C NMR spectrum contains two signals for the carbon atoms of the imino groups at δ 169.22 and 198.62 typical of 4*H*-imidazole derivatives (see Ref. 2). Based on these data, the structure of 2-methoxy-4,4-dimethyl-5-phenyl-4*H*-imidazole (presumably, a product of more profound reduction) was assigned to compound **14**.

The methoxynitrones **12** and **13a** obtained are liquids that gradually isomerize at room temperature to give compounds **15** and **17**, as in the case of 4-methoxy-2,2,5,5-tetramethyl-2,5-dihydroimidazole 3-oxides.[1] Compound **15** is able to bind a molecule of water. Its covalent hydrate **16** was isolated in the individual state (according to NMR spectroscopic data, it is dehydrated in DMSO to regain form **15**). Methoxynitrone **13b** is a stable crystalline compound. The IR spectra of methoxynitrones **12** and **13a,b** reveal bands at 1610—1640 cm^{-1}

Scheme 1



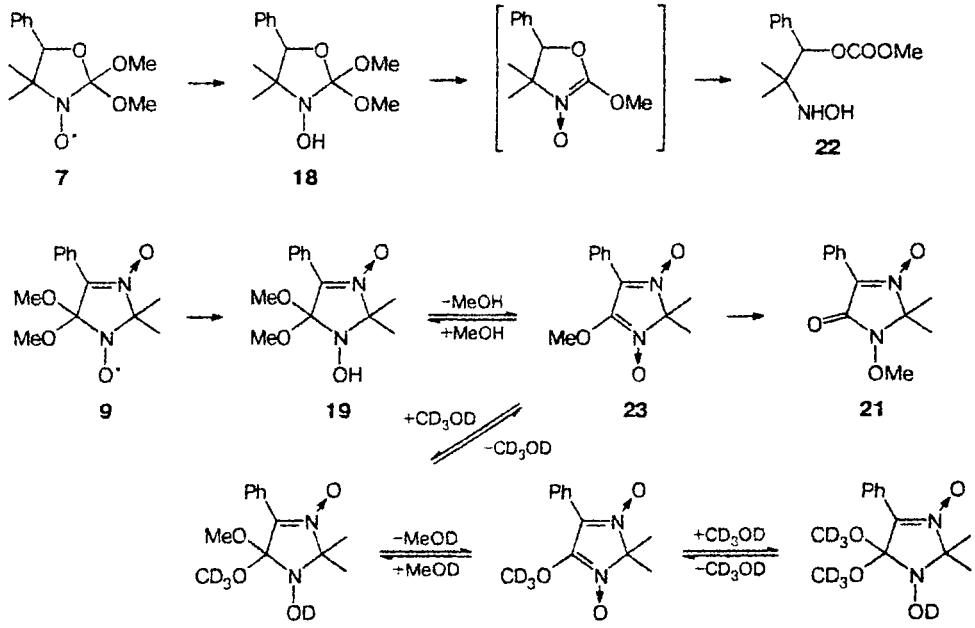
R = Ph (**a**), $CONH_2$ (**b**)

characteristic of the C=N bond in an α-methoxynitrone group, and their ^{13}C NMR spectra contain signals at δ 148—153 for the carbon atoms of this group (*cf.* Refs. 7, 9, and 10).

Similar to the previously described reduction of 2,2-dimethoxy-2,5-dihydroimidazole-1-oxyl 3-oxide (**8**),[2] the reduction of SNRs **7** and **9** occurs without elimination of a methanol molecule to give dimethyl acetals of cyclic *N*-hydroxyamides **18** and **19** (Scheme 2). Unlike 1-hydroxy-2,2-dimethoxy-5,5-dimethyl-4-phenyl-2,5-dihydroimidazole 3-oxide (**20**),[2] which is a stable crystalline compound, its isomeric 1-hydroxy-5,5-dimethoxy-2,2-dimethyl-4-phenyl-2,5-dihydroimidazole 3-oxide (**19**) gradually isomerizes at room temperature into 1-methoxy-1,2-dihydroimidazol-5-one (**21**), and 1-hydroxy-2,2-dimethoxy-4,4-dimethyl-5-phenyltetrahydrooxazole (**18**) is transformed into *N*-(2-methoxycarbonyloxy-1,1-dimethyl-2-phenylethyl)hydroxylamine (**22**) in quantitative yield upon chromatography on silica gel (similarly to the above-mentioned hydrolysis of 4,5-dihydrooxazole 3-oxides **2**).

NMR and UV spectroscopic data suggest that in methanol there exists an equilibrium mixture of compound **19** with 5-methoxy-2,2-dimethyl-4-phenyl-2*H*-imidazole 1,3-dioxide (**23**). When solutions of compound **19** in

Scheme 2



CD_3OD are kept for a long period of time at room temperature, the methoxy groups in compounds **19** and **23** are gradually replaced by CD_3O groups, and methoxynitrone **23** partially isomerizes into compound **21**.

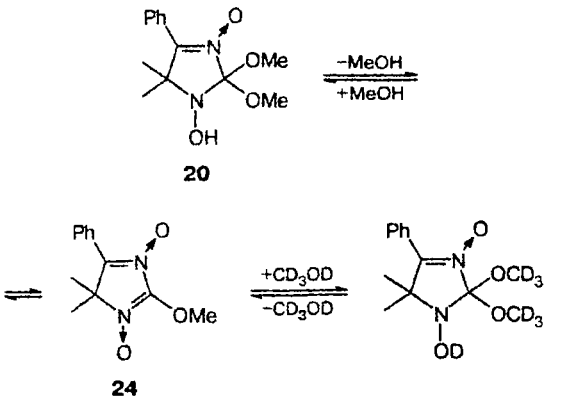
The reversible character of addition of a methanol molecule to methoxynitrone **23** changes our concept of the mechanism of oxidative alkoxylation of 2,2-dimethyl-4-phenyl-2*H*-imidazole 1,3-dioxide[5]: the formation of SNR **9** in this reaction seems not to follow the cation-radical mechanism, as supposed earlier, but occurs as a result of oxidation of compound **19** formed upon nucleophilic addition of methanol to methoxynitrone **23**. In other cases, oxidative alkoxylation of alkoxynitrones may also proceed *via* addition of alcohol followed by oxidation.

Apparently, all alkoxynitrones can reversibly bind an alcohol molecule, and the point of this equilibrium depends on the character of substituents at the nitron (acetal) carbon atom. Introduction of an *N*-oxide fragment and an acceptor heteroatom into the neighboring position with respect to the acetal carbon atom stabilizes the corresponding acetal.

Unlike 1-hydroxy-2,5-dihydroimidazole 3-oxide (**19**), solutions of compound **20** in CD_3OD contain no admixture of the corresponding methoxynitrone even in the presence of CD_3ONa (NMR spectroscopic data). However, the methoxy groups are gradually replaced by CD_3O groups under the action of CD_3ONa in CD_3OD. Such replacement can proceed *via* intermediate methoxynitrone **24** (Scheme 3).

One could expect that the reversible character of addition of a methanol molecule to methoxynitrones would also allow introducion of other alkoxy groups

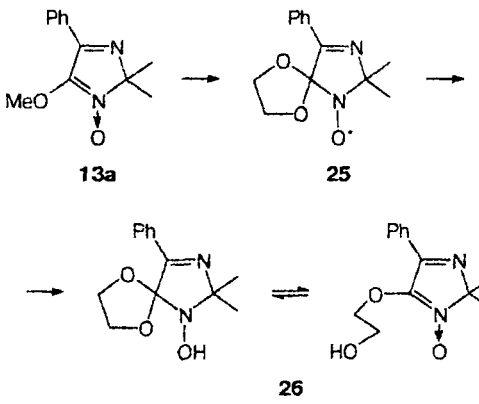
Scheme 3



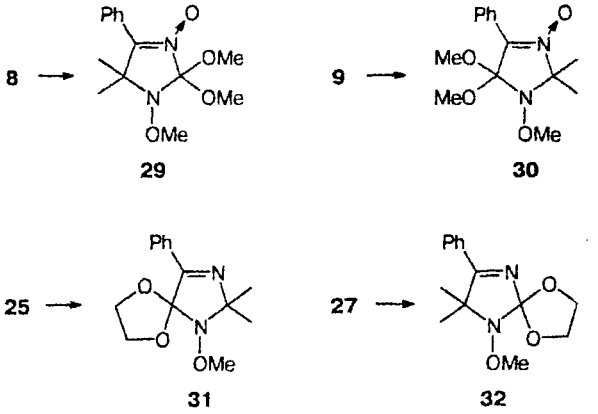
into the substrate molecule. Oxidation of methoxynitrone **13a** with manganese dioxide in ethylene glycol resulted in SNR **25**, which cannot be obtained by oxidizing 2,2-dimethyl-4-phenyl-2*H*-imidazole 1-oxide under the same conditions (Scheme 4).

It is known that dioxolane derivatives are usually more stable than dimethyl acetals. Indeed, the reduction of SNRs **4** and **6** affords methoxynitrones, whereas that of their spirodioxolane analogs **25** and **27** results in 1-hydroxy-2,5-dihydroimidazoles **26** and **28**. The UV spectra (KBr) of these compounds contain absorption bands at 240 nm that correspond to the absorption of a phenylazomethine fragment and no bands in the longer wavelength region that appeared in their UV spectra are recorded in an alcohol. According to NMR spectroscopic data, compound **26** exists in methanol predomi-

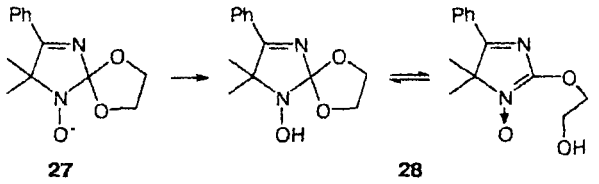
Scheme 4



Scheme 5



nantly in the form of 2*H*-imidazole 1-oxide, and the content of 1-hydroxy-2,5-dihydroimidazole is as low as 8%. In contrast, compound **28** exists in solutions predominantly in a cyclic form, the content of 4*H*-imidazole 3-oxide in CD_3OD and $CDCl_3$ being *ca.* 20%.

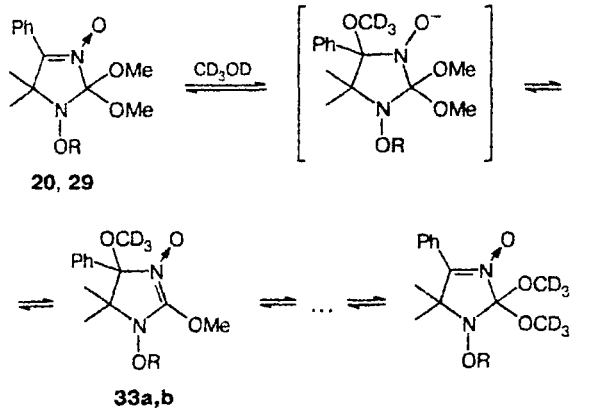


Previously, it was shown that the reactions of 2,2,5,5-tetramethyl-2,5-dihydroimidazole-1-oxyls and their 3-oxides with methylhydrazine yield, along with 1-hydroxy derivatives as reduction products, 1-methoxy derivatives. Stable nitroxyl radicals **8**, **9**, **25**, and **27** react with methylhydrazine in a similar way, and the methyl group substituting for the hydrogen atom prevents elimination of alcohol or opening of the dioxolane ring, thus stabilizing the acetal fragment (Scheme 5). The 1-methoxy-2,5-dihydroimidazoles **29**—**32** obtained are stable crystalline colorless compounds. However, unstable acetals cannot always be stabilized in this way. For example, we failed to obtain the 1-methoxy derivative from SNR **6a** under these conditions, and compounds **13a** and **17** were isolated from the reaction mixture.

As in the case of compound **20** described above, keeping of compound **29** in CD_3OD in the presence of CD_3ONa leads to gradual replacement of the methoxy groups in position 2 of the heterocycle by CD_3O groups (Scheme 6). Under these conditions, compounds **20** and **29** seem to exist in equilibrium with the corresponding 2-imidazoline 3-oxides (**33a,b**).

Thus, the reduction of SNRs with the alkoxy groups at the nitroxyl α-carbon atom results, depending on the environment of the acetal fragment, in either α-alkoxynitrones or acetals of *N*-hydroxyamides, the latter being capable of reversible elimination of an alcohol molecule, which provides grounds to expect them to be as reactive as methoxynitrones, *e.g.*, in reactions with nucleophilic agents.

Scheme 6



R = H or D (**a**), Me (**b**)

Experimental

IR spectra were recorded on Specord M-80 and Bruker IFS 66 spectrometers (crystalline samples in pellets with KBr (concentration 0.25%, pellet thickness 1 mm); liquids in CCl_4 (concentration 5%)). UV spectra were obtained with a Specord UV VIS spectrometer in ethanolic solutions and in pellets with KBr (see above). ^1H NMR spectra of compounds **2**, **11**, **18**, **22**, and **34** were recorded on a Bruker WP 200SY spectrometer. The ^1H and ^{13}C NMR spectra of the other compounds were recorded on a Bruker AC 200 spectrometer in 1—5% solutions with a signal from a solvent as a standard. ^{13}C signals were assigned from an analysis of intensities, *J*-modulated spectra, and the published data.[9,12—15] High-resolution mass spectra were recorded on a Finnigan MAT 8200 spectrometer (direct inlet).

Table 1. Characteristics of the compounds synthesized

Compound	Yield (%)	M.p. /°C	Found / Calculated (%) C	H	N	Molecular formula	IR, ν/cm^{-1} (KBr)	UV, λ_{max}/nm (log ε) (in ethanol)
2b	90	Oil	76.5 76.4	6.4 6.4	5.2 5.3	$C_{17}H_{17}NO_2$		233 (4.04); 332 (3.86)
2c	90	168—170	71.8 71.6	6.2 6.0	10.5 10.4	$C_{16}H_{16}N_2O_2$	1600, 1570 (C=N, C=C)	335 (3.85)
2d	90	Oil		297.13600[a] 297.13648		$C_{18}H_{19}NO_3$	2840 (C—H, OMe)[b]	255 (4.03); 308 (4.04)
3d	70	Oil	69.4 69.5	6.4 6.7	4.3 4.3	$C_9H_{22}NO_4$	2840 (C—H, OMe)[b]	276 (3.40)
10	60	Oil	55.4 55.3	9.4 9.7	12.6 12.9	$C_{10}H_{21}N_2O_3$	2840 (C—H, OMe)[b]	228 (3.43); 334(1.48)
11b	95	159—162	71.0 71.6	6.7 6.7	4.9 4.9	$C_{17}H_{19}NO_3$	1720 (C=O)	230 (4.13)
11d	95	122—125		315.14890[a] 315.14705		$C_{18}H_{21}NO_4$	1750 (C=O); 2830 (C—H, OMe)	258 (4.25)
12	70	Oil		218.10535[a] 218.10552		$C_{12}H_{14}N_2O_2$	1620, 1595 (C=N)[b]; 2840 (C—H, OMe)[b]	225 (3.62); 240 (3.70); 401 (3.43)
13a	70	Oil		218.1046[a] 218.1055		$C_{12}H_{14}N_2O_2$	1610, 1515 (C=N)[c]; 2865 (C—H, OMe)[c]	230 (4.33); 270 (4.34)
13b	90	150—160 (decomp.)	45.7 45.4	6.3 6.0	23.0 22.7	$C_7H_{11}N_3O_3$	1690 (C=O); 1640, 1570 (C=N); 2860 (C—H, OMe); 1710 (C=O)[c]; 3520, 3470, 3400 (NH)[c]	318 (3.63)
14	50	48—50	70.8 71.3	6.7 6.9	13.7 13.9	$C_{12}H_{14}N_2O$	1630 (C=O); 2830 (C—H, OMe)	257 (3.95); 280 (4.00)
16	50	158—165 (decomp.)	61.1 61.0	6.8 6.8	11.9 11.9	$C_{12}H_{16}N_2O_3$	1725 (C=O); 2830 (C—H, OMe)	
17	90	Oil		218.10543[a] 218.1055		$C_{12}H_{14}N_2O_2$	1720 (C=O)[c]; 2840 (C—H, OMe)[c]	265 (4.12)
18	90	Oil					2840 (C—H, OMe)[b]; 3590, 3470 (OH)[b]	
19	70	120—122	58.6 58.6	6.8 6.8	10.4 10.4	$C_{13}H_{18}N_2O_4$	1575, 1560 (C=N, C=C); 2850 (C—H, OMe)	287 (4.24)
21	90	83—85	61.8 61.5	6.2 6.0	11.9 12.0	$C_{12}H_{14}N_2O_3$	1725 (C=O); 2830 (C—H, OMe)	232 (4.14); 305 (3.95)
22	70	108—110	60.5 60.3	7.0 7.1	5.8 5.9	$C_{12}H_{17}NO_4$	1760 (C=O); 2850 (C—H, OMe)	252 (2.25); 258 (2.41); 264 (2.30)
25	50	115—117	63.5 63.2	6.4 6.1	11.2 11.3	$C_{13}H_{15}N_2O_3$	1620 (C=N)	248 (4.23)
26	90	98—101	63.3 62.9	6.7 6.5	11.2 11.3	$C_{13}H_{16}N_2O_3$	1620 (C=N)	238[d]; 228 (4.05); 265 (3.99)
28	70	170—173	62.9 62.9	6.6 6.5	11.4 11.3	$C_{13}H_{16}N_2O_3$	1600 (C=N)	244[d]; 244 (4.10); 401 (2.09)
29	30	90—93	60.4 60.0	7.2 7.2	10.4 10.0	$C_{14}H_{20}N_2O_4$	2820, 2850 (C—H, OMe)	290 (3.96)
30	25	78—80	60.0 60.0	7.2 7.2	9.6 10.0	$C_{14}H_{20}N_2O_4$	2815, 2840 (C—H, OMe)	290 (4.23)
31	20	48—50	64.6 64.1	7.0 6.9	10.6 10.7	$C_{14}H_{18}N_2O_3$	2810 (C—H, OMe)[b]	244 (4.13)
32	25	99—102	64.3 64.1	7.0 6.9	10.6 10.7	$C_{14}H_{18}N_2O_3$	2800 (C—H, OMe)	244 (4.15)
34	68	152—154	72.5 72.2	7.0 7.0	4.7 4.7	$C_{18}H_{21}NO_3$	2850 (C—H, OMe)	310 (4.44)

[a] *m/z*. [b] In CCl_4. [c] In $CHCl_3$. [d] In KBr.

Table 2. ^1H and ^{13}C NMR spectral data for the heterocyclic compounds synthesized

Compound	Solvent	^1H NMR, δ, *J*/Hz	^{13}C NMR, δ
2b	CD_3OD	1.06, 1.73 (both s, each 3 H, gem. Me); 5.81 (s, 1 H, CH); 7.49 (m, 5 H, Ph); 7.30, 8.10 (both m, 3 H and 2 H, N=C—Ph)	
2c	$CDCl_3$	1.05, 1.69 (both s, each 3 H, gem. Me); 5.51 (s, 1 H, CH); 7.49 (m, 5 H, Ph); 8.31, 8.77 (AA′BB′, Py, J = 6)	
2d	$CDCl_3$	1.02, 1.67 (both s, each 3 H, gem. Me); 3.84 (s, 3 H, OMe); 5.43 (s, 1 H, CH); 7.37 (m, 5 H, Ph); 6.96, 8.51 (AA′BB′, C_6H_4, J = 9)	
12	$CDCl_3$	1.71 (s, 6 H, gem. Me); 4.28 (s, 3 H, OMe); 7.48, 8.00 (both m, 3 H and 2 H, Ph)	22.75 (gem. Me); 57.92 (OMe); 76.70 (<u>C</u>Me$_2$); 152.78 (C=NO); 180.07 (C=N); Ph: 129.61 (C_i); 127.15 (C_o); 128.96 (C_m); 132.79 (C_p)
13a	CD_3OD	1.60 (s, 6 H, gem. Me); 4.48 (s, 3 H, OMe); 7.53, 8.11 (both m, 3 H and 2 H, Ph)	24.06 (gem. Me); 59.51 (OMe); 94.89 (<u>C</u>Me$_2$); 148.18 (C=NO); 161.49 (C=N); Ph: 131.46 (C_i); 128.86 (C_o); 129.63 (C_m); 133.03 (C_p)
13b	$CDCl_3$	1.51 (s, 6 H, gem. Me); 4.32 (s, 3 H, OMe); 6.70, 7.00 (both br.s, each 1 H, NH_2)	23.51 (gem. Me); 59.27 (OMe); 94.63 (<u>C</u>Me$_2$); 156.06 (C=NO); 160.93 (C=N); 156.07 (C=O)
14	$(CD_3)_2SO$	1.47 (s, 6 H, gem. Me); 3.90 (s, 3 H, OMe); 7.56, 8.09 (both m, 3 H and 2 H, Ph)	20.05 (gem. Me); 55.92 (OMe); 77.30 (<u>C</u>Me$_2$); 169.22 (O—C=N); 198.62 (C=N); Ph: 129.60 (C_i); 128.79 (C_o); 128.95 (C_m); 132.39 (C_p)
15	$(CD_3)_2SO$	1.53 (s, 6 H, gem. Me); 3.17 (s, 3 H, OMe); 7.48, 8.00 (both m, 3 H and 2 H, Ph)	22.49 (gem. Me); 49.76 (OMe); 67.05 (<u>C</u>Me$_2$); 160.45 (C=O); 188.83 (C=N); Ph: 129.64 (C_i); 128.74 (C_o); 129.06 (C_m); 133.17 (C_p)
16	$(CD_3)_2SO$	0.52, 1.27 (both s, each 3 H, gem. Me); 2.93 (s, 3 H, OMe); 7.61 (m, 5 H, Ph); 8.80 (br.s, 1 H, NH); 9.95 (br.s, 1 H, OH)	17.90, 20.29 (gem. Me); 48.50 (OMe); 67.93 (<u>C</u>Me$_2$); 91.54 (<u>C</u>—Ph); 171.70 (C=O); Ph: 136.42 (C_i); 127.06 (C_o); 127.60 (C_m); 128.18 (C_p)
	CD_3OD	0.68, 1.42 (both s, each 3 H, gem. Me); 3.07 (s, 3 H, OMe); 7.46 (m, 5 H, Ph)	18.80, 21.15 (gem. Me); 51.05 (OMe); 71.26 (<u>C</u>Me$_2$); 93.98 (<u>C</u>—Ph); 164.43 (C=O); Ph: 137.96 (C_i); 128.91 (C_o); 129.94 (C_m); 130.25 (C_p)
17	CD_3OD	1.47 (s, 6 H, gem. Me); 4.07 (s, 3 H, OMe); 7.34, 8.11 (both m, 3 H and 2 H, Ph)	25.62 (gem. Me); 57.62 (OMe); 94.80 (<u>C</u>Me$_2$); 159.60 (C=O); 166.70 (C=N); Ph: 131.47 (C_i); 129.32 (C_o); 129.61 (C_m); 132.40 (C_p)
18	$(CD_3)_2CO$	0.73, 1.27 (both s, each 3 H, gem. Me); 3.35 (s, 3 H, OMe); 3.54 (s, 3 H, OMe); 4.87 (s, 1 H, CH); 7.36 (m, 5 H, Ph)	
19	CD_3OD	1.63 (s, 6 H, gem. Me); 3.52 (s, 6 H, gem. OMe); 7.51, 8.48 (both m, 3 H and 2 H, Ph)	23.23 (gem. Me); 53.14 (OMe); 91.10 (<u>C</u>Me$_2$); 112.70 (<u>C</u>(OMe)$_2$); 138.19 (C=NO); Ph: 127.51 (C_i); 128.85 (C_o); 129.31 (C_m); 132.90 (C_p)
21	CD_3OD	1.76 (s, 6 H, gem. Me); 4.05 (s, 3 H, OMe); 7.52, 8.40 (both m, 3 H and 2 H, Ph)	24.93 (gem. Me); 66.57 (OMe); 89.65 (<u>C</u>Me$_2$); 163.91 (C=O); 131.10 (C=NO); Ph: 127.00 (C_i); 128.61 (C_o); 129.31 (C_m); 132.21 (C_p)
23	CD_3OD	1.83 (s, 6 H, gem. Me); 3.37 (s, 3 H, OMe); 7.53, 8.28 (both m, 3 H and 2 H, Ph)	23.87 (gem. Me); 61.76 (OMe)
26[a]	CD_3OD	1.62 (s, 6 H, gem. Me); 3.85 (t, 2 H, CH_2OH, J = 3); 5.20 (t, 2 H, CH_2, J = 3); 7.58, 8.22 (both m, 3 H and 2 H, Ph)	23.96 (gem. Me); 62.05 (CH_2OH); 74.22 (CH_2); 94.72 (<u>C</u>Me$_2$); 148.12 (C=NO); 161.96 (C=N); Ph: 131.57 (C_i); 129.08 (C_o); 129.50 (C_m); 133.07 (C_p)
26[b]	CD_3OD	1.45 (s, 6 H, gem. Me); 4.12, 4.32 (both m, each 2 H, CH_2CH_2); 7.50, 7.85 (both m, 3 H and 2 H, Ph)	25.06 (gem. Me); 64.32, 66.97 (CH_2CH_2)
28[a]	CD_3OD	1.75 (s, 6 H, gem. Me); 3.85 (m, 2 H, CH_2OH); 4.80 (m, 2 H, CH_2); 7.54, 8.19 (both m, 3 H and 2 H, Ph)	
28[b]	CD_3OD	1.50 (s, 6 H, gem. Me); 4.25 (m, 4 H, CH_2CH_2); 7.54, 7.84 (both m, 3 H and 2 H, Ph)	25.06 (gem. Me); 66.90 (CH_2CH_2); 70.23 (<u>C</u>Me$_2$); 118.00 (O—C—O); 182.29 (C=N); Ph: 133.68 (C_i); 129.25 (C_o); 129.70 (C_m); 132.65 (C_p)
29	CD_3OD	1.59 (s, 6 H, gem. Me); 3.72 (s, 6 H, gem. OMe); 3.81 (s, 3 H, NOMe); 7.55, 8.05 (both m, 3 H and 2 H, Ph)	23.85 (gem. Me); 53.93 (gem. OMe); 64.82 (NOMe); 65.90 (<u>C</u>Me$_2$); 118.70 (<u>C</u>(OMe)$_2$); 142.80 (C=NO); Ph: 127.51 (C_i); 125.52 (C_o); 129.75 (C_m); 132.11 (C_p)

(to be continued)

Table 2 (*continued*)

Compound	Solvent	^{1}H NMR, δ, *J*/Hz	^{13}C NMR, δ
30	$CDCl_3$	1.63 (s, 6 H, gem. Me); 3.50 (s, 6 H, gem. OMe); 3.77 (s, 3 H, NOMe); 7.48, 8.60 (both m, 3 H and 2 H, Ph)	23.28 (gem. Me); 52.47 (gem. OMe); 63.74 (NOMe); 89.48 (<u>C</u>Me$_2$); 112.31 (<u>C</u>(OMe)$_2$); 133.51 (C=NO); Ph: 126.39 (C_i); 126.91 (C_o); 128.11 (C_m); 130.18 (C_p)
31	$(CD_3)_2CO$	1.40 (s, 6 H, gem. Me); 4.20, 4.34 (both m, each 2 H, CH_2CH_2); 3.71 (s, 3 H, NOMe); 7.45, 7.87 (both m, 3 H and 2 H, Ph)	25.84 (gem. Me); 66.38 (CH_2CH_2); 64.65 (NOMe); 95.22 (<u>C</u>Me$_2$); 119.93 (O—C—O); 166.23 (C=N); Ph: 133.01 (C_i); 128.29 (C_o); 129.07 (C_m); 131.41 (C_p)
32	$(CD_3)_2CO$	1.48 (s, 6 H, gem. Me); 4.13 (m, 4 H, CH_2CH_2); 3.72 (s, 3 H, NOMe); 7.48, 7.86 (both m, 3 H and 2 H, Ph)	23.65 (gem. Me); 66.13 (CH_2CH_2); 65.01 (NOMe); 69.22 (<u>C</u>Me$_2$); 128.87 (O—C—O); 178.27 (C=N); Ph: 133.06 (C_i); 128.97 (C_o); 129.35 (C_m); 131.91 (C_p)

[a] Acyclic tautomer.
[b] Cyclic tautomer.

4,4-Dimethoxy-1,2,2,5,5-pentamethyltetrahydroimidazole-3-oxyl (**10**) was synthesized* by oxidation of 1,2,2,5,5-pentamethyl-2,5-dihydroimidazole 3-oxide with PbO_2 in methanol for 10 to 14 days. The syntheses of compounds **20**, **27**, **3a—c**, **2a**, and **7** were described previously.[2,3] Condensation of *N*-(2-hydroxy-1,1-dimethyl-2-phenylethyl)hydroxylamine with 4-methoxybenzaldehyde, performed according to the known procedure,[3] resulted in *N*-(2-hydroxy-1,1-dimethyl-2-phenylethyl)-α-(4-methoxyphenyl)nitrone (**34**), whose oxidation in methanol (by analogy with the published data[3]) gave SNR **3d**. Nitrone **34**, ^{1}H NMR ($(CD_3)_2SO$), δ: 1.28, 1.50 (both s, each 3 H, gem. Me); 3.79 (s, 3 H, OMe); 5.15 (d, 1 H, OH, *J* = 5 Hz); 6.00 (d, 1 H, C<u>H</u>—OH, *J* = 5 Hz); 7.49 (s, 1 H, N=CH); 6.97, 8.36 (AA′BB′, C_6H_4, *J* = 9 Hz); 7.21, 7.30 (both m, 3 H and 2 H, Ph).

4,5-Dihydrooxazole *N*-oxides (2b—d) were obtained by reducing SNRs **3b—d** according to the known procedure.[6]

***N*-(2-Aroyloxy-1,1-dimethyl-2-phenylethyl)hydroxylamines (11b,d)** were isolated from samples **2b,d** kept in air at 25 °C for more than 10 to 15 days. By the end of the transformation, the samples crystallized completely. The resulting compounds **11b,d** were recrystallized from an ethyl acetate—hexane (4 : 1) mixture. ^{1}H NMR ($CDCl_3$), δ, **11b**: 1.09, 1.17 (both s, each 3 H, gem. Me); 6.23 (s, 1 H, C<u>H</u>); 7.46 (m, 5 H, Ph); 7.30, 8.10 (both m, 3 H and 2 H, OCOPh); **10d**: 1.06, 1.24 (both s, each 3 H, gem. Me); 3.90 (s, 3 H, OMe); 6.22 (s, 1 H, C<u>H</u>); 7.48 (m, 5 H, Ph); 7.15, 8.11 (AA′BB′, C_6H_4, *J* = 9 Hz). MS **10d** (EI, 70 eV), *m/z* (I_{rel} (%)): 315 [M^+] (3.5), 297 [$M^+ - H_2O$] (40).

Reduction of SNRs 4, 5, 6a,b, 9, 10, 25, and 27 (general procedure). Zinc powder (grade PTs 12, 1 g, 15 mmol) and NH_4Cl (0.5 g, 9 mmol) were added by portions with stirring to a cooled (0 °C) solution of an SNR (5 mmol) in 15 mL of methanol. The reaction mixture was stirred until the color of the radical disappeared (0.5 to 5 h), and then the precipitate that formed was filtered off and the solvent removed *in vacuo*. The residue was dissolved in $CHCl_3$, the precipitate was filtered off, and the solution was concentrated again. The resulting compounds **19**, **26**, and **28** were recrystallized from an ethyl acetate—hexane (2 : 1) mixture, while compound **13b** from an acetone—dichloromethane (1 : 1) mixture. Compounds **1**, **12**, **13a**, and **14** were isolated by chromatography on silica gel Kieselgel 60 (Merck) in $CHCl_3$ (in the case of compound **12**, the sorbent was pre-deactivated with 20% water). Compound **14** was recrystallized from hexane. The IR spectrum of the compound **1** obtained corresponds to the previously published data.[1] Compounds **16**, **17**, and **21** were isolated by chromatography on silica gel ($CHCl_3$ as the eluent) from samples **12**, **13a**, and **19** all kept at 25 °C. Compound **16** was recrystallized from methanol, and compound **21** from hexane.

3-Hydroxy-2,2-dimethoxy-4,4-dimethyl-5-phenyltetrahydrooxazole (18) was obtained by reducing SNR **7** as described[3] for SNR **3a**. The solution formed upon treatment of SNR **7** with NH_2OH in ethanol was concentrated *in vacuo* at a bath temperature not higher than 20 °C. The residue was dissolved in $CHCl_3$, the precipitate was filtered off, and the solution was reconcentrated *in vacuo*. Compound **18** was not additionally purified before recording its spectra. The content of the major component was at least 90% (^{1}H NMR data). Column chromatography on silica gel ($CHCl_3$ as the eluent) gave ***N*-(2-methoxycarbonyloxy-1,1-dimethyl-2-phenylethyl)-hydroxylamine (22)**, ^{1}H NMR (CD_3OD), δ: 0.96, 1.10 (both s, each 3 H, gem. Me); 3.74 (s, 3 H, OMe); 5.87 (s, 1 H, C<u>H</u>); 7.37 (m, 5 H, Ph).

1,3-Dioxolane-2-spiro-5′-(2′,2′-dimethyl-4′-phenyl-2′,5′-dihydroimidazole-1′-oxyl) (25) was obtained by oxidation of methoxynitrone **13a** with MnO_2 as described[2] for the synthesis of SNR **27**. The chloroform solution formed upon extraction from the reaction mixture was washed with water, dried with $MgSO_4$, and concentrated, and the residue was recrystallized from hexane.

Synthesis of 1-methoxy-2,5-dihydroimidazoles 29, 30, 31, and 32 (general procedure). A 0.2 *M* solution of methylhydrazine in diethyl ether was added dropwise to a solution of SNR **8**, **9**, **25**, or **27** (1 mmol) in 1 mL of $CHCl_3$ or diethyl ether. After decolorization, the reaction mixture was placed in a refrigerator for 12 h, the precipitate of **20**, **19**, **26**, or **28** that formed was filtered off, and the solution was concentrated *in vacuo*. The residue was chromatographed using plates with a nonfixed layer (Kieselgel 60, Merck, $CHCl_3$ as the eluent). The final compounds **29**, **30**, **31**, and **32** were recrystallized from hexane.

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* Synthesized by M. A. Voinov according to the known procedure.[1]

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